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Microscopic estimation of archaeological hardwood stabilised with selected impregnants

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Abstract: Results of a study on impregnation of waterlogged archaeological oak and elm wood with 60% water solutions of sucrose, lactitol and polyethylene glycol 300 (PEG 300) revealed some differences in dimensional stabilisation effect. This observation prompted undertaking scanning electron microscopic analysis of the places of penetration and deposition of the modifying substances in order to find the most effective method of conservation of ancient wood. The SEM photographs performed before and after the impregnation and drying procedures have been presented in the article.

Keywords: waterlogged archaeological wood, conservation, impregnation, dimensional stabilisation, SEM analysis

Introduction

During the archaeological works in the Castle Hill (Wzgórze Zamkowe) area in Szczecin the remains of wooden houses from 11th (oak 13) to 13th (elm 11) century were discovered. Preliminary studies have shown that the objects were built of oak and elm wood and revealed a various degradation degree of the material. Research on dimensional stabilisation of different decayed hardwood, performed in order to find out the best possible means to protect against shrinkage of waterlogged wood tissue, were described in details in previous publications [Babiński 2000 and 2001]. Present investigation was undertaken in order to reveal differences of different impregnate penetration between slightly and heavily degraded waterlogged archaeological hardwood.

Wood conservation procedure

The tests [Babiński 2000 and 2001] have proved that the degree of degradation of archaeological wood determined on the basis of the loss of wood substance (loss of mass) [Grattan and Mathias 1986] was slightly for oak (15.8%) and significant in the case of elm (64.3%) (Table 1).

Three impregnants: sucrose, lactitol and polyethylene glycol 300 (PEG 300) have been tested. All the impregnants have similar molecular weight, viscosity and ability to saturate wood tissue. The main difference is that sucrose and lactitol are solid state crystalline materials, while PEG 300 is a liquid.

The samples of the two types of wood were subjected to the same impregnation procedure. The waterlogged samples 50 (T) x 50 (R) x 10 (L) mm were immersed in water solutions of sucrose, lactitol and PEG 300. The impregnation procedure was begun in a 10% solution, then in one-week cycles, the concentration of the solution was increased by 10%, till the final concentration of 50%. To prevent the growth of micro-organisms, 1% of

Kemobicid DP 3 preparation was added to each of the solutions. The temperature of impregnation solutions of concentrations from 10 to 50% was 20°C, and for the 60% solutions it was 50°C. The samples impregnated with sucrose and PEG 300 were dried to constant mass at 20°C in the air of relative humidity of 44%, while the samples impregnated with lactitol were prior to this procedure preliminary dried at 50°C (Table 2).

Table 1

Selected parameters characterising the properties of investigated archaeological wood

Wood	Maximum moisture content	Conventional density	Loss of mass	Shrinkage		
				β_T	β_R	β_{CS}*
-	%	kg/m^3	%	%		
Oak	143	480	15.8	16.6	8.8	24.0
Elm	443	200	64.3	24.2	13.5	34.4

* $\beta_{CS} = [\beta_T + \beta_R - (\beta_T \times \beta_R/100)]$ – cross-section shrinkage

Table 2

The modes of impregnation and drying of wood samples

Impregnant	The initial and final concentration of impregnating solution	Drying parameters
Sucrose	10% → 60%	T = 20°C RH = 44%
PEG 300		
Lactitol		T=50°C for 24 h and then T=20°C, RH=44%
Control unimpregnated samples		T=20°C, RH=44%

Table 3

The degree of shrinkage of archaeological wood (before and after impregnation) measured after drying to the moisture content of about 9%

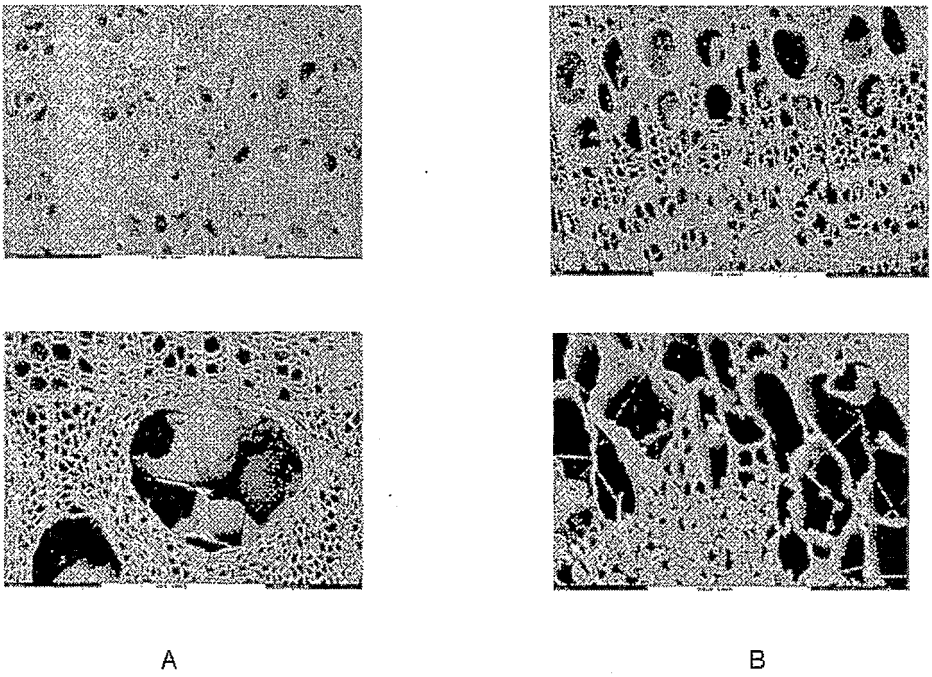
Wood	Oak			Elm		
	β_T	β_R	β_{CS}	β_T	β_R	β_{CS}
	%			%		
Unimpregnated	14.2	7.0	20.2 (100)*	21.3	11.8	30.6 (100)
Impregnated with						
- sucrose	3.4	1.3	4.7 (23)	1.1	0.2	1.3 (4)
- lactitol	4.9	1.8	6.6 (33)	2.7	0.2	2.9 (9)
- PEG 300	-0.2	0.1	-0.1(0)	-0.7	0.0	-0.7 (-2)

( )* – the values in parentheses describe the degree of shrinkage expressed in percent of shrinkage of unimpregnated wood

The dimensional stabilisation of wood was appraised on the basis of the shrinkage of the cross-section of the samples (β_{CS}), calculated on the basis of the measured linear shrinkages (β_T and β_R). The linear dimensions of the samples were measured to an accuracy of 0.01 mm, before and after the conservation, and the results are given in Table 3 The data show that the best dimensional stabilisation was secured for both types of wood after impregnation with PEG 300 . The next best result is sucrose and the worst result of the three is lactitol.

Microscopic estimation of wood samples

After the conservation procedures a series of SEM photographies was taken for each sample in order to confirm the degree of wood samples degradation, determine the sites of the impregnates penetration and deposition in the wood tissue (Figs. 1 to 7).



A B

Fig. 1. The cross-sections of the samples of archaeological oak (A) and elm (B) wood

Presented photographs (Fig.1) are the evidence of diversified destruction degree of wood tissue for both kinds of archaeological timber. When analysing pictures of anatomical crossections, it could be observed, that the decay process of cell walls of wooden fibres was much more intense at elm (Fig. 1B) than oak (Fig. 1A). In elm tissue practically all fibres have the walls strongly degraded and such timber is characterised by the mass loss reaching 64%. However oak wood, due to great natural durability and shorter lapse of time (about 200 years) was only partially degraded, wich certifies slight share of maximally degraded fibres, and mass loss about 16%. The tested timber occurred in soil in changeable moisture conditions, became degraded by soft rot fungi and bacteria. Evidence

of that of the caused of degradation is the picture of excavated wood of elm presented on the fig. 1B. There can be seen hyphae and spores of fungus (with diameter 8 μm). Such biotical factors are forceing decomposition of cellulose and hemicelluloses, being main components of cell walls. The places of cellulose and hemicelluloses takes in such cases water, and therefore maximum moisture content of excavated wood is always much higher from maximal content of water in excavated timber.

Figs. 2-7 24 photographs selected from 170, are presenting anatomical cross-sections of archaeological oak and elm wood samples impregnated with the three tested preparations. The criteria of selection were well-visible structural features and places of impregnate penetration and deposition in the wood tissue.

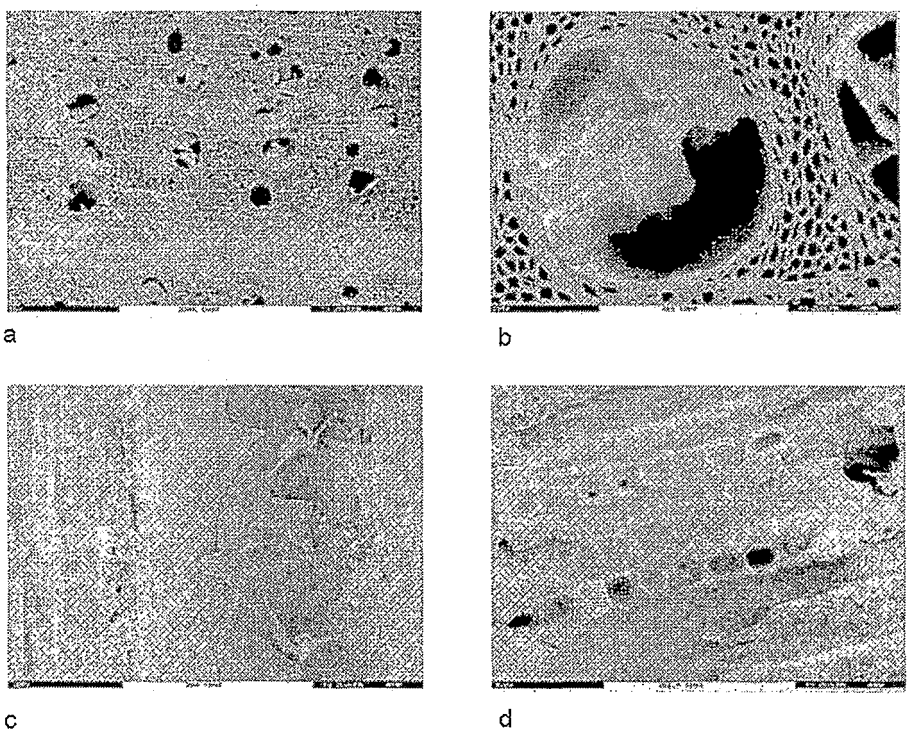
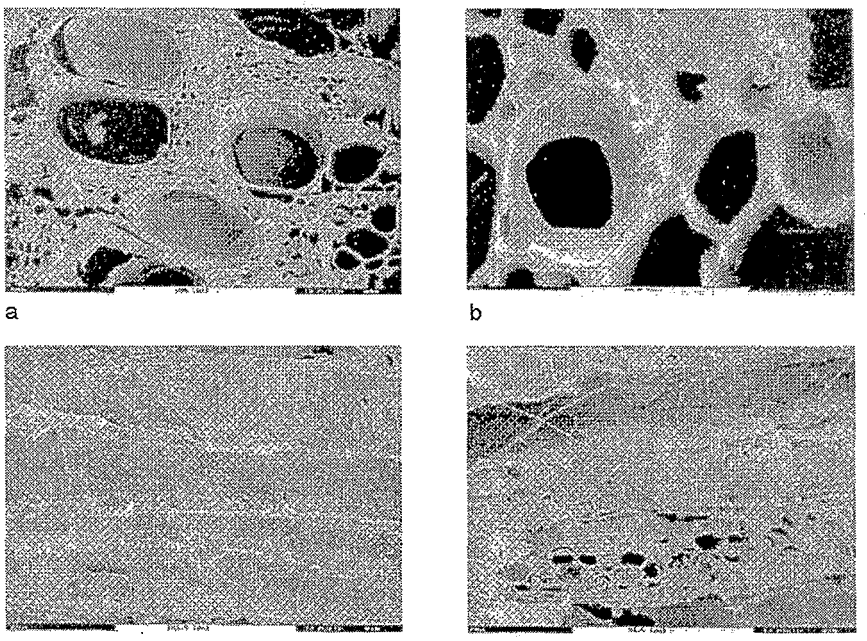


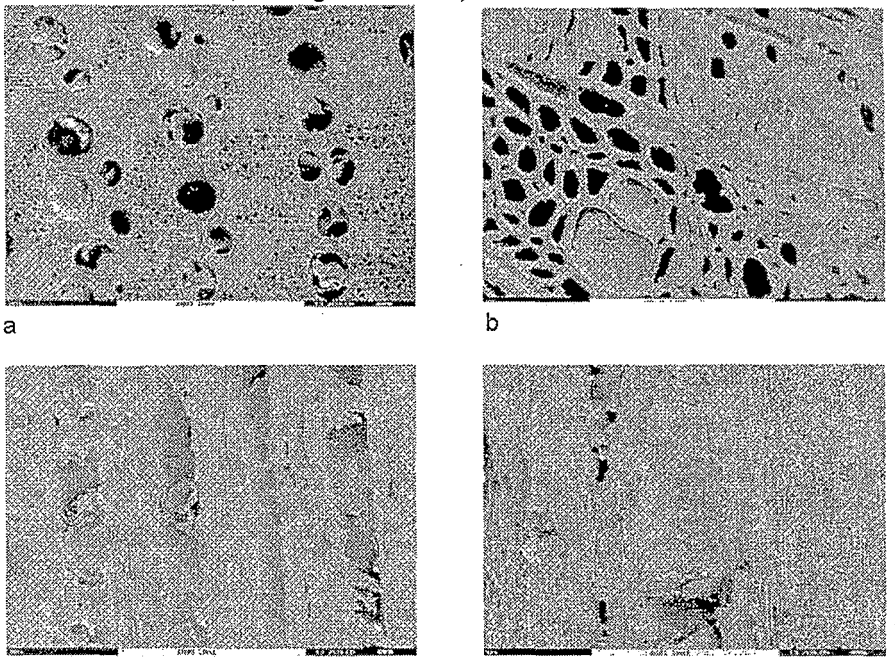
Fig. 2 Archaeological oak wood tissue impregnated with saccharose (a,b –cross section, c – radial section, d – tangential section)



a b

c d

Fig. 3 Archaeological elm wood tissue impregnated with saccharose (a,b –cross section, c – radial section, d – tangential section)



a b

c d

Fig. 4 Archaeological oak wood tissue impregnated with lactitol (a,b –cross section, c – radial section, d – tangential section)

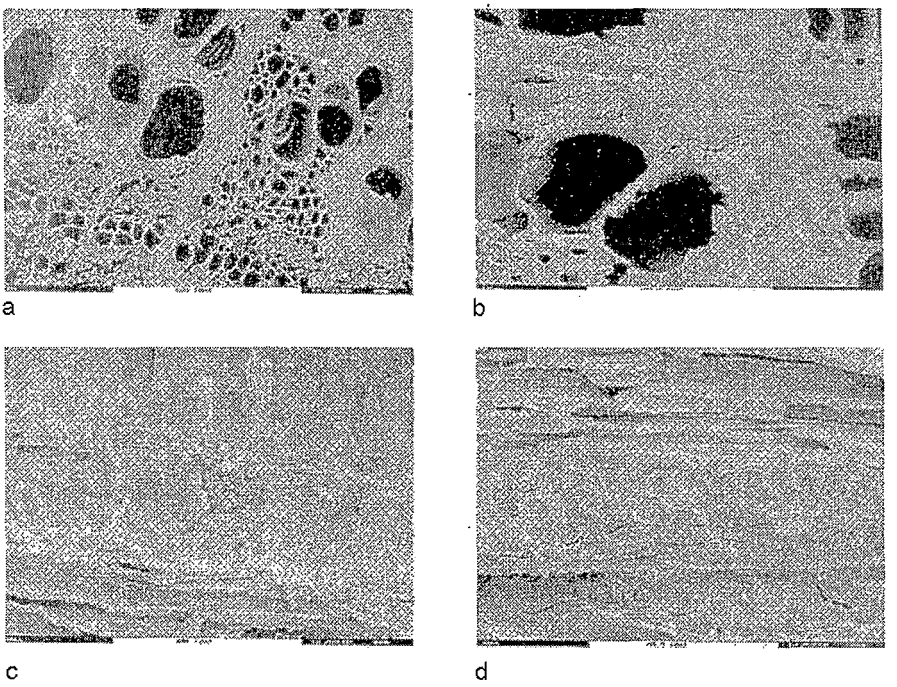


Fig. 5 Archaeological elm wood tissue impregnated with lactitol (a,b –cross section, c – radial section, d – tangential section)

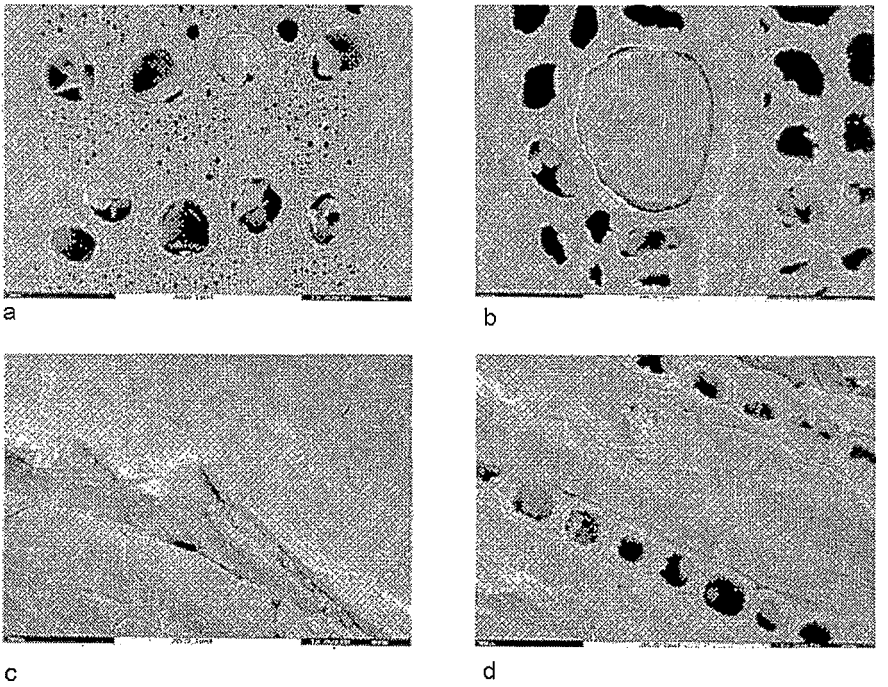


Fig. 6 Archaeological oak wood tissue impregnated with PEG 300 (a,b –cross section, c – radial section, d – tangential section)

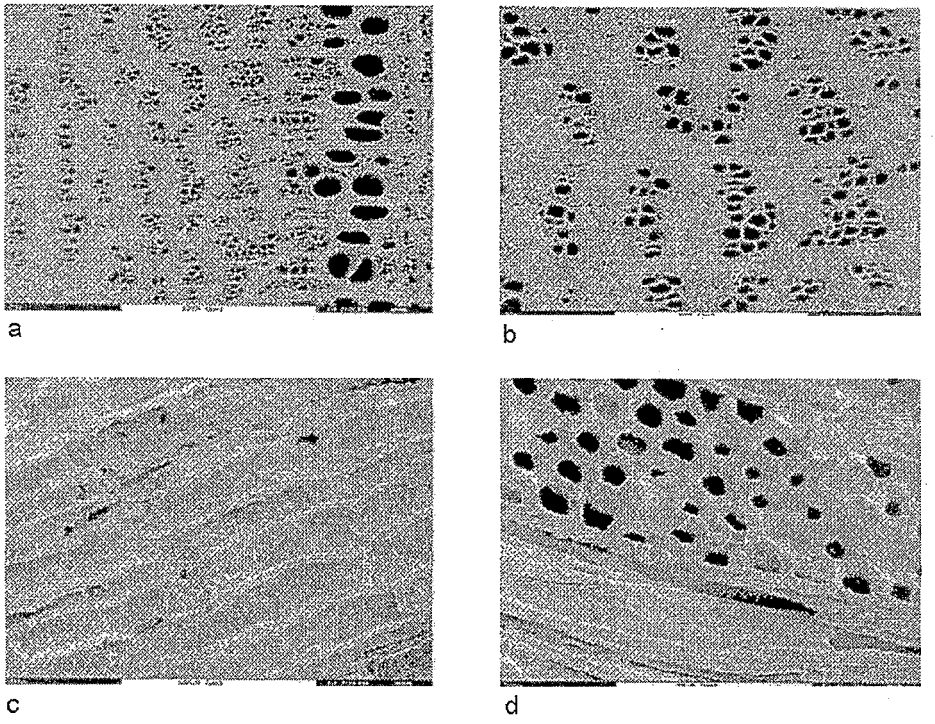


Fig. 7 Archaeological elm wood tissue impregnated with PEG 300 (a,b –cross section, c – radial section, d – tangential section)

The singled out properties of modifying substance enabled to analyse tending to final evaluation of preservation procedures of excavated timber.

In result of such behaviour, is was stated, that the highest qualification value could be assumed to the polyethylene glicol (PEG 300). Such preservation chemical introduced into excavated wood of broadleaved ring porous kinds of timber is characterised by following positive features and properties:

- it is penetrating degraded cell walls of wood fibres,
- it collects on inside walls of vessels (and thylles), tracheids, and parenchymatic cells,
- it fills cellular voids and occurs in degraded wood,
- it creates continuous and elastic layer,
- particles of polyglycol, exchanging the water, are maintaining wood tissue in quasi-swelled state.

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Streszczenie: *Ocena mikroskopowa wykopaliskowego drewna liściastego stabilizowanego wybranymi impregnatami.* W badaniach nad konserwatorskim nasycaniem archeologicznego drewna dębu i wiązu, 60% wodnymi roztworami sacharozy, laktitolu i poliglikolu etylenowego 300 (PEG 300), uzyskano nieznacznie zróżnicowany efekt stabilizacji wymiarowej. Zdecydowano przeto dokonać mikroskopowej analizy miejsc penetracji i osadzania się w tkance drzewnej substancji modyfikującej celem wytypowania najkorzystniejszej metody konserwacji zabytkowego drewna. W artykule przedstawiono zdjęcia drewna wykopaliskowego przed oraz po zaimpregnowaniu i wysuszeniu wykonane na skaningowym mikroskopie elektronowym.

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The computerization of the statistical process control in lumber industry

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Abstract: *The computerization of the statistical process control in lumber industry* . One qualified possibilities of the use of the computer technics during the statistical process control. One gave the example of the use in lumber industry .

Key words: computer , SPC , lumber industry

Introduction

In the sphere of the assurance of the quality since a long time one uses statistical methods. Main areas of her uses is the inspection of raw materials /of goods for further processing/, the final inspection of products and the running inspection of the manufacturing process. An aim of the statistical process control /SPC/ is the prevention of the production of the defective article which can appear at the traditional method of the leaning quality inspection on the final research. Herself method SPC , being based on the idea of time sheets Shewarta , is well-known already since a long time. The however wider introduction SPC was limited connected difficulties with a technics measuring - and computational. The situation changed radically along with with the arrival of the era of quick and cheap computers. These computers have at their disposal with programmes which make possible the execution of the test on the normal schedule , the calculation of indicators of the efficiency of machines and of processes , and also the leadership and presenting of cards of the adjustment of the quality. They have possibilities of development and ratings of results of measurement. Effects of rating have the form of tables and of histograms. A most important consequential advantage from the usage SPC is the avoidance of the formation of productive defects already on the stage of the production. In many cases the elimination of sources of their formation. Results of the inspection used are as direct to of the regulation set machine tools. Introducing the properly well-chosen method of prognosing of results one can foresee , whether and the when given feature of the quality goes beyond outside the admissible area. Thanks to this one can also properly earlier to react , correcting properly sets of the device.

The example- use of the computerization spc in lumber industry

The lumber industry shows the considerable delay at the use of the technics SPC with relation to of other industries. In sawmills SPC one can use reducibly of the scattering of the thickness of the lumber. Potential economic advantages at the use of this method consist in the enlargement of the efficiency of the lumber and to the diminution of the scattering of the thickness of the finished product. Enlarged efficiency of the lumber will cause lower manufacturing costs. The diminution of the scattering of the thickness of the lumber will profit receivers by the enlargement of the value of the product. The system SPC uses control charts , properly to define the scattering of the thickness of the lumber in the sawmill. Supervisory borders on graphs show , whether changes of the thickness are natural for the process , or else

this are the change from the special reason. Measurement of the thickness of the lumber are executed in key - places of the manufacturing process. The system SPC gives to the operator "Head - Rig", to the operator "Re - saw", to the sorter of the lumber and supervisors in "the real time" the change of the value of the thickness of the lumber. Solution of this problem become described on the example realized by The University of Tennessee , Tennessee Forest Products Center. This is the investigative programme folding from two phases. In the phase I to the measurement of the thickness of the lumber one uses of electronic , digital micrometers /slide calipers/ with the radio - data transmission. At the measurement of the thickness of the board takes under the attention six measurement , These six measurements is seated along the board , three measurement are executed along every side
/Fig. 1/.

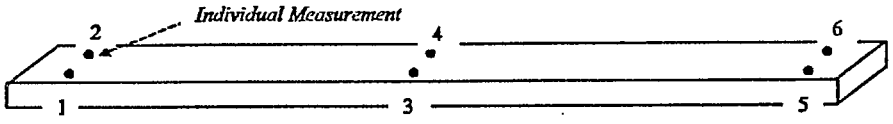


Fig.1. Thickness measurement locations per board

Data thicknesses of the lumber are shown in "real-time" operators of machine tools , to the sorter of the lumber and to the management at the use of the technics human machine interface /HMI/. This is the programme being with the interface among the man and the machine. Created are so-called. synoptic screens being with the realistic image of the industrial process . The technician HMI shows on-screen of the computer the manufacturing process. Operators of devices are warned about productive problems by alarms visual and of a sound , detecting au courant appearing productive problems. Systems HMI are joint with systems of the statistical process control /SPC/. In the phase II the measurement of the thickness of boards is executed by the laser in "real - time". Systems HMI are joint with systems of programmable logic controllers /PLC/. In the dependence from the thickness , boards are earmarked by automatized system the controlled spray by PLC. Detectable of the presence of the board one used the visional camera. Boards can be also marked into the any manner at the switched turned off automatic mode. On the drawing 2 one showed the example of the system /HMI – Wonderware InTouch/.

Conclusions

The use of the technics of the statistical process control /SPC/ and human machine interface technology /HMI/ reducibly of oscillations of the thickness of the lumber makes possible the improvement of the manufacturing process and the enlargement of the efficiency of materials. Will bring this considerable financial advantages. It belongs to guide researches the distinctive making possible use of this technics in different manufacturing processes of the wood industry.

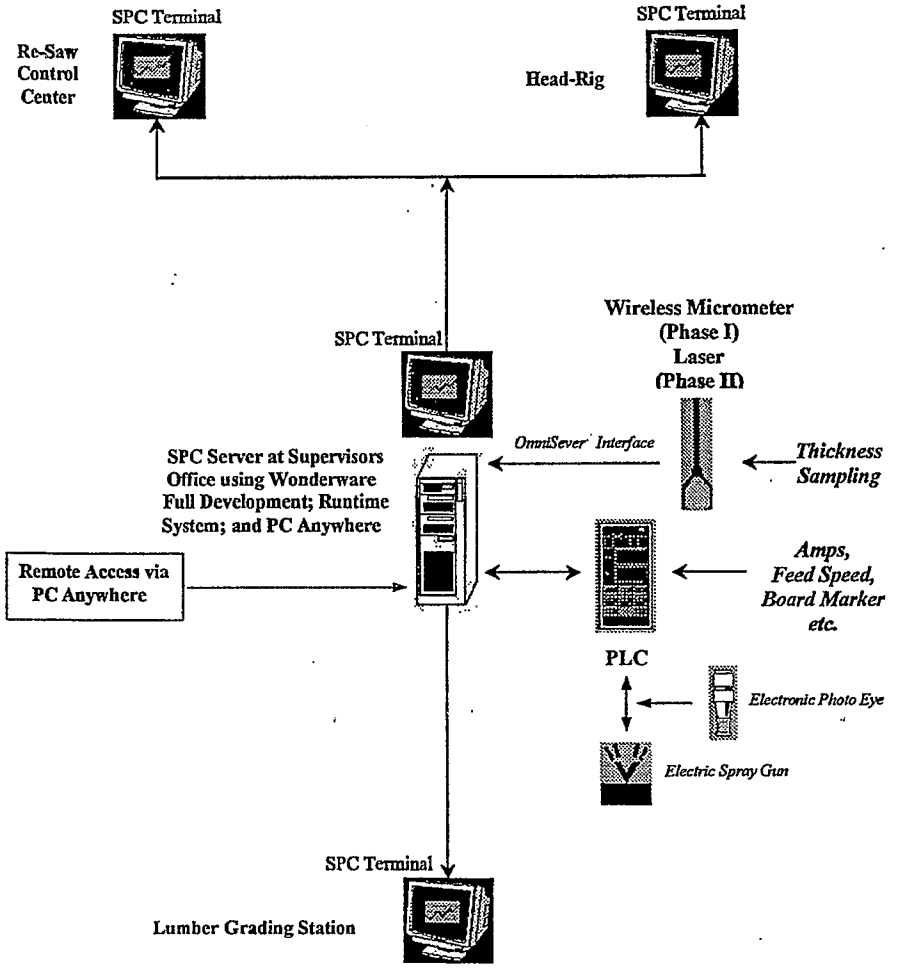


Fig. 2. Hardware System Architecture

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Streszczenie: *Komputeryzacja statystycznego sterowania procesem w przemyśle tartacznym.* Określono możliwości zastosowania techniki komputerowej podczas statystycznego sterowania procesem. Podano przykład zastosowania w przemyśle tartacznym.

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Some elements of the anatomical structure of spruce wood growing in Latvia

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Abstract: Comprehensive studies on spruce wood have been made in Latvia since 1998. These studies embrace the anatomical structure of spruce wood as well as the relevance and dependence of its parameters. The results are compared with other publications to evaluate the quality and competitiveness of Latvian spruce, which makes it possible to assess the forestry prospects for spruce in different areas. The task of the report is to show the dependence of the spruce wood anatomical structure on forest growth conditions and the locality of the sample in the stem. Wood samples were taken at the stem butt-end (R) at ¼, ½ and ¾ of the height, in its sapwood (A), core (K) and juvenile (S) wood. The average annual ring width (G_{pl}), late wood percentage in the annual ring (G_{vk}%), double cell wall width and diameter of tracheids both in early ($T_{r\,ak}$) and late ($T_{r\,vk}$, $T_{2w\,vk}$) wood, and tracheid length (T_l) were characterized. A comparative analysis of the data obtained shows that, in the majority of cases, the spruce wood anatomical structure is greatly affected by the location of the wood sample in the stem and the forest growth conditions.

Keywords: Norway spruce, *Picea abies L.* Karst., anatomical structure

Introduction

In Latvia, the woodworking industry is developing rapidly, which, in its turn, dictates the necessity of a more strict forest inventory and forest trees quality control. One of the most widespread tree species, comprising 18 % of the stock in Latvia, is spruce. Spruce and spruce forests are assessed from the biological and ecological point of view, although are not investigated from the viewpoint of wood structure and properties.

The aim of this study was to characterize the main anatomical structure parameters of the wood of Norway spruce (*Picea abies L.* Karst.) growing in the Kurzeme territory (Western upland of Latvia), i.e. annual ring width (G_{pl}), late wood width in the annual ring ($G_{pl\,vk}$), the share of late wood in the annual ring (G_{vk}%), tracheid length (T_l), its double cell wall width as well as cross-sectional dimensions in the radial direction in early ($T_{r\,ak}$, $T_{2w\,ak}$) and late wood ($T_{r\,vk}$, $T_{2w\,vk}$).

Experimental

For experiments, samples of Norway spruce were taken in stocks located in Rucava, Rinda and Misa forest-divisions, Kurzeme upland.

Table 1

Distribution of spruce forests in terms of growth conditions

Forest type	Forest area		Growing stock	
	×1000 ha	%	10^6 m^3	%
Dry forests	374.1	68.8	67.3	74.4
Wet forests	75.1	13.8	9.2	10.2
Drained forests	94.5	17.4	13.9	15.4
Total	543.7	100	90.4	100

As can be seen from Table 1, the sampling areas were chosen in three most widespread forest growth condition types, namely, drained (*Myrtillosa turf. Mel).*, *dry (Vacciniosa)* and wet (*Hylocomiosa).*

All three forest types for tree growth and wood development were different. Hence, they are expected to differ the wood structure and, therefore, wood properties.

All sample trees were Kraft class II trees. After trimming, the sample trees were measured and cross cut. The stems division was made according to Sachsse and the method modified at the Latvian State Institute of Wood Chemistry (SACHSSE et al., 1988). To examine the variations in the wood structure and properties along the length of the tree, wood blanks were taken at four different heights, namely, at the butt-end (R), ¼ of the stem height (1/4), in the middle (1/2) and ¾ of the stem height (3/4).

The average annual ring width, as well as late and early wood width in the annual ring were determined using a reflecting microscope MKTF-1 with a 80x magnification. The number of tracheid rows and their average radial cross-sectional dimensions were determined for each annual ring. The share of the annual ring wood was calculated, correspondingly taking for the basis these measurement data, i.e. the number of late and early wood tracheids in the annual ring and the corresponding tracheid radial cross-sectional dimensions. Tracheid parameters were determined using the reflecting microscope MKTF-1 with a gauge measurement television device – the cross-section dimensions and double cell wall width in the radial direction, both in early and late wood, were measured. The tracheid length was measured using a stereoscopic microscope MBS-9 with a 12x magnification. For each parameter, 100 measurements were made, from which average data were calculated. Measurements were made with an accuracy of 0.95.

Results and Discussion

After determining the anatomical parameters, the linear correlation analysis of the obtained parameters was made, taking for the basis the results obtained for all sample trees. The linear correlation is characterized by the corresponding variation in the second parameter as one of the two parameters under study varied. The manifestation of this tendency is calculated from the relationship (ARKHIPOVA et al. 1997):

$$r_{x,y} = cov_{x,y}/s_y \cdot s_x$$

where:

$r_{x,y}$ - linear correlation coefficient between the variable x and y;

$cov_{x,y}$ - covaration between the variable x and y;

s_x, s_y - standard deviation of the variable x and y.

Table 2

Values of spruce wood anatomical parameters

	$G_{pl.}$, mm	$G_{pl\,vk.}$, mm	G_{vk}, %	$G_{pl\,ak}$, mm	$T_{r\,ak}$, µm	$T_{r\,vk}$, µm	$T_{2w\,ak}$, µm	$T_{2w\,vk}$, µm	T_l, mm	Forest type
R–S	3.28	0.78	23	2.50	28.07	19.65	3.18	6.35	2.29	Dry forests (*Vacciniosa Hylocomiosa*)
R–K	3.39	0.87	26	2.51	37.73	24.71	4.27	7.28	3.24	
R–A	2.25	0.68	31	1.55	38.67	26.66	4.80	7.43	3.89	
¼-K	3.95	0.97	25	2.98	35.72	24.19	3.95	7.31	3.61	
¼-A	2.43	0.88	29	1.54	37.96	24.78	4.50	8.33	4.24	
½-K	4.15	0.87	23	3.28	33.45	21.85	3.91	6.89	3.33	
½-A	2.38	0.74	31	1.62	36.71	22.00	4.13	6.87	3.95	
¾-K	3.49	0.89	24	2.60	32.56	21.74	3.77	7.23	2.65	
¾-A	2.61	0.88	33	1.73	35.56	21.74	4.16	7.86	3.53	
R–S	1.69	0.54	31	1.15	23.85	17.49	4.03	6.72	2.22	Drained forests (*Myrtillosa turf. mel.*)
R–K	1.69	0.44	26	1.26	32.96	20.13	4.24	7.36	3.21	
R–A	1.94	0.62	31	1.32	35.36	21.36	4.41	6.82	3.89	
¼-K	2.21	0.47	22	1.74	29.98	18.62	3.91	6.67	3.61	
¼-A	1.06	0.40	38	0.67	35.14	21.31	4.42	8.71	4.71	
½-K	2.51	0.83	34	1.68	32.15	19.97	4.15	6.24	2.83	
½-A	2.14	0.90	43	1.24	34.66	21.57	4.29	7.16	4.40	
¾-K	2.56	0.92	37	1.65	26.31	19.94	4.30	6.07	3.46	
¾-A	1.85	0.76	40	1.09	32.68	20.11	4.02	8.14	4.58	

Designations:
G_{pl} – average annual ring width, mm;
$G_{pl\,vk}$, $G_{pl\,ak}$ – late and early wood annual ring width, mm;
G_{vk} – late wood percentage in the annual ring;
$T_{r\,ak}$, $T_{r\,vk}$ – diameter of tracheids in early and late wood, µm;
$T_{2w\,ak}$, $T_{2w\,vk}$ – double cell wall width of tracheids in early and late wood, µm;
T_l – tracheids lenght, mm;
R-S – butt-end, juvenile wood
R-K – butt-end, heartwood
R-A – butt-end, sapwood
¼-K – 0.25 of the stem height, heartwood
¼-A – 0.25 of the stem height, sapwood
½-K – 0.5 of the stem height, heartwood
½-A – 0.5 of the stem height, sapwood
¾-K – 0.75 of the stem height, heartwood
¾-A – 0.75 of the stem height, sapwood

An examination of the obtained anatomical parameters (Table 2) shows that all wood parameters are variable depending on the location in the tree stem height or cross-section, as well as depending on the growing type.

There is no noticeable correlation among the annual ring parameters as the stem height varies. However, this is observed depending on the location in the stem cross-section. The annual ring width for sapwood exceeds that for heartwood, namely, by about 70 % at all stem heights. In terms of the growing types, the annual ring width in dry forests is higher by about 50 % on the average. The amount of late wood is greater in drained forests, i.e. by about 5 % in comparison with the amount of late wood in the year ring for spruce trees growing in dry forests.

Tracheid length values from the stem butt-ends grow by 10 % up to ¼ of the stem height, both in heartwood and sapwood, and tend to decrease towards the ¾ of the stem height (in comparison with the stem butt-end by about 15 %). In the stem transverse direction, the

tracheid length values are higher by 20 % for sapwood in comparison with heartwood. Tracheid length values, depending on the forest type, vary by 7 %. The longest tracheids are characterized for spruce growing in the dry forest type.

There is no noticeable correlation among the tracheid double cell wall width values as the stem height varies, while the greatest width in the stem cross-sectional direction is for sapwood, namely by about 5 %. Depending on the forest type, the tracheid double cell wall width varies minimally, namely by 3 %. The greatest tracheid cell width for early wood is observed in the case of spruce wood from the dry forest type, and that for late wood tracheids in the case of drained forests.

Tracheid cross-sectional dimensions, both in sapwood and heartwood, tend to grow in the direction from the butt-end to the end. In the stem cross-sectional direction, the tracheid dimensions are greater for sapwood, namely by about 5 %. The cross-sectional dimensions for early wood tracheids are greater for spruce wood grown in the dry forest type, namely, by 10 %, and those for late wood tracheids by 15 %.

To elucidate the conditions affecting the wood parameter values, a correlation analysis was made (Table 3). It has been found that the annual ring width (1.06-4.15 mm) correlates essentially with the late wood tracheid cross-sectional dimension (0.51). An essentially negative correlation has been shown by the amount of late wood in the annual ring with the early wood width in the annual ring (-0.53). An essential correlation has been shown by early wood tracheid cross-sectional dimensions with the late wood tracheid cross-sectional dimension (0.63) and tracheid length (0.55).

Unfortunately, information on the sample's exact location in the wood stem as well as the forest type where this tree grew is practically missing in the reviewed literature.

Table 3

Correlation among the values of the anatomical parameters of spruce

	G_{pl}	$G_{pl\,vk}$	G_{vk}	$G_{pl\,ak}$	$T_{r\,ak}$	$T_{r\,vk}$	$T_{2w\,ak}$	$T_{2w\,vk}$	T_l
G_{pl}		0.63*	- 0.27	0.95*	0.14	0.35	- 0.40	- 0.25	- 0.44
$G_{pl\,vk}$			0.49	0.35	0.21	0.51*	- 0.29	- 0.13	- 0.20
G_{vk}				- 0.53*	0.13	0.21	0.10	0.16	0.27
$G_{pl\,ak}$					0.07	0.21	- 0.39	- 0.26	- 0.45
$T_{r\,ak}$						0.63*	0.47	0.40	0.55*
$T_{r\,vk}$							0.34	0.13	0/14
$T_{2w\,ak}$								0.45	0.46
$T_{2w\,vk}$									0.43
T_l									

Footnote:

* correlation is significant, with a probability of 99 %

the rest - correlation is significant, with a probability of 95 %.

The examination of the tracheid parameters (Table 4) shows that the tracheids of spruce growing in Latvia are longer than those for spruce grown in Germany, but shorter than those for spruce grown in Russia. Double cell wall width values for early wood do not differ essentially, while the double cell wall width of late wood for spruce grown in Germany is essentially greater. The radial cross-sectional dimensions of early wood are greater for spruce grown in Germany.

Table 4

Comparison of spruce wood tracheid parameters

State [Reference]	Tracheids lenght, mm	Double cell wall width of tracheids, μm		Diameters of tracheids cells in early wood, μm
		Early wood	Late wood	
Latvia (Kurzeme)	2.22 – 4.71	4.13	7.20	32
Russia [3]	1.5 – 5.3	–	–	–
Germany [6]	2.90	4.0	11.0	35
[4]	3.20	–	–	–

Conclusions

Summarizing the data on the performed studies and the correlation analysis, and comparing the spruce wood structure in Latvia and elsewhere, the following should be noted. Annual ring width is greater for spruce grown in dry forests, namely by about 40% as compared with spruce grown in drained forests.

The share of late wood in the annual ring is about 30 % from the total annual ring width.

The amount of late wood in the annual ring is greater for spruce grown in drained forests in comparison with spruce grown in dry forests.

The longest tracheids for spruce wood are at the ¼ of the stem height.

Tracheid cross-sectional dimensions, both for spruce grown in dry forests and that grown in drained forests, as well as for heartwood and sapwood, tend to diminish in the direction from the butt-end to the ¾ of the stem height.

There is a significant positive correlation between the annual ring width and early and late wood width, while the annual ring width is not essentially affected by the early wood tracheid dimensions.

Tracheid length values for spruce grown in Latvia are greater by approximately 0.5 mm than those for spruce grown in Germany, while the tracheid length range is smaller than that for spruce grown in Russia.

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Changes in the optical properties of birch wood as a result of hydrothermal treatment

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Abstract: The analysis of the plywood market shows that customers prefer birch plywood of lighter hues. Light birch wood veneer logs are exported to Latvia from Finland as well as the Novgorod region, Russia.

A question arises - why does such a situation emerge? Why is the Latvian birch plywood not so light as the birch plywood from Finland?

To find a solution to these questions, a critical assessment of factors such as different birch species and their growth areas, soil conditions, forest growth types, climatic conditions, soil mineral composition, wood structure, its morphological structure and chemical composition, etc. is necessary.

A reflecting spectrophotometer CM-2600d (MINOLTA) as well as a devise designed at the Technical University in Zvolen (TUZVO) was employed in the experiments.

It has been shown that the optical properties of birch wood depend on both the species, silver birch (*Betula pendula* Roth.) and downy birch (*Betula pubescens* Ehrth.), and the conditions of the hydrothermal treatment of birch wood, exemplified by silver birch wood. It has been shown that downy birch wood is lighter than silver birch wood. Data were obtained on the effect of the conditions (water temperature 40 °C, 60 °C, 70 °C, 80 °C and treatment time 6, 16, 24 and 36 hours) of the hydrothermal treatment of silver birch wood on the visible part of the reflection spectrum with the precision ± 0.01%.

Keywords: wood optical properties, silver birch (*Betula pendula* Roth.), downy birch (*Betula pubescens* Ehrh.), wood reflection, hydrothermal treatment

Introduction

The investigation of the furniture market shows that customers currently prefer furniture made of birch wood of definite brightness. This is especially typical for production of plywood.

To examine how it would be possible to increase the brightness of plywood, it is very important to investigate the dependence of the optical properties of wood in the visible part of the spectrum (mainly reflecting) on the hydrothermal treatment of wood (water temperature and heating time), as well as the dependence of the optical properties of freshly-cut birch wood on the tangential section side (the samples' outside and inside *versus* the stem centre), and also humidity.

This year, it has been observed in the furniture exhibition in Birmingham (United Kingdom) that customers tend to choose birch wood furniture more readily. Also in the furniture exhibition held in Cologne (Germany), the demanding German customer chooses the furniture from birch wood, whose colour does not differ much from that of Canadian maple. However, the analysis of the plywood market shows that customers tend to choose birch plywood of lighter hues.

Much attention has been recently attached to the optical properties of wood, especially its brightness. It is important to know the optical properties when designing the living-spaces' interior and furniture, while it is especially important in plywood production, where consumers tend to prefer the whiter Finnish plywood, whose reflection is only by several percent higher than that for plywood produced in Latvia.

Knowing that everything is dictated by fashion in the consumers' world, it should be remembered that the proper understanding of the consumers' demands and the knowledge of the resources' (wood's) properties makes it possible to be aware of one's own possibilities and organize an economically attractive production, thus prudently utilizing the greatest wealth – forests.

Hence, it is important to investigate the optical properties of the commercially utilized birch species, namely, silver birch (*Betula pendula* Roth.) and downy birch (*Betula pubescens* Ehrh.), and to elucidate the factors that affect the optical properties of wood. When considering the plywood production process, it can be seen that the hydrothermal treatment of wood is one of the essential operations influencing the optical properties of birch wood.

Since the oxidation of low-molecular extractive phenol substances occurs in freshly-cut birch wood on the sample's surface after its mechanical processing, then, already in a couple of hours, the light sample's surface changes the colour from light white to light brown.

It is known that wood changes its natural colour during its service time as a result of the effect of different factors, including air, light fungal damages, as well as a whole range of physical and chemical actions in storage and during processing (BOROVIKOV & UGOLEV 1989).

It has been shown that samples of Japanese cypress (*Chamaecyparis obtusa* Sieb. Et Zucc.) and spruce (*Picea* sp.), endured at elevated temperatures and humidity, noticeably change their colour, turning darker (MITSUI et al. 2001).

Methods

It is known that wood is assigned to diffuse scattering radiation materials. Hence, to provide the objective measuring of its reflection, it is necessary to observe the scattered radiation. This can be achieved with the help of the optical sphere, using which the scattered radiation can be gathered and transmitted to a radiation sensor and further registered on a display. Such an opportunity is provided by the spectrophotometer CM–2600d (MINOLTA), which measures the sample's reflection coefficient with a precision of ± 0.01 % in the spectrum visible part range 360-700 nm (SPECTROPHOTOMETER CM-2600d). Using such a device, it is possible to measure different reflection components of the spectrum. i.e. SCI (Specular Component Included) and SCE (Specular Component Excluded). Generally, the colour may be expressed in terms of hue, lightness and saturation. The hue classifies the colour in terms of red, yellow, green, etc. Lightness can be measured independently of the hue and may be represented on a vertical axis with the top showing the brightest and the bottom the darkest colours. Saturation, expressing how vivid or dull the colour is, may be represented on horizontal axes when these three colour attributes are shown in a three-dimensional system. Such a system helps to better visualize the relationship between hue, lightness and saturation.

To objectively determine the colour, one can either observe the colours to make visual comparisons to the selected standards or use one of the more scientific methods of colorimetry (RESCH et al. 2000):

the XYC tristimulus values and the associated Yxy colour space form (the base of the present colour space as defined by the Commission Internationale de l'éclairage, CIE);

the L* a* b* colour space method, the very popular CIE lab-system;

the L*C*h colour space which uses cylindrical coordinates (C* is chroma and h the hue angle) instead of the rectangular ones of the L*a*b* colour space or

spectrophotometry measuring the reflection of an object that is illuminated within the range of a selected spectrum.

According to the three component theory of colour vision, the eye is able to receive the three primary colours, red, green, and blue, and all colours seen are mixtures of these. As defined by CIE, the XYC tristimulus values can be calculated by using the colour-matching functions or x(s), y(s) and z(s) with high sensitivities in the red, green and blue wavelength regions, respectively, as seen by a "Standard Observer". The CIE also defined a colour space for graphing the colour in two dimensions indepedent of the lightness. This Yxy colour space contains the tristimulus value Y which is identical to lightness as well as the chromaticity coordinates x, y calculated from the tristimulus values XYZ. The results of colour measurements can then be visualized in the CIE xy chromaticity diagram for the colour space in which the achromatic colours are located toward the centre of the diagram, and the chromaticity increases toward the edges.

The L*a*b* - colour space contains L* as lightness and a* and b* as chromaticity coordinates with + a* and – a* the red and green as well as + b* and – b* the yellow and blue directions, respectively. The a* and b* values increase from the achromatic centre of the space outward with increases in the saturation of the colour.

To determine the reflection coefficient L* in the visible part of the spectrum, 22 samples were used from both silver birch and downy birch woods, with the dimensions in the axial, tangential and radial directions 20 mm, 80 mm and 10 mm, respectively (Table 2).

Experiments on the optical properties of silver and downy birch wood were also made at the Zvolen Technical University (TUZVO), the Department of Wood Science, using an original colorimeter. The measurements were made in the following spectrum regions: red, green and blue. Sample dimensions were 60 × 60 × 10 mm (axial – 60 mm, tangential – 60 mm and radial – 10 mm). The sample number was 16 from each species. The obtained results were processed using the programs "Color" and "Lucia". Both these programs were shown to give rather similar results, therefore data obtained using the program "Lucia" are provided in the present paper (Table 3).

In hydrothermal treatment experiments, two kinds of samples sawn out from silver birch veneer log (top-end diameter 50 cm) sapwood were used, namely, small (40 × 40 × 10 mm) and large (120 × 120 × 120 mm).

Since an area with at least Ø 8 mm is necessary for diffusion reflection measurements, the small samples with the dimensions (in axial, tangential and radial directions) 40 x 40 x 10 mm were used, which had a direct contact with water.

Samples with the dimensions in the tangential, axial and radial directions 120 mm, 120 mm and 10 mm, respectively, were sawn out from the larger hydrothermally treated samples (120 × 120 × 120 mm), which were processed under the same conditions. Thus, samples were obtained, which had no direct contact with water, which actually occurs in commercial veneer log hydrothermal treatment pools.

Modelling of the wood hydrothermal treatment process

To determine the dependence of the optical parameters of birch wood on the water hydrothermal treatment conditions, the samples were treated in thermostats under mild hydrothermal treatment conditions at 40 °C, under severe hydrothermal conditions at 80 °C, and at intermediate temperatures of 60 °C and 70 °C (Table 1).

Table 1

Birch wood samples hydrothermal treatment time and water temperature

Heating time, h	16	24	36	24	24	6	16	24	36
Temperature, °C	40	40	40	60	70	80	80	80	80

Reflection was measured for samples of both types after the hydrothermal treatment immediately after taking them out from the thermostat and weighing. Then they were left to stay on a laboratory table at room temperature, and, after a certain time, the measurement was repeated, thereby determining the reflection value depending on moisture.

When the samples' moisture was close to the room equilibrium moisture content, a half of the samples was sanded, thereby removing the oxidized layer. This made it possible to elucidate the optical parameters of wood after its hydrothermal treatment. The measurement of the parameters of these samples was similar to that of non-sanded samples.

Results and Discussion

Reflection coefficients for wood of different silver birch and downy birch species are shown in Table 2.

Table 2

Reflection coefficients for wood of different silver birch and downy birch species

Reflection L*, %					
Silver birch	Downy birch	Silver birch	Downy birch	Silver birch	Downy birch
82.29	85.40	83.74	83.87	82.66	87.91
83.25	85.44	83.13	84.25	82.48	86.29
82.87	84.85	83.19	86.93	80.34	86.15
82.37	86.25	81.00	85.14	78.52	86.20
82.46	83.51	80.40	86.77	82.44	86.64
83.49	83.56	77.68	87.99	83.66	85.75
78.28	84.23	79.48	86.14	–	–
80.58	85.14	83.90	84.80	–	–

Average values L*: silver birch – 81.74 %, downy birch – 85.60 %, the difference makes up 3.86 %. Based on the statistical processing of these data, it is assumed that at the probability P = 95 % and P = 99 %, the difference between the average values of the reflection coefficients of downy birch and silver birch is significant.

The values of brightness for wood samples of different birch species (16 from each species), obtained using the "Lucia" technique developed by TUZVO, are shown in Table 3.

Table 3

Brightness of wood for silver birch and downy birch growing in Latvia

Species	Spectrum region		
	Red	Green	Blue
Silver birch	246	227	196
Downy birch	238	212	180

It can be seen that downy birch wood is lighter in comparison with silver birch wood in all the three spectrum regions.

In plywood production, the hydrothermal treatment time is crucial, therefore, it is important to know, how the hydrothermal treatment time affects the wood brightness. To elucidate this, the reflection of freshly-cut birch wood *versus* the hydrothermal treatment time under mild hydrothermal treatment conditions at +40 °C and severe conditions at +80 °C, as well as at the intermediate temperatures +60 °C and +70 °C, was measured. The small samples, after the hydrothermal treatment, were dried to the oven dry state, and, without grinding, reflection was measured from both inside and outside. Reflection was measured also for parallel non-ground samples in the oven dry state without hydrothermal treatment (Table 4), where reflection values are presented as average ones from 8 samples.

Table 4

Reflection of birch wood samples prior to and after hydrothermal treatment

Temperature and time	Measurement scheme	L* after processing, %		L* without processing, %	
		Outside	Inside	Outside	Inside
40 °C; 16 h	SCI	65.05	63.18	83.63	83.04
	SCE	64.57	62.72	83.03	82.43
40 °C; 24 h	SCI	65.81	65.69	83.25	82.55
	SCE	65.36	62.97	02.62	81.90
40 °C; 36 h	SCI	64.54	64.96	82.92	82.94
	SCE	64.08	64.55	82.27	82.37
60 °C; 24 h	SCI	61.40	62.30	74.80	75.26
	SCE	61.11	61.97	74.27	74.65
70 °C; 24 h	SCI	62.27	62.86	75.93	75.59
	SCE	62.04	62.63	75.56	75.19
80 °C; 36 h	SCI	62.72	62.38	74.03	74.40
	SCE	62.50	62.20	73.83	73.95
80 °C; 6 h	SCI	67.57	66.35	77.11	77.02
	SCE	67.37	66.14	76.69	76.67
80 °C; 24 h	SCI	64.66	61.80	75.53	76.33
	SCE	64.52	61.62	75.11	75.95
80 °C; 16 h	SCI	65.72	62.11	76.43	75.34
	SCE	65.59	61.94	75.88	74.91

It can be seen that, as the hydrothermal treatment time increases at one temperature, the reflection of freshly-cut birch wood decreases both for small and large samples (Figs. 1 and 2). For samples heated at +40 °C for 16, 24 and 36 hours, these parameters for oven dry wood differ moderately, namely, by 1.68 % according to SCI and by 1.71 % according to SCE. Apart from this, the curve is slightly bended, which means that, at the greater heating time, brightness at first tends to decrease, and then grows again.

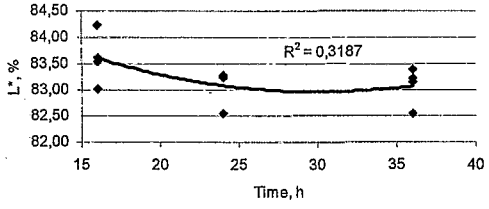


Fig. 1. Reflection of small samples *versus* the treatment time at the temperature + 40°C

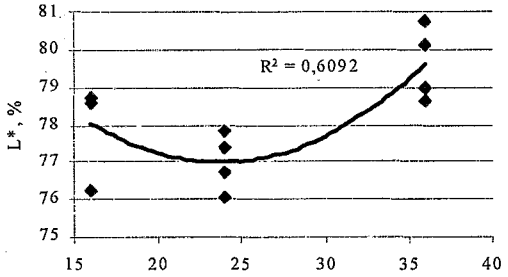


Fig. 2. Reflection of large samples *versus* the treatment time at + 40 °C

For small samples subjected to the hydrothermal treatment at +80 °C for 6, 16, 24 and 36 hours, as the samples' heating time increases, reflection decreases linearly. This difference between the treatment time 6 hours and 36 hours makes up even 4.40 % according to SCI and 4.19 % according to SCE (Fig. 3).

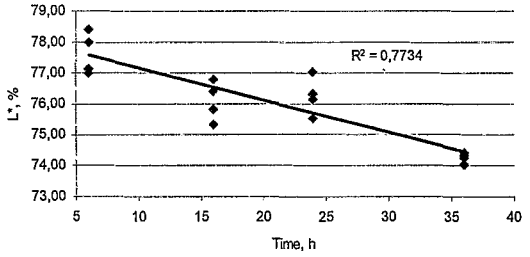


Fig. 3. Reflection of small samples *versus* the treatment time at the temperature + 80 °C

For large samples, this linear dependence is less pronounced (Fig. 4).

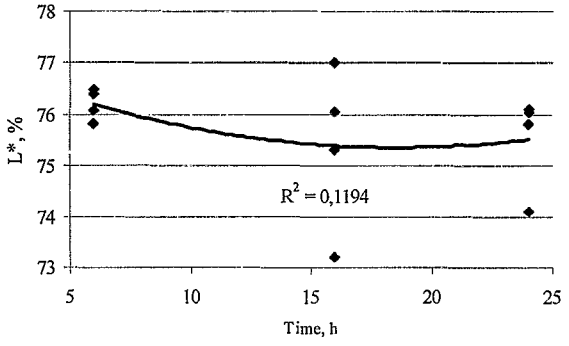


Fig. 4. Reflection of large samples *versus* the treatment time at the temperature + 80 °C

It is important to elucidate the dependence of the birch wood reflection on temperature. Therefore, the temperature range from +40 °C to +80 °C and the samples' endurance time 24 hours were chosen in the experiment. Summarizing the data, it can be seen (Figs. 5 and 6) that the wood reflection is essentially dependent on the wood hydrothermal treatment temperature, and it is the highest at +40 °C. As the hydrothermal treatment temperature increases to +80 °C, the reflection capacity of wood decreases dramatically to 70 °C, and then starts to grow again.

Depending on the hydrothermal treatment conditions, wood reflection can increase or decrease even by 8.89 % according to SCI and 8. 61 % according to SCE.

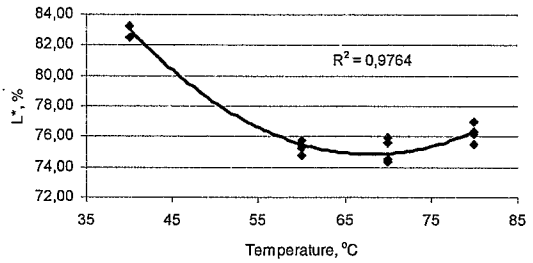


Fig. 5.Reflection of small samples *versus* the treatment temperature at the endurance time 24h

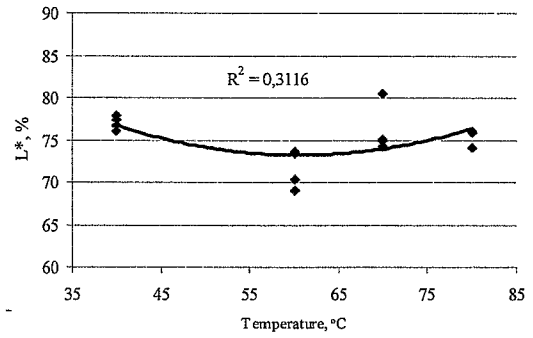


Fig.6. Reflection of large samples *versus* the treatment temperature at the endurance time 24 h

Conclusions

1. An essential difference between the reflection of the woods of different birch species or their brightness was observed. Such a difference was observed between silver birch (*Betula pendula* Roth.) and downy birch (*Betula pubescens* Ehrh.) in the visible range of the reflection spectrum. This was ascertained by two different methods, i.e. the original "Lucia" method developed at TUZVO (Technical University in Zvolen, Department of Wood Science) and by the spectrophotometer MINOLTA CM – 2600d. It has been shown that, in the case of the latter method, reflection L* for downy birch is 85.60 %, while that for silver birch is 81.74 %,

and the difference is 3.86 %. In this case, it is significant, with the probability P = 95 % as well as P = 99 %.

2. A close correlation between the silver birch wood hydrothermal treatment temperature and the wood reflection L* was observed. As the wood hydrothermal treatment temperature was increased from +40 °C to +70 °C, the wood reflection decreased, while, in the temperature range from +70 °C to +80 °C, it somewhat increased. Depending on the hydrothermal treatment conditions temperature, the difference between the reflection values reached 8-9.
3. There is a close correlation between the silver birch wood hydrothermal treatment time in the case of severe conditions (+80 °C) and the wood reflection, i.e. as the hydrothermal treatment time increases, reflection tends to decrease linearly. In the case of the mild conditions (+40 °C) of the hydrothermal treatment, the correlation between the hydrothermal treatment time and reflection, on the average, is close, namely, as the hydrothermal treatment time increases from 16 to 30 hours, the reflection value tends to decrease, while, as the hydrothermal thermal time exceeds 30 hours, it tends to increase again.
4. There is no essential difference between the reflection values for a silver birch wood sample in the tangential cut on the sample's side directed to the centre (the inner side) and the side directed to the periphery (the outer side).
5. A difference between the optical properties of silver birch wood for the small samples (whose surface is in close contact with the hydrothermal treatment agent, water) and the large samples (whose surface is not in direct contact with the hydrothermal treatment agent, water) depending on the hydrothermal treatment conditions was observed (Figs. 1-6). This is explained by the fact that, in birch wood, which is in close contact with water, the oxidation of low-molecular extractive phenol substances occurs, which is hampered as a large wood sample is subjected to hydrothermal treatment.

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Tytuł: Zmiana właściwości optycznych drewna brzozowego pod wpływem obróbki hydrotermicznej.

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Physico-mechanical properties of spruce wood growing in Latvia

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Abstract: As a result of the assessment of the physico-mechanical characteristics of Norway spruce (*Picea abies* L. Karst.) growing in the western part of Latvia, its strength properties have been shown to be considerably higher than those specified in the normative and technical documentation of Germany (DIN 68 364) and Russia (ГСССД 237-87). For example, the compression strength along the fibres, bending strength, Young's modulus and density, on the average, exceed the specified indices by 24 %, 31 %, 28 %, and 10 %, respectively.

Keywords: Norway spruce, *Picea abies* L. Karst., wood properties, density, Young's modulus, bending strength, compression strength.

Introduction

Forests, occupying 45 % of the Latvia's territory, are one of the main riches of this country (FOREST INDUSTRY OF LATVIA 2000; LATVIAN STATE FORESTRY 2001). Norway spruce (*Picea abies* L. Karst.) ranks third in terms of importance among other tree species in Latvia. The popularity of spruce wood both in Latvia and abroad, especially in many European countries, is explained by a wide range of its applications such as building, finishing work, manufacture of furniture and musical instruments, in the pulp-and-paper industry and other fields. This dictated the many-year studies of the physico-mechanical and technological properties of spruce wood.

Unfortunately, until recent times, the systematic studies on spruce wood as well as its physico-mechanical and technological properties were lacking in Latvia, and it is only recently that the comprehensive studies on the properties of spruce wood depending on the growth conditions and other factors have been launched.

The aim of the present study was the preliminary assessment of the mechanical properties of spruce wood growing in the Western part of Latvia, in particular, compression strength along the fibres, bending strength, as well as modulus of elasticity in flexure.

Apart from this, the obtained parameters of the mechanical properties of spruce wood were compared with similar indices for spruce wood in the neighbouring countries such as Germany, Russia and Belarus.

Methods

Spruce wood for the studies was logged in dry forests in a range of forest-divisions in Western Latvia.

The samples were prepared according to the methods described in (NIEMTZ 1993; P@ZGAJ et al. 1997; UGOLEV 2001).

According to the scheme accepted in our techniques, each stem was sawn throughout the stem height into 4 parts, namely, butt-end, as well as 1/4, 1/2, and 3/4 of its height. The top part (3/4) was not used in our experiments owing to the small cross-sectional dimensions and the problems of producing the required samples. Samples were taken from spruce trees corresponding to the Kraft Class II according to the classification accepted in Latvia. It means that these trees occupy the leading place in stands.

To determine the physico-mechanical characteristics, the following German standards were chosen: DIN 52 182 for density, DIN 52 185 for compression strength along the fibres and DIN 52 186 for bending strength and Young's modulus.

Mechanical parameters were determined on a testing machine ZWICK/Z100, equipped with a computer with a special program, displaying graphically the process of loading and destruction of each standard sample, with the automatic input and storage of these data in the database.

Samples with the following dimensions were cut out for testing: for determining compression strength (in a tangential direction T – 20 mm, in a radial direction R – 20 mm and in longitudinal direction Axial– 30 mm), for determining bending strength and Young's modulus (T – 20 mm, R – 20 mm and Axial – 360 mm).

To determine the mechanical and elastic characteristics of wood, samples from both the sapwood and inner part of the stem were used.

Results and Discussion

Table 1 shows the mean values of some physico-mechanical properties of spruce wood growing in dry forests of Western Latvia.

Table 1

Mean values of the physico-mechanical properties of spruce wood

Indices	Unit of measure	Inner part of the stem	Sapwood	Mean value
Density	кg/m^3	506	508	507
Compressive strength along the fibres	MPa	56.3	55.5	55.9
Bending strength	MPa	106.45	106.40	106.42
Young's modulus	GPa	13.69	13.64	13.66

An analysis of the data obtained by us and their comparison with the results of other researchers (KOLLMANN & COTE 1968; NIEMZ 1993; POZGAJ et al. 1997; UGOLEV 2001) shows that the main strength parameters (compression strength and bending strength) are closely connected with the density of wood.

Thus, in the cross-section of the butt-end part of the stem, wood density both in the inner part (closer to the heartwood) and its outer part (sapwood) remains practically unchanged. The same is valid for the strength characteristics, i.e. compression strength along the fibres and bending strength as well as Young's modulus.

The analysis of the experimental results shows a close correlation between the density of spruce wood and its modulus of elasticity in flexure, as well as the ultimate

strength in compression and ultimate strength in bending. The linear correlation coefficient for the specified characteristics is within 0.74-0.85. A close correlation between the modulus of elasticity in flexure and the ultimate strength in compression along the fibres as well as ultimate strength in bending (within 0.80-0.93) was found.

Other sections of the stem at the heights (1/4, 1/2) show a similar pattern.

Thus, we observed no distinctions in the strength characteristics of spruce wood both in the inner (sapwood) and outer (close to the centre) parts of the stem. This confirms again the known regularity that the mechanical properties of ripe wood are even throughout the cross-section of the stem.

An analysis of the distribution of density and the strength characteristics variations throughout the height of the stem has shown that the lowest density of wood was found for the butt-end part of the stem (Table 2). The lowest mechanical strength indices for spruce wood were also found

Table 2

Variations in the physico-mechanical properties of spruce wood throughout the stem

Relative height of the stem	Density, kg/m^3	Ultimate strength, MPa		Modulus of elasticity in flexure E, GPa
		in compression	in bending	
Butt-end	502	53.7	105.3	13.17
0.25	508	56.3	108.0	13.95
0.50	542	60.2	112.9	14.64
0.75	525	54.2	105.7	13.55

With an increase in the stem height, the density and mechanical characteristics for spruce wood gradually increase up to the middle of the stem, where they reach a maximum, then decrease again to 90 % from the maximum value of the compression strength along the fibres, to 94 % for ultimate strength in bending and 92.5 % for modulus of elasticity in flexure. At the same time, accordingly, the density value decreases to 96.9 % from the maximum value.

To compare the values of physico-mechanical characteristics for spruce wood growing in the Western part of Latvia, let us correlate them with the corresponding indices for spruce wood growing in the neighbouring countries at the standard moisture 12 % (Table 3).

Table 3

Comparative data of the physico-mechanical characteristics for spuce wood in some european states

State and reference	Ultimate strength, MPa		Modulus of elasticity in flexure E, GPa	Density, kg/m^3
	in compression	in bending		
Germany				
[4]	40.0	68	10.00	470
[9]	50.0	78.0	11.00	455
Central districts of the European part of Russia [14]	45.0	78.6	9.60	445
Belarus [14]	45.2	74.5	9.69	465
Leningrad region [14]	49.3	83.4	–	475
Lithuania [14]	47.5	81.6	–	465
Ukraine [14]	44.0	80.7	–	426
Latvia .	55.9	106.42	13.66	507

As follows from these data, the strength characteristics for Norway spruce obtained by us are, on the average, higher than those for other European regions, namely, compression strength by 24 %, bending strength by 31 %, modulus of elasticity in flexure by 28 % and mean density by 10 %.

As follows from the data obtained, the comparison of the mechanical properties of spruce wood only with density is somewhat superficial, which is testified by the cytochemical reactions in the deformation sites, performed (MOSKALEVA 1957; ERINSH 1998) to study the residual submicroscopic capillarity of wood fibres, in particular, late tracheids.

Conclusions

For spruce wood under study, the density and mechanical parameters do not change in the cross-sectional direction from the middle part of the stem towards the bark.

As the height of the stem increases, density and mechanical parameters tend to grow from the butt-end to the middle of the stem, then these parameters somewhat decrease.

Compression strength along the fibres for the wood of spruce growing in the Western part of Latvia as well as ultimate strength in bending and modulus of elasticity in flexure are higher than those in the neighbouring states

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Tytuł: Fizyko-mechaniczne właściwości drewna świerkowego pochodzącego z Łotwy.

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Physical properties and anatomical structure of pine wood

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Abstract: The present paper considers variations in the values of the annual ring parameters and physical properties of the wood of the main forest species in Latvia – common pine (*Pinus sylvestris L.*), depending on three factors - forest growth conditions (dry, wet and drained forest types), the growth region in Latvia (Central, Vidzeme, Kurzeme, Latgale) and the localization of a wood sample in the stem. Wood samples were taken at the stem butt-end (H_0) - ¼, ½ and ¾ of the height (H) in its sapwood, core and juvenile parts. Average annual ring width (G_{pl}), the share of late wood in the annual ring ($G_{vk\%}$), double cell wall width and diameter of tracheids both in early (T_{2W_ak}, T_{R_ak}) and late (T_{2W_vk}, T_{R_vk}) wood, tracheids length (T_L), wood density in the oven dry state (ρ_0), wood linear swelling in tangential (α_{tg}) and radial (α_{rad}) directions, volume swelling (α_V) as well as wood linear shrinkage in tangential (β_{tg}) and radial (β_{rad}) directions, volume shrinkage (β_V), water absorption ($W_ū$) and wood moistening (W_m) were established for samples. A comparative analysis of the data obtained shows that, in the majority of cases, the greatest effect on the pine wood properties formed is exerted by the localization of a wood sample in the stem and forest growth conditions, but not by belonging of a pine growth site to different growth regions in Latvia.

Keywords: pine, wood, anatomical structure, physical properties

Introduction

Forests are among Latvia's greatest riches. Forest wood resources are only a few of the renewable resource types on the globe. Therefore, most comprehensive information is necessary both about forests on the whole and on their main product, wood. The problem of forests, as well as the role they play in human and social life, has become urgent in the last decade, since forests are not regarded any more only as a wood resource, but are closely connected with categories such as ecology, recreation, landscape, etc.

Latvia can be proud of its forest resources – forests occupy 2.89 million ha or 44.7 % of its territory, with a total stock volume of 545.9 million m^3 (SILIŅŠ 2000). From the earliest times, common pine (*Pinus sylvestris L.*) has been the most widespread tree species in Latvia. Even now, pine stands occupy the greatest part of Latvia's forest territory – 38.0 %, with the total volume 233.3 million m^3. Unfortunately, exhaustive information on the pine wood structure and properties is currently lacking. It should be mentioned that, in Latvia, the technical properties of pine growing on its territory had been investigated in the 1920s (KALNIŅŠ 1930), although, in compliance with the requirements of that time, most attention was concentrated on the investigation of the physico-mechanical properties of wood. Therefore, already after World War II, the same author suggested that a deeper study of the structure and properties of pine wood and the wood of other tree species be carried out (KALNIŅŠ 1949).

Goals and tasks of the study

The goal of the present study was to give the main anatomical structure parameters, such as annual ring width (G_{pl}), share of late wood in the annual ring ($G_{vk\%}$), tracheid length (T_L), its double wall width and cross-sectional dimensions in the radial direction for early (T_{2W_ak}, T_{R_ak}) and late wood (T_{2W_vk}, T_{R_vk}) of *Pinus sylvestris L.* growing in Latvia's territory, and its physical properties, such as wood density ($\square_0$), volume swelling ($\square_V$) and shrinkage ($\square_V$), wood linear swelling in radial ($\square_{rad}$) and tangential ($\square_{tg}$) directions, wood linear shrinkage in radial ($\square_{rad}$) and tangential ($\square_{tg}$) directions, as well as water absorption ($W_{\bar{u}}$) and wood moistening (W_m) characteristics.

So that these characteristics be as exhaustive as possible, the effect of the main factors on the values of the above-mentioned wood parameters should be taken into account. Based on the data available in the literature (WAGENFUHR 1988; KRUSSMAN 1983) as well as the generally accepted theoretical conclusions, wood growth conditions (forest types), the localization of the wood sample in the tree stem, as well as the growth region, were taken as these factors. Thus, the task of the present study was to ascertain the variations in the values of the investigated parameters as a result of the effect of the above-mentioned factors and to establish the extent of this effect.

Wood as a material possesses different properties, whose values are determined by the structure peculiarities, as well as the form, sizes, structural arrangement, etc. of its anatomical elements. To establish the existing regularities among them, the task of the study was also to determine the correlations and the significance of their effects among the anatomical parameters of the investigated wood.

Methods

Latvia's territory is not too great, to be 64.5 thousand km^2. However, based on the existing scientific conclusions on the suitability of individual tree species to different ecological and climatic conditions, with the aim to preserve the ecological stability of forests as well as their adaptability and stability against antropogeneous stress factors, the following testing sites were chosen throughout the whole Latvia's territory, namely, in the vicinity of Misa, Tome, Smiltene, Saule, Liepupe, Silene, Rinda, Ance, Slitere, Rucava and Pampāļi in compliance with the methods developed in the research programs of the Latvian Council of Science "New Materials of Wood and Plant Origin" and "Theoretical Models of Multifunctional Forestry in Latvia".

Based on the Latvian forest typology, three groups of forest growth conditions were differentiated (Table 1), namely, dry (*Vacciniosa*), wet (*Sphagnosa*), and drained (*Cladinosa Callunosa*) forests types where sample sites were chosen for taking pine wood samples.

Table 1

Distribution of pine forests in terms of growth conditions

	Forest area		Growing stock	
	thousand ha	%	million m^3	%
Dry forest types	635.4	59.6	149.1	63.9
Wet forest types	226.7	21.3	40.4	17.3
Drained forest types	203.0	19.1	43.8	18.8
Total	1065.1		233.3	

To characterize each sample site, it was envisaged to use three sample trees. In terms of their parameters, the chosen and sawn down sample trees complied with the growth characterization, i.e. these were healthy trees, with normal formation of the crown, conforming to Kraft Class 2.

As the task of the study, it was supposed to determine the values of anatomical parameters and physical properties in different parts of the stem. Knowing that the chosen sample trees would be of different height and dimensions, a method for crosscutting of the obtained stems and wood sample selection was necessary that would later enable the comparison of the values obtained. Thus, the stem crosscutting (Fig. 1) was performed in four places, namely, at the butt-end (H_0), which provides the most exhaustive information on the tree growth history, and at the stem height relative units: ¼ H (bold timber assortment), ½ H (small-dimension timber assortment), and ¾ H (paper wood assortment).

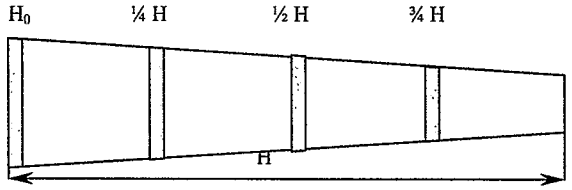


Fig. 1. Scheme of stem sampling

In its turn, to determine the values of the anatomical parameters and physical properties of wood in the stem cross-section, radial core board blanks were sawn out from the cuts obtained as a result of crosscutting (Table 2). These sawn out blanks made it possible to prepare wood samples for determining of both anatomical parameters and physical properties.

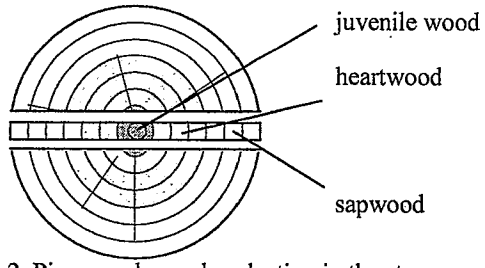


Fig. 2. Pine wood sample selection in the stem cross-section

All the studies on the wood anatomical structure and the determination of its parameters were performed according to conventional methods applied in wood structure studies, which are widely described in the literature (JATSENKO-KHMELEVSKY 1954; CHAVCHAVADZE 1979; WAGENFUHR 1988). In its turn, the determining of the physical properties of wood was based on DIN Standards (1991).
To process the results of the studies, descriptive statistical parameters, as well as correlation analysis and dispersion analysis were employed (ARKHIPOVA et al. 1997; LIEPA 1974).

Results and discussion.

The examination of the obtained values of pine wood anatomical parameters and physical properties was started with the general information on the data obtained for all sample trees used in the study (Tables 2, 3). This was carried out with the aim to demonstrate the total average, minimum and maximum values of the investigated parameters as well as the relative spread of separate measurements (variation coefficient) around the average value, and to find the study's precision index that characterizes the spread of the sample group's average values around those of the general group. Apart from this, the number of measurements made is also given, which, as a matter of fact, shows also the number of sites where separate wood samples were taken (total number of separate measurements made – 48000 for tracheid parameters, 10000 for annual ring parameters, and 20000 for physical properties of wood).

Table 2

Values of the physical properties of pine wood

	ρ_0 kg/m^3	α_{rad} %	α_{tg} %	α_V %	β_{rad} %	β_{tg} %	β_V %	W_m %	$W_{ü}$ %
Average value	480	4.1	8.7	13.0	3.8	7.6	11.2	20.3	172
Minimum value	340	0.6	3.6	6.5	0.2	1.0	2.4	10.4	86
Maximum value	750	9.4	12.8	22.1	6.7	11.0	17.8	27.5	253
Number of measurements	297	297	297	297	250	250	250	282	299
Variation coefficient, %	14.4	29.3	20.7	20.8	34.2	21.1	23.2	8.4	16.9
Precision of the study, %	0.8	2.4	1.1	1.5	2.6	1.3	1.8	0.5	1.2

Table 3

Values of the anatomical parameters of pine wood

	G_{pl} mm	$G_{vk\%}$ %	$T_{R\,ak}$ mkm	$T_{R\,vk}$ mkm	$T_{2W\,ak}$ mkm	$T_{2w\,vk}$ mkm	T_L mm
Average value	1.69	30.0	37.46	25.33	4.53	7.1	3.44
Minimum value	0.27	10.5	18.60	15.52	2.51	3.3	1.52
Maximum value	5.19	57.6	66.65	61.10	8.13	12.2	4.38
Number of measurements	236	143	155	155	199	199	123
Variation coefficient, %	53.3	35.7	21.8	26.7	23.6	23.2	15.7
Precision of the study, %	3.6	3.0	1.8	2.1	1.8	1.7	1.5

Tables 2 and 3 show that, for the majority of the investigated parameters, the variation coefficient exceeds 20 %, and the maximum value is shown by wood annual ring width (55.3 %). Similar variation coefficient values have been established by R.Wimmer in his study on pine wood (WIMMER 1991): ρ_0 – 12.9 %; swelling parameters 18.3-276 %, G_{pl} - 49.2 %, $G_{vk\%}$ - 28 %. Despite the sufficiently high variation coefficient values, the precision index of the study is up to 3.0 %, which is indicative of a good precision, while only G_{pl} shows 3.6 %, which is also classified as fully satisfactory precision (ARKHIPOVA 1997).

Correlation between the values of anatomical parameters and physical properties

On the basis of all sample wood data, a pair correlation analysis of the anatomical parameters of the investigated wood was made.

The results obtained (Table 4) show that, since an essential correlation exists among all physical properties of wood, the majority of them (except $W_ü$) show a positive correlation. Almost that close correlation, both among them and with the physical properties of wood, is shown also by the values of annual ring width and the share of late wood in the annual ring. This indicates that certain regularity exists between these wood properties and structure parameters, which has an essential effect on their mutual variations, both qualitative and quantitative. The problem of the interrelation between wood density and annual ring width has been widely analyzed (WIMMER 1991; BOSSHARD 1974). It has been stated that, although annual ring width has a negative effect on the wood density value, the share of late wood in the annual ring shows even a closer positive correlation with wood density. Based on the data gained in this study (Table 4), it has been established that annual ring width has a negative action on the wood density value (correlation coefficient –0.33). However, the share of late wood in the annual ring (correlation coefficient +0.61) exerts a higher and positive effect on the annual ring width value. Hence, it is exactly the share of late wood in the annual ring, and not the annual ring width that may be regarded as the most essential factor governing wood density.

Wood tracheid parameters also form sufficiently close positive correlations among themselves (Table 4), although not so unambiguous as those established between the

Table 4

Correlation between the values of the anatomical parameters and physical properties of pine wood

	ρ_0	α_{rad}	α_{tg}	α_V	β_{rad}	β_{tg}	β_V	W_m	$W_{ū}$	G_{pl}	$G_{vk\%}$	$T_{R\,ak}$	$T_{R\,vk}$	$T_{2W\,ak}$	$T_{2w\,vk}$	T_L
ρ_0		0.60**	0.53**	0.63**	0.63**	0.52**	0.59**	-0.02	-0.89**	-0.33*	0.61**	0.06	-0.04	0.11	0.14	-0.27*
α_{rad}			0.49**	0.79**	0.72**	0.42**	0.58**	0.24**	-0.57**	-0.30	0.46**	0.03	0.06	0.19*	0.15	0.01
α_{tg}				0.89**	0.44**	0.79**	0.67**	0.27**	-0.44**	-0.41	0.56**	0.19	0.05	0.21*	0.25**	-0.02
α_V					0.71**	0.75**	0.78**	0.29**	-0.55**	-0.37	0.61**	0.18	0.08	0.22*	0.23**	0.01
β_{rad}						0.66**	0.88**	0.25**	-0.57**	-0.40	0.49**	0.06	0.09	0.21*	0.07	0.01
β_{tg}							0.92**	0.25**	-0.45**	-0.41	0.56**	0.10	0.13	0.30**	0.13	-0.08
β_V								0.26**	-0.53**	-0.42	0.58**	0.10	0.16	0.33**	0.12	-0.05
W_m									0.06	-0.24	0.15	-0.11	0.13	0.01	-0.05	0.06
$W_{ū}$										0.25	-0.56**	-0.08	-0.06	-0.21*	-0.19*	0.25*
G_{pl}											-0.44**	-0.11	-0.09	-0.23**	-0.25**	-0.12
$G_{vk\%}$												0.40**	0.24	0.46**	0.57**	0.11
$T_{R\,ak}$													0.20	0.35**	0.37**	0.25*
$T_{R\,vk}$														0.17*	-0.02	0.15
$T_{2W\,ak}$															0.69**	0.20*
$T_{2w\,vk}$																0.17
T_L																

** - significant correlation of the result at the level of confidence 99%

* - significant correlation of the result at the level of confidence 95%

physical properties of wood and annual ring parameters. Apart from this, an essential positive correlation between tracheid double wall width and radial cross-sectional values, and the values of the share of late wood in the annual ring is established, which suggests that the share of wood substance in the tracheid grows as the wood with larger tracheids is formed.

Variations in the values of wood anatomical parameters and physical properties throughout the wood stem

The fact that the values of wood parameters vary considerably already throughout the tree itself has been observed long ago (KALNIŅŠ 1930). The data obtained in the present study on the variations in the values of pine wood anatomical parameters and physical properties in the axial direction of the tree stem and its cross-section, and those on the significance of these variations are tabulated in Tables 5-8, where average values of the parameters under examination and the critical Fischer value of the performed dispersion analysis (F_{crit}) are presented, the Fischer ratio (F) is calculated, and it is demonstrated whether the dispersion analysis shows the essential effect of the mentioned factors (+) on the values of the investigated wood parameters and properties or not (-).

Table 5

Values of the physical properties of pine wood in the stem axial direction

	ρ_0 kg/m^3	α_{rad} %	α_{tg} %	α_V %	β_{rad} %	β_{tg} %	β_V %	W_m %	$W_{\bar{u}}$ %
H_0	547	4.6	9.4	14.1	4.3	8.1	12.1	20.0	144
¼ H	486	4.3	9.3	14.0	4.2	8.2	12.1	20.4	170
½ H	452	3.8	8.6	12.6	3.6	7.6	10.9	20.4	183
¾ H	432	3.6	7.7	11.5	3.3	6.6	9.6	20.4	191
F	70.77	12.12	15.03	17.55	11.38	14.97	14.95	0.89	59.34
F_{crit}	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
Significance	+	+	+	+	+	+	+	-	+

Table 6

Values of the anatomical parameters of pine wood in the stem axial direction

	G_{pl} mm	$G_{vk\%}$ %	$T_{R\,ak}$ mkm	$T_{R\,vk}$ mkm	$T_{2W\,ak}$ mkm	$T_{2w\,vk}$ mkm	T_L mm
H_0	1.63	34.1	37.94	24.99	4.74	7.44	3.33
¼ H	1.80	28.8	39.21	29.17	4.87	7.04	3.23
½ H	1.90	23.6	36.92	24.10	4.23	6.96	3.62
¾ H	1.75	23.6	35.96	25.53	4.18	7.03	3.58
F	0.67	8.17	0.71	2.07	5.05	1.11	2.72
F_{crit}	2.66	2.69	2.66	2.66	2.65	2.65	2.68
Significance	-	+	-	-	+	-	+

The data presented in Tables 5-8 show that the localization of the wood sample in the tree stem is a very essential factor, which affects the values of wood anatomical

parameters and physical properties. Thus, essential changes are found in the tree stem cross-section (juvenile and core wood, as well as sapwood) for all wood parameters under study. However, no essential changes are found in the wood stem axial direction for a part of tracheid cross-section parameters, as well as for wood annual ring widths.

Table 7

Values of the physical properties of pine wood in the stem cross-section

	ρ_0 kg/m^3	α_{rad} %	α_{tg} %	α_V %	β_{rad} %	β_{tg} %	β_V %	W_m %	$W_{\bar{u}}$ %
Juvenile wood	447	4.6	4.7	9.1	2.2	2.3	4.3	18.6	170
Heartwood	468	3.7	8.3	12.2	3.4	7.1	10.2	19.9	177
Sapwood	495	4.4	9.4	14.1	4.4	8.3	12.3	20.8	167
F	7.19	14.86	52.44	33.80	27.25	51.52	43.60	19.31	3.98
F_{crit}	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Significance	+	+	+	+	+	+	+	+	+

Table 8

Values of the anatomical parameters of pine wood in the stem cross-section

	G_{pl} mm	$G_{vk\%}$ %	$T_{R\,ak}$ mkm	$T_{R\,vk}$ mkm	$T_{2W\,ak}$ mkm	$T_{2w\,vk}$ mkm	T_L mm
Juvenile wood	2.52	19.6	34.64	25.77	4.16	6.13	3.22
Heartwood	1.62	33.1	37.99	25.27	4.65	7.74	3.47
Sapwood	1.07	36.7	39.75	24.95	4.78	7.72	3.62
F	48.60	37.77	5.61	0.19	6.62	25.40	6.33
F_{crit}	3.05	3.08	3.06	3.06	3.04	3.04	3.07
Significance	+	+	+	-	+	+	+

When examining the mutual variation dynamics of wood density, annual ring width and the share of late wood in the annual ring both in the stem axial direction and its cross-section, it can be seen that the values of wood density and the share of late wood in the direction from the tree butt-end to its end decrease, while, in the direction from the wood core outward, they tend to increase. On the contrary, in the wood annual ring direction from the tree core outward, they decrease, while no pronounced regularities are observed in the stem axial direction. This agrees well with the observed correlations among the above considered parameters (Table 4).

Dependence of the values of anatomical parameters and physical properties on tree growth conditions

As the effect of the forest growth conditions and growth region (pine origin region) was compared, the values of wood density, annual ring width and the share of late wood in the annual ring were taken (Tables 9 and 10). As can be seen, no essential effect of the growth region was found for any of the above mentioned parameters.

Table 9

Values of pine wood density and annual ring parameters in different regions of latvia

	ρ_0 kg/m^3	G_{pl} mm	$G_{vk\%}$ %
Central	552	1.23	36.4
Kurzeme	562	1.17	37.8
Latgale	603	1.18	49.2
Vidzeme	562	1.33	43.5
F	0.59	0.03	3.34
F_{crit}	2.84	4.74	6.94
Significance	-	-	

Table 10

Values of pine wood density and annual ring parameters in different growth conditions

	ρ_0 kg/m^3	G_{pl} mm	$G_{vk\%}$ %
Dry forest types	564	1.24	41.1
Wet forest types	538	1.22	38.4
Drained forest types	520	1.31	44.8
F	3.70	0.04	3.70
F_{crit}	3.21	3.27	3.42
Significance	+	-	+

For forest growth conditions, the highest average value was found for dry forest pine butt-end; in its turn, the values of both annual ring width and the share of late wood in the year ring were higher for the drained forest type. The performed dispersion analysis shows that forest growth conditions have a profound effect on the values of wood density and the share of late wood in the annual ring, not affecting essentially the annual ring width.

Conclusions

1. In the majority of cases, the localization of a wood sample in the tree stem, both in the vertical and horizontal plane, affects dramatically the values of the anatomical structure parameters and physical properties of wood.

2. Forest growth conditions (forest type) affect dramatically the values of wood density and the share of late wood in the annual ring.

3. Both the anatomical structure parameters and physical properties of wood show essential correlations.

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Tytuł: Fizyczne właściwośći i anatomiczna struktura drewna sosnowego.

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Dependence of heat value on moisture for sawdust pellets and chips

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Abstract: Based on the analysis of the wood elements content for wood of different tree species, the thermodynamic properties of chips, and sawdust pellets and granules have been established.
Combustion heat values, depending on the relative moisture content of wood, are presented. Based on the data available in the literature, employing the calculation formulas, the experimental combustion heat values are compared. The calculated combustion heat values, determined using the Mendelejev's formula, as compared to those determined using a calorimetric bomb, are within the limits of experimental error.
At the relative moisture content of chips 40 % and the boiler efficiency 0.8 1 Gcal (4.1868 GJ = 1.163 MWh), 512 kg or 2.05 m^3 (solid volume 0.83 m^3) wood chips are required for heat energy generation.

Keywords: chips, wood, sawdust pellets and granules, heat (calorific) value, combustion heat, moisture content

Introduction

According to the currently available prognosis data for the world's primary energy utilization, since the fossil fuel stock tends to diminish, it is envisaged to utilize up to 18 % of the natural renewable resources for heat and electric energy generation in the coming 50 years (GLOBAL ENERGY 1998). Owing to the increase in cost of the traditional energy carriers and the world's crisis fluctuations, as well as the depletion of the traditional energy carriers (petroleum, gas), their expenses will increase dramatically, and the utilization of renewable energy carriers becomes increasingly urgent.

Therefore, Latvia must get ready for utilizing alternative energy sources and, first of all, energy wood. Thus, for example, 17.6 PJ (peta 10^{15} joule) energy, or 11.4 % from all consumed primary energy resources, was produced from wood in Latvia in 2000 (DOLACIS et al. 2001). The Latvia's potential wood energy resources are estimated to ensure an annual heat energy production of 70.4 PJ. Apart from this, according to the Latvian legislation, all heat and electric energy producers should efficiently utulize the local energy resources (water, wind, sun, biomass) available in Latvia, observing the environment protection regulations and ensuring the stable development of energy production.

By now, distinct data are available in the literature on the heat value of different fuel wood and its components. There is often even no indication on what the question is – the highest heat value Q_h, or the lowest one Q_l. Therefore, to clarify the thermo-physical properties of fuel wood and elucidate the effect of its moisture content on the heat value, different tree species types and samples were analysed.

Examination of the heat value of different wood species

More and more attention has been recently paid to the production of chips, sawdust pellets and granules from wood processing residues and their utilization in heat generation

(DOLACIS et al. 1999). Since the waste wood of different tree species, jointly with bark, is used for the production of chips, pellets and granules, it is important to know the heat value of the wood of different tree species.
Since the determination of the heat value of fuel is connected with the application of relatively complicated apparatus as well as definite culture and traditions, it is important to review the literature data on the heat value of different tree species (table 1).

Table 1

The highest heat value Q_h for wood and bark of different tree species in oven dry conditions

Species	Highest heat value, Q_h, kJ/kg		References
	Wood	Bark	
Pine (*Pinus sylvestris* L.)	20 628	20 201	[14]
Spruce (*Picea* L.)	20 088	20 318	[14]
Birch (*Betula* L.)	19 277	22 956	[14]
Silver birch (*Betula pendula* Roth.)	19 190 ± 50	23 240 ± 110	[10]
White birch (*Betula pubescens* Ehrth.)	19 340 ± 160	23 350 ± 200	[10]
Black alder (*Alnus glutinosa* L.)	19 440 ± 140	20 400 ± 110	[10]
Aspen (*Populus tremula* L.)	19 980 ± 50	20 220 ± 130	[10]
Aspen (*Populus tremula* L.)	19 782	22 093	[14]
White alder (*Alnus incana* L.)	20 063	22 093	[14]

Table 1 shows the heat value of birch bark, where the share of birch-bark is relatively small, while the heat value of the birch-bark itself is relatively high, to be 30 000 kJ/kg (BOROVIKOV & UGOLEV 1989). The heat value of fuel wood depends heavily on its moisture content. The heat value of wood is governed by its element composition: carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and somewhat sulphur (S), non-combustible compounds – ashes (A), as well as moisture content (for characterizing of fuel wood, mainly the relative moisture W_{rel} is used, i.e. the ratio between the evaporated water mass and the initial mass of the sample, expressed in percentage) (Fig. 1).

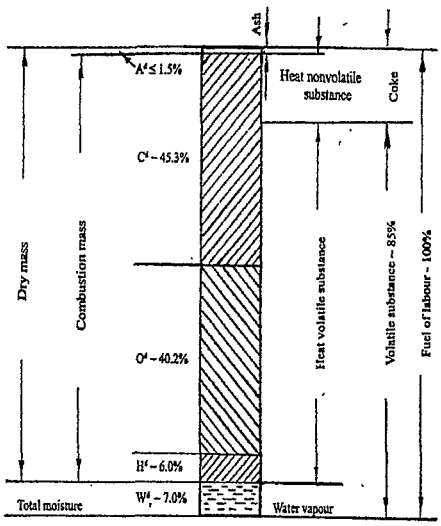


Fig. 1. Flow diagram of the content of sawdust pellets: C – carbon; H – hydrogen; O – oxygen; A – ash

If the content of separate components in the material is expressed in mass percentage, then the working state of the fuel is characterized by the following composition:

$$C^w + H^w + O^w + N^w + S^w + A^w + W^w_{rel} = 100\ \%$$

Wood consists mainly of organic substances, which occupy not less than 99 % from the total water-free mass. The organic share of the oven dry wood contains 49-50 % of carbon, 43-44 % of oxygen, about 6 % of hydrogen, 0.1-0.3 % of nitrogen and 0.1-1.0 % of ash. The ash contains calcium, potassium, sodium, magnesium, small amounts of phosphorus, sulphur and other elements (UGOLEV 2001).

According to Prof. Nikitin (NIKITIN 1962), a specialist in wood chemistry, the average content of elements in oven dry wood (mass %) is as follows: carbon – 49.5 %, hydrogen – 6.3 % and oxygen – 44.2 %.

As the relative moisture of wood varies, the content of its elements in dry wood changes proportionally (table 2).

Table 2

Changes of wood elements (C, O, H) depending on the relative moisture content (W_{rel}), %

W_{rel}, %	C, %	H, %	O, %
0	49.5	6.30	44.20
1.0	49.0	6.24	43.76
2.0	48.5	6.17	43.33
3.0	48.0	6.11	42.89
4.0	47.5	6.05	42.45
5.0	47.0	5.99	42.01

6.0	46.5	5.92	41.58
7.0	46.0	5.86	41.14
8.0	45.5	5.80	40.70
9.0	45.0	5.73	40.27
10.0	44.6	5.67	39.73
11.0	44.1	5.61	39.29
12.0	43.6	5.54	38.86
13.0	43.1	5.48	38.42
14.0	42.6	5.40	38.00
15.0	42.1	5.36	37.54
16.0	41.6	5.29	37.11
17.0	41.1	5.23	36.67
18.0	40.6	5.17	36.23
19.0	40.1	5.10	35.80
20.0	39.6	5.03	35.37

Carbon is the main burning element in wood. As a result of the full combustion of 1 kg of carbon to CO_2, 34 068 kJ of heat is released (VANIN 1950). If incomplete combustion of carbon to CO takes place, then only about 10 200 kJ is released (OSIPOV 1991). Hydrogen is a very active burning element. Dry wood contains about 6.3 % of hydrogen. The combustion of 1 kg of hydrogen results in the release of 143 105 kJ of heat and 9 kg of water. The moisture in wood diminishes its heat value, as much heat (about 2 700 kJ) is to be consumed for warming up and evaporation of 1 kg of water (OSIPOV 1991).

Fuel is characterized by its combustion heat or heat value. If the heat generated in the combustion time, as the formed steam is condensed and cooled, is added to the heat liberated by the fuel, then the so-called highest fuel combustion heat (Q_h) is generated. If the steam condensation and cooling heat is discarded, allowing it to flow away in the burning process, the lowest fuel combustion heat (Q_l) is obtained.

Determining of combustion heat for cut-up wood pressed materials

One of the experimental methods for determining the highest wood combustion heat is the combustion of a sample in a calorimetric "bomb" (ZIIKEEV & KORELIN 1948). After processing of the measurement results, the highest wood combustion heat Q_h^b kJ/kg or kcal/kg is obtained (where h – the highest combustion heat, b – that determined in the calorimetric bomb). If other units of measure are used, then the values of their coefficients are as follows: 1 kJ = 0.239 kcal = 0.278 Wh = 0.0239×10^{-6} t_{oe}; 1 kcal = 4.1868 kJ = 1.163 Wh = 0.1×10^{-6} t_{oe}; 1Wh = 3.6 kJ = 0.86 kcal = 0.086×10^{-6} t_{oe} (t_{oe} – tons in oil equivalent).

Table 3 shows the values for combustion heat (Q_h^b) and relative moisture (W^a_{rel} – in this case, the analytical sample is designated with the index "a") obtained on the basis of the analysis of sawdust pellets and granules, performed by "CED" and "Stali", Ltd.

Table 3

High heat value (Q_h) and relative moisture (W_{rel}) of sawdust pellets

Sample	W_{rel}, %	Highest heat value, Q_h, kJ/kg
1	5.4 ± 0.1	18 506 ± 210
2	7.0 ± 0.1	19 176 ± 210
3	7.8 ± 0.1	18 422 ± 210
4	8.1 ± 0.1	18 464 ± 210
5	7.6 ± 0.1	18 380 ± 210

Data for the results of the analysis of sawdust pellets are presented also in Fig. 2, which shows that the heat value for samples No. 3, 4 and 5 differ little and are within the limits of experimental error. Hence, the pellets' moisture $W^a_{rel} = 7.8$ % can be assumed average, to which the average highest combustion heat of 18 422 kJ/kg corresponds.

As the analytical relative W^a_{rel} varies, the corresponding highest combustion heat at the other relative moisture W^w_{rel} can be determined from the formula:

$$Q_h = Q_h^b \times [(100 - W^w_{rel}) / (100 - W^a_{rel})], \text{ kJ/kg}$$

The average highest heat value for oven dry wood, calculated from this formula, is equal to 19 980 kJ/kg, while, at the $W^w_{rel} = 12$ %, it is 17 583 kJ/kg.
Heat, together with fume gases and steam in the furnace, is commonly also carried away through the draught (ISO 1928):

$$Q_l = Q_h^b - 212.10 \times H - 0.775 \times O - 24.42 \times W^w_{rel} = 16\,966 \text{ kJ/kg}$$

where: $Q_h^b = 18\,422$ kJ/kg,
$W^a_{rel} = 7.8$ %,
$H = 5.82$ % and $O = 40.3$ %.

From this formula, the lowest combustion heat values are plotted in Fig. 2.
The working fuel lowest combustion heat at the definite moisture of the pellets in the case of burning in a furnace at a constant (atmospheric) pressure is calculated from the formula (ISO 1928-76):

$$Q_l^w = (Q_h^w - 212.10 \times H^w - 0.775 \times O) \times$$
$$\times [(100 - W^w_{rel}) / (100 - W^a_{rel})] - 24.42\ W^w_{rel}, \text{ kJ/kg}$$

At the moisture content 0 %, $Q_h^w = 18\,607$ kJ/kg (4 444 kcal/kg), while at $W^w_{rel} = 12$ % $Q_l^w = 16\,081$ kJ/kg (3 841 kcal/kg).

For comparison purposes, let us refer to DIN 51 731 requirements for sawdust pellets: moisture content $W \leq 12.0$ %; heat value 19 500 – 17 500 kJ/kg; ashes ≤ 1.5 %. For our average sawdust pellet samples at the relative moisture $W = 12.0$ %, the highest combustion heat is 17 583 kJ/kg, which differs from DIN 51 731 requirements by 0.47 %.

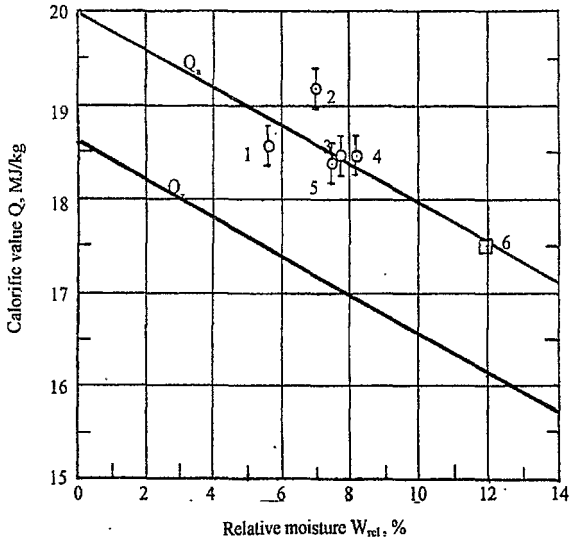


Fig. 2. Dependence of the heat value of sawdust pellets and granules on moisture content: Q_h – highest heat value; Q_l – lowest heat value; 1, 2, 3, 4, 5 – number of pellets samples according to Table 3; 6 – sample according to DIN 51 731

Calculation of the combustion heat of cut-up wood pressed materials from the Mendelejev's formula

The highest combustion heat of the fuel can be assessed by the Mendelejev's formula (OSIPOV 1991):

$$Q_h^W = 339.1 \times C^W + 1\,256 \times H^W - 109\,(O^W - S^W_v),\ kJ/kg$$

where:

"v" at S^W_v - sulphur volatile components.

At W = 0: $C^W = 49.5$ %; $H^W = 6.3$ %; $O^W = 44.2$ % and $S^W_v \sim 0$, the highest working heat value $Q_h^W = 19\,880$ kJ/kg. However, at $W^W_{rel} = 12.0$ %, Table 2 shows the following percentage composition of elements: $C^W = 43.6$ %; $H^W = 5.54$ % and $O^W = 38.86$ %, at which $Q_h^W = 17\,503$ kJ/kg. The corresponding combustion heat of the fuel is calculated from the formula:

$$Q_l^W = Q_h^W - 25.1\,(9 \times H^W + W^W_{rel}),\ kJ/kg$$

At $W^W_{rel} = 0$, $Q_l^W = 18\,457$ kJ/kg, while at $W^W_{rel} = 12.0$ %, $Q_l^W = 15\,950$ kJ/kg. A comparison of the experimentally obtained combustion heat values for cut-up wood pressed material fuel with the values calculated from the Mendelejev's formula shows that the difference between them is negligible and does not exceed 1 %.

Some thermo-physical properties of chips

The requirements for fuel chips are not strictly regulated. Their sizes, bark admixtures, rot, ash content, moisture, etc. are determined by agreement with the consumer. However, the crucial factors that determine their price are the ash content and moisture, which determine the energy capacity of the chips.

The next factor that affects the amount of chips in the hold is the stacking factor.

The stacking factor of the cut-up wood is the capacity of the compact wood comprising the chips or sawdust against their bulk volume at the given moisture content.

Stacking factors are calculated for pulpchips. The pulpchips are accounted in m^3 in terms of the wood solid density, rounding off to 0.1 m^3. To convert the bulk gravity to solid density, the stacking factor is applied. In the case of employing the railway transport with mechanical loading devices or a pneumoloader, this factor is 0.36 and 0.41, respectively. If the transportation distance exceeds 650 km, this factor grows up to 0.41 and 0.43, respectively. In the case of the truck transport, it grows from 0.36 to 0.42 if the distance exceeds 50 km (GOST 15 815-83).

Values of bulk gravity for pine and spruce wood, converted to solid density, are shown in table 4.

Table 4

Bulk gravity (bulk m^3) factors for pine and spruce wood chips converted to solid density (solid m^3) factors [2]

Value	Species	Moisture, absolute/relative, %						
		20/16.7	30/23.1	40/28.6	50/33.3	60/37.5	70/41.2	80/44.4
Bulk gravity, kg/m^3	Pine	188	196	211	225	240	254	267
	Spruce	185	191	215	226	236	245	257
Solid density, kg/m^3	Pine	520	550	590	640	680	720	760
	Spruce	460	490	520	560	600	640	670
Stacking factor, K	Pine	0.362	0.356	0.358	0.351	0.353	0.353	0.351
	Spruce	0.402	0.390	0.413	0.404	0.393	0.383	0.383

The conversion of the chips' measurement mass (bulk gravity) units to volume (solid density) units at definite moisture is determined from the formula:

$$V = G/\rho_w \text{ solid } m^3$$

where:

V is the chips volume in solid m^3,

G is the chips mass produced in a shift, t,

ρ_w is the chips wood density at the given moisture, t/m^3.

The stacking factor for fuel chips is commonly equal to that for pulpchips. For purposes of technological calculations, the following stacking factors for cut-up wood and its residues are recommended (GOLOVKOV et al. 1987):

Chips from harvest waste..... 0.30...0.36
Chips from wood processing residues..... 0.32...0.38
Freshly poured sawdust..... 0.20...0.30
Sawdust deteriorated in storage ..... 0.33...0.37

For chips from freshly cut wood of different species at the relative moisture (W_{rel}), the lowest heat value Q_l for 1 solid m^3 (solid volume or bulk m^3) is as follows: 5 920 MJ/m^3 (bulk m^3) for spruce at W_{rel} = 50 %; 6 720 MJ/m^3 for pine at W_{rel} = 48 %; 7 370 MJ/m^3 for birch at W_{rel} = 45 %; 6 560 MJ/m^3 for aspen at W_{rel} = 50 %.

Chips with the relative moisture about 45-50 % are commonly supplied to the furnace, and it can reach 60 % in winter.

The relative moisture content and lowest heat values for fuel chips are shown in table 5.

The optimum moisture of fuel chips is 40%, with the lowest heat value 10 200 MJ/kg and the ash content 1 %, which corresponds to the bulk gravity 250 kg/m^3. 1 solid m^3 of the chips corresponds to 2.4 bulk m^3.

At the chips' relative moisture 40 % and the furnace efficiency 0.8, for production of 1 Gcal (4.1868 GJ = 1.163 MWh) of heat carrier, 512 kg or 2.05 m^3 (0.83 m^3 solid m^3 – solid volume) of chip wood is required.

Table 5

The lowest combustion heat (Q_l) *versus* relative moisture content (W_{rel}) for fuel chips

Chips moisture, %	Q_l, MJ/kg	Chips moisture, %	Q_l, MJ/kg	Chips moisture, %	Q_l, MJ/kg
25	13.394	39	10.438	53	7.486
26	13.180	40	10.216	54	7.273
27	12.967	41	10.011	55	7.059
28	12.753	42	9.801	56	6.845
29	12.548	43	9.596	57	6.632
30	12.326	44	9.374	58	6.431
31	12.125	45	9.169	59	6.217
32	11.912	46	8.956	60	6.004
33	11.698	47	8.742	61	5.811
34	11.492	48	8.541	62	5.585
35	11.279	49	8.328	63	5.376
36	11.066	50	8.144	64	5.162
37	10.865	51	7.901	65	4.940
38	10.641	52	7.687	–	–

Conclusions

1. In compliance with closed furnace requirements that relate to cut-up wood pressed material, its moisture cannot exceed 12 % (permissible moisture range 0-12%), and the highest and lowest combustion heat in this moisture range varies from 19 980 kJ/kg to 17 583 kJ/kg, and from 18 607 kJ/kg to 16 081 kJ/kg, respectively.
2. Estimated from the Mendelejev's formula, the highest and lowest combustion heat for cut-up wood pressed materials at the relative moisture variations from 0 to 12 % varies from 19 880 kJ/kg to 17 503 kJ/kg and from 18 457 kJ/kg to 15 950 kJ/kg, respectively. The calculated wood heat values, determined using the Mendelejev's formula, as compared with the measurements in the calorimetric bomb, are within the limits of experimental error.
3. At the relative moisture of chips 40 % and the furnace's efficiency 0.8, for production of 1 Gcal (4.1868 GJ = 1.163 MWh) of heat carrier, 512 kg or 05 m^3 (0.3 m^3 - solid volume) of chip wood are required.

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Tytuł: Zależność ciepła spalania brykietów z trocin i zrębków od ich wilgotności.

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Lower explosibility limits of pine and beech wood dusts

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Abstract: *Lower explosibility limits of pine and beech wood dusts.* The wood dust, generete during a woodworking is able to create with air explosive mixtures, which is one of the main hazards in wood processing industry.

The aim of this work was a determination of the lower explosibility limit as a parameter defining the smallest concentration of a combustible component in a dust-air mixture, for two chosen dusts: a pine and a beech dust in dependence of their humidity and dispersion degree.

Introduction

Wood dust, which generate almost on every stage of woodworking process, creates in wood industry one of the greatest hazards. Dispersed in air may form dust-air clouds of such a concentration that are very sensitive to ignition and usually explode in presence of ignition sources commonly met in industry. Every explosion causes serious material losses, sometimes also injuries and/or death of working staff.

Since the possibility of occurrence of dust-air mixture explosion basically decides a concentration of combustible dust in it, the basic parameter characterizing explosion ability of a given dust there is a value of its lower explosibility limit.

Lower Explosibility Limit – LEL – is defined as the lowest concentration of a combustible component in dust-air mixture, below which the mixture does not explode, because there is no spontaneous flame propagation from ignition source onto the whole mixture.

It is very important to know that the value of lower explosibility limit is affected by many factors as for example: dust moisture content and dispersion degree, chemical constitution, volatile content, combustibility and some thermodynamic dust properties.

The aim of this work was determining the lower explosibility limits of pine and beech dusts in dependence of their moisture and dispersion degree.

Characteristic of tested materials

The dusts tested were taken from a grinding process of a pine and beech sawn timber, edged with no defects, using abrasive paper of grain size number 120 and hand grindery. The grinding process was made cross-grain.

A dust obtained on that way has been sieved by a screen 320 μm size, on purpose to remove shavings and impurities from grinding process. After 72 hours a moisture content of tested dusts has been determined, which for beech dust was 8,2% and for pine dust was 8,7%. Such prepared materials were taken to the measurements of their selected physical properties:

1. **Hygroscopicity investigation.** Time for coming up to the saturation humidity for dust samples in the climatic chamber at defined humidity 76% has been measured. The results allowed to prepare a graph, which served to conditioning the dust samples in the lower explosibility limits researches.

2. **Sieve (grain size) analysis.** The investigation has been made according to polish standard PN-71/C-04501, using a laboratory vibrating sorter. The sieves with mesh sizes: 200, 100, 71, 56 and 40 μm have been used. The grain size distribution has been shown on figures 1 and 2.

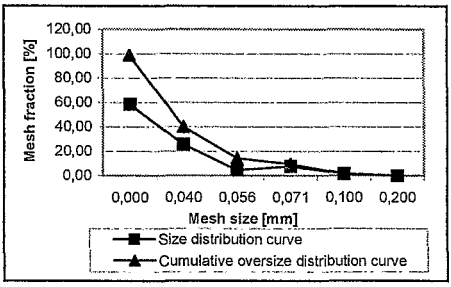


Fig.1. Grain size analysis of a beech dust.

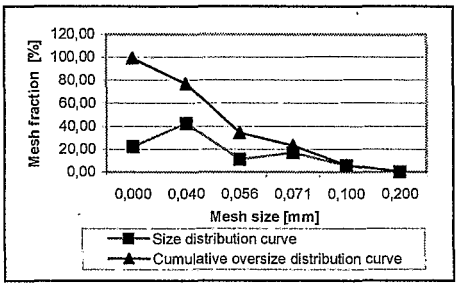


Fig.2. Grain size analysis of a pine dust.

3. **Microscopic analysis.** The smallest observed particles of pine dust had dimensions: 5,77; 3,55; 3,54 μm and particles of beech dust particles: 2,36; 2,38 and 1,14 μm.

4. **Determination of apperent densities of dust shell and a cone angle of heaped dust.** The results of determinations made according to polish standards: (PN-74/Z-04002/02) and (PN-74/Z-04002/07) have been collected in table 1.

Table 1. Experimental results of Determination of apperent densities of dust shell and a cone angle of heaped dust.

parameter / dust type	Apperent densities		Cone angle of heaped dust
	of shaked dust shell	of heaped dust shell	
pine dust	0,248	0,132	54°
beech dust	0,266	0,219	47°

During the investigations it has been noticed that the pine dust particles combined into bigger agglomerates. A beech dust was loose and did not combine into agglomerates.

Method of determining the lower explosibility limit

In the research practice such a minimum concentration of combustible component in a mixture with air or other oxidizing agent is taken as a value of lower explosibility limit, which gives a pressure rise equal 50 kPa (PN-84/C-01200/08).

The experiments had been run in the research explosion chamber constructed according to polish standard PN-84/C-01200/08. It was a vertical cylinder of 6,4 dm^3 volume with diameter to height ratio equal 0,5. A pyrotechnic igniter of 220 J energy had been mounted in the middle of the cylinder height, on its axis. A dust sample had been placed inside dispersion container, above which there was a dispersion nozzle. Dust dispersion into a dust-air cloud had been made by a blow of compressed air. Such a set of devices and dispersion procedure had been designed by P.Wolański (Technical University of Warsaw). Ignition of a dust-air mixture in the chamber had been made by explosion of the igniter used. The pressure – time

history had been registered using a pressure sensor, amplifier, A/D converter and processed by a computer as shown on fig. 3.

Determination of the lower explosibility limits for the pine and beech dusts has been done in two stages, using dust samples with parameters as follows:

- Samples of 0%, 7%, 14% humidity which contained all dust fractions from sieve analysis (grain size < 320 μm)
- Samples of 0% humidity, grain size < 71 μm.

The fixed humidity of dust samples have been realized by conditioning the samples in a climatic chamber for a time taken from earlier prepared graph. In the second stage of investigations the dusts with particles size below 71 μm have been used, because it is commonly known from literature that such dusts are extremely explosive in mixtures with air.

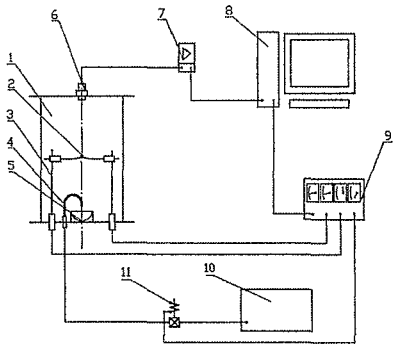


Fig. 3. Measuring stand for LEL determination. 1-Cylindical explosion vessel of 6,4 dm^3 volume, 2-ignition source, 3-electrodes, 4-dust dispersing nozzle, 5-dust sample container, 6-pressure sensor, 7-amplifier, 8-computer with A/D converter, 9-control device for dust dispersion and ignition, 10-air compressor, 11-electromagnetic valve.

Results

The results of LEL measurements for the pine and beech dusts have been shown on figures 4 and 5.

Lower explosibility limit for the pine dust, for the sample including all sizes of particles below 320 μm, in dependence of its humidity was as follows:

- For humidity 0% - 86 g/m^3,
- For humidity 7% - 94 g/m^3,
- For humidity 14% - 136 g/m^3.

Lower explosibility limit for the beech dust, for the sample including all sizes of particles below 320 μm, in dependence of its humidity was as follows:

- For humidity 0% - 80 g/m^3,
- For humidity 7% - 83 g/m^3,
- For humidity 14% - 89 g/m^3.

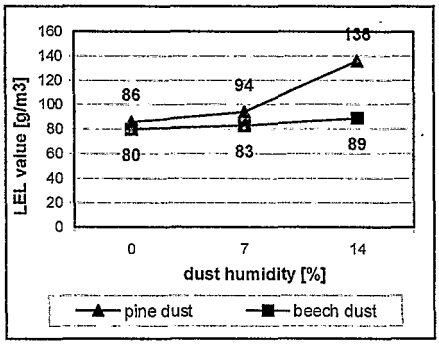


Fig.4. The influence of dust humidity on its lower explosibility limit value.

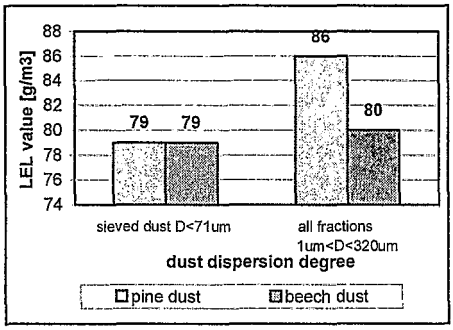


Fig.5. The influence of dust dispersion degree on its lower explosibility limit value.

Conclusions

1. For the pine dust as well as for the beech dust tested increasing humidity level causes an increase of the lower explosibility limit value.
2. An increase of humidity level causes much greater decrease of explosion ability for the pine dust than for the beech dust tested.
3. An increase of dispersion degree causes a clear decrease of LEL value and increase of explosion ability only in the case of the pine dust tested. In the case of the beech dust such an influence is much smaller.
4. Lower explosibility limits of the pine and beech dusts, for particles size below 71 μm and humidity 0%, is equal in both cases 79 g/m^3.
5. The beech dust prepared and tested in the same conditions as the pine dust shows a greater explosion ability than the pine dust.

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Standards

1. PN-71/C-04501 Sieve analysis. Rules of testing.
2. PN-75/Z-04002/13 Air purity protection. Tests of dust physical properties. Determination of dust humidity.
3. PN-74/Z-04002/00 Air purity protection. Tests of dust physical properties. Introduction and scope of the standard.
4. PN-74/Z-04002/02 Air purity protection. Tests of dust physical properties. Determination of apperent densities and static porosities of dusts shell.
5. PN-74/Z-04002/07 Air purity protection. Tests of dust physical properties. Determination of cone angle of heaped dust.
6. PN-84/C-01200/01 Fire hazard and explosive conditions. Parameters of inflammability and explosion. Terminology and definitions.
7. PN-84/C-01200/08 Fire hazard and explosive conditions. Parameters of inflammability and explosion.

Streszczenie: *Dolna granica wybuchowości pyłów z drewna sosny i buka.* Pył drzewny powstający podczas obróbki mechanicznej drewna zdolny jest do tworzenia z powietrzem mieszanin wybuchowych, co stanowi jedno z głównych zagrożeń w zakładach przemysłu drzewnego. W niniejszej pracy oznaczono dolną granicę wybuchowości jako parametr określający minimalne stężenie wybuchowe składnika palnego w mieszaninie dla dwóch wybranych pyłów: sosnowego i bukowego w zależności od wilgotności tych pyłów i stopnia ich rozdrobnienia.

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Minimum ignition energies of pine and beech wood dusts

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Abstract: During a woodworking, especially in grinding processes, very fine wood dust has been produced. Its presence creates a real fire and explosion hazard in wood processing industry. Such a dust dispersed in air may form a dust-air cloud, which can ignite and explode when enough strong ignition source appears. The aim of this work was to determine the minimum ignition energies (MIE) of pine and beech wooddust-air mixtures of 63 μm particle size and 0% moisture. Because one of the main factors affecting the value of MIE fof dusts there is a degree of its size reduction a grain size distribution of tested dusts has also been determined.

Introduction

A notion of dust may be defined as a set of particles of a solid which passes through a sieve 300 μm mesh size and individual particles may be a part either dispersed phase (dust cloud) or a dust layer.

During a woodworking some wood wastes have been produced, significant part of them is a fine wood dust called also a wood flour. It concerns mainly grinding processes when produced dust characterizes extremely small grains sizes and dust presence is damaging to worker's health as well as creating fire and explosion hazard. Dust clouds in air are able to ignition and explosion while enough strong ignition source appears. One of the main parameters characterising ignition ability of dusts is so called minimum ignition energy of dust cloud.

Minimum Ignition Energy – MIE – is the smallest ammount of energy of electric spark generated by high voltage transformer or capacitor discharge required is able to ignite a dust-air cloud in test conditions. The main factors affecting the MIE value are: dust particle size, dust moisture content, dust cloud concentration and ignition delay time.

The aim of this work was determining the minimum ignition energies of pine and beech wood dusts of 63 μm particle size and 0% moisture (according to MIE determination procedure).

Material tested

The dusts tested were taken from a grinding process of a pine and beech sawn timber using abrasive paper of grain size number 120. A dust obtained on that way has been sieved by a screen 320 μm size, tested for moisture content, which for pine dust was 8,7% and for beech dust was 8,2% and finally tested for a grain size according to polish standard PN-71/C-04501. The results of the grain size analysis are shown on figures 1 and 2.

During the grain size analysis it has been noticed that the pine dust particles combined into bigger agglomerates that automaticly lowered their dispersion state. A beech dust was loos and did not combine into agglomerates.

A dust destined for MIE testing has been sieved through a sieve 63 μm size and dried to 0% moisture content in 100^{O}C in a laboratory drying owen.

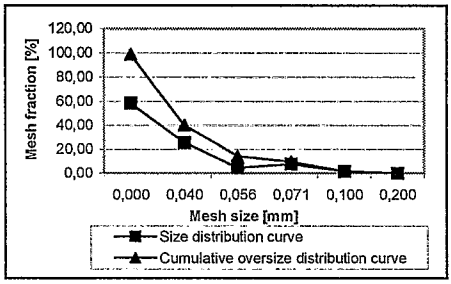


Fig.1. Grain size analysis of a beech dust.

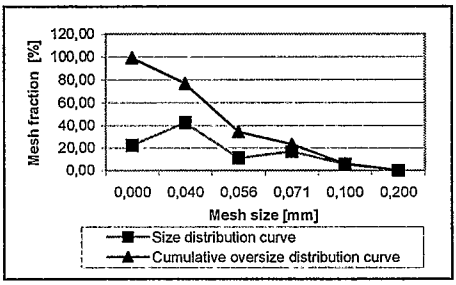


Fig.2. Grain size analysis of a pine dust.

Method of determining the minimum ignition energy

The principle of the method used is based on the measurements of the real values of discharge energies of a high voltage capacitor which caused ignition of a dust-air mixture in a test apparatus as well as thouse which did not cause ignition of a tested dust cloud (according to polish standard PN-84/C-01200-09). According to test procedure the minimum ignition energy, MIE lies between the lowest energy value (E2) at which ignition occured and the energy (E1) at which in at least 10 succesive experiments no ignition was observed. However, for purpose of simplification often only the lower limit value (E1) is specified as the minimum ignition energy MIE. The precise value called the statistic ignition energy (Es) can be estimated by use of the probability of ignition as follows:

$$Es = 10^{(\log E2 - I[e2] \times (\log E2 - \log E1) / ((NI + I)[E2] + 1))}$$

Where is: E2 – the lowest value of spark energy by which the ignition occured,
E1 – the highest value of spark energy by which the ignition did not occure,
I[E2] – number of tests with ignition at the energy E2,
(NI+I)[E2] – total number of tests at the energy E2.

The experiments have been run in the apparatus for determining the minimum ignition energy called MIKE 3 showh on fig. 3. The main part of it is modified Hartmann's tube made of glass of 1,2 dm^3 volume, in which a dust-air mixture is produced and its ignition is observed. The dust sample is placed in a special designed mushroom-shaped dust container and dispersed by a blow of compressed air of 0,7 MPa pressure. The dust-air cloud produced on that way is than ignited by a spark discharge between two electrodes. The testing device is connected to a PC computer which controls all parameters of experiment, is responsible for data acquisition and calculating the value of statistic ignition energy using an equation written above.

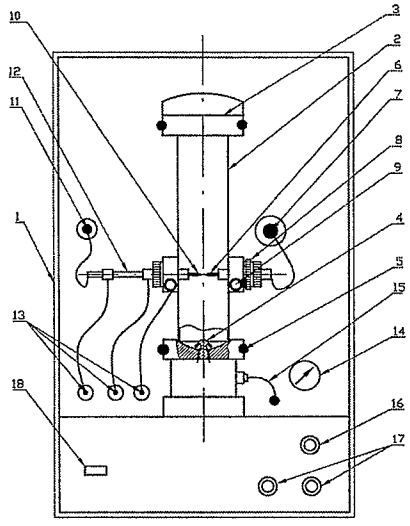


Fig. 3. Apparatus for minimum ignition energy of dust-air mixtures measurement. 1-housing, 2-glass Hartmann's tube of 1,2 dm^3 volume, 3-upper moving cover, 4-dispersion device, 5-fastenings, 6-high-voltage electrode, 7-high-voltage connection, 8-spark gap handwheel, 9-electrofe fastening device, 10-moving electorde (earthed), 11-earth connection, 12-pneumatic cylider, 13-pressure connection for moving electrode, 14-pressure gauge, 15-compressed air connection, 16-key for inlet valve, 17-keys for moving electrode and outlet valve, 18-on/off switch.

The minimum ignition energy has been determined in normal ambient temperature and normal oxygen content in dust-air cloud. The measurements have been done in a wide range of dust concentrations and inductance in dischsrge circuit allowing to determine the values of MIE and Es. The presence of inductance in discharge circuit causes the elongating the test time and makes the probability of ignition greater than with no inductance (the values of MIE detrmined wit inductance are usually smaller than those determined with no inductance in discharge circuit). In this work two values of ignition delay times were used: 90 and 60 ms. For both of dusts used: pine and beech the ignition delay times as well as dust-air cloud concentration have been changed until finding the values of their minimum ignition energies.

Results

The results of MIE measurements for the pine and beech dusts have been shown on figures 4 and 5 and in tables 1 and 2.

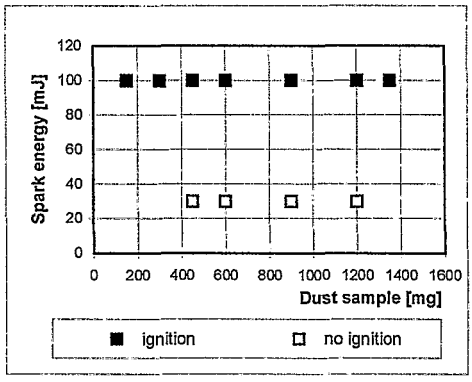


Fig.4. The measurements of MIE for a pine dust.

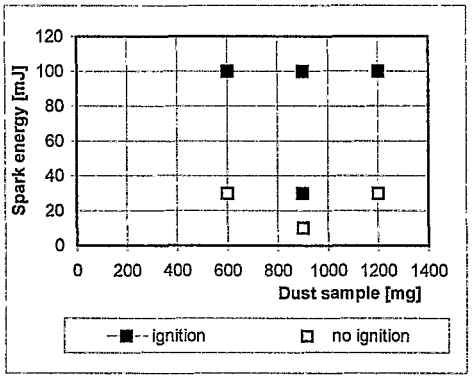


Fig.5. The measurements of MIE for a beech dust.

On the basis of obtained results the values of the statistic ignition energies have been calculated for both dust samples which were: 36 mJ for a pine dust and 17 mJ for a beech dust. It can be stated that the beech dust ignites much easier then the pine dust. It is caused by two main factors:

- the beech dust had a bigger percentage of smaller grains than the pine dust,
- the pine dust had a trend to agglomerate in complex particles and was difficulter to dispersing than the beech dust.

The obtained values of MIE for pine and beech dusts fall within the range of values given in literature. For wood dusts there is a range reported from 12 mJ (J.Fangrat, M.Woliński, P.Wolański, 1987) to 47 mJ (P.Krzystolik, J. Śliż, 1976).

Comparing obtained values of the minimum ignition energies of both dusts tested to the values of MIE of other dust from literature (from about 0,5 mJ for aluminium to over 10 J for melamine – W. Bartknecht, 1987) the authors of this paper may state that they are low, so the pine and beech dusts can be assigned to a group of organic dusts easy ignitable.

Table 1. Experimental results of MIE measurement for a pine dust.

Series	Dust sample [mg]	Spark energy [mJ]	Ignition delay time [ms]	Ignition at
1	900	100	90	3
2	900	30	90	-
3	600	100	90	1
4	600	30	90	-
5	1200	100	90	2
6	1200	30	90	-
7	900	30	60	-
8	900	100	60	1
9	600	100	60	1
10	600	30	60	-
11	450	100	60	1
12	450	30	60	-
13	300	100	60	1
14	150	100	60	1
15	1350	100	60	1

Table 2. Experimental results of MIE measurement for a beech dust.

Series	Dust sample [mg]	Spark energy [mJ]	Ignition delay time [ms]	Ignition at
1	900	100	90	1
2	1200	100	90	1
3	1200	30	90	-
4	900	30	90	5
5	900	10	90	-
6	600	100	90	1
7	600	30	90	-
8	900	30	60	2
9	900	10	60	-

Conclusions

1. Minimum ignition energy of pine dust of moisture 0% and particle size D<63 μm has been determined as 36 mJ, and of beech dust (for the same parameters of moisture and grain size) as 17 mJ.
2. The beech dust ignites easilier than the pine dust.
3. The values of MIE of the dusts tested comparing to the values of MIE of other industrial dusts taken from the literature are low enough for assigning them to a group of easy ignitable dusts.

References

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Standards

1. PN-71/C-04501 Sieve analysis. Rules of testing.
2. PN-84/C-01200/01 Fire hazard and explosive conditions. Parameters of inflammability and explosion. Terminology and definitions.
3. PN-84/C-01200/09 Fire hazard and explosive conditions. Parameters of inflammability and explosion. Determination of minimal energy of spark ignition of dusts.

Streszczenie: *Minimalna energia zapłonu pyłów z drewna sosny i buka.* Podczas obróbki drewna, a szczególnie w procesie jego szlifowania, powstają bardzo drobne pyły, których obecność stanowi poważne zagrożenie pożarowe i wybuchowe w halach produkcyjnych zakładów przemysłu drzewnego. Pyły te, unosząc się w powietrzu tworzą obłoki, które przy zaistnieniu odpowiednio silnego źródła energii mogą się zapalać i wybuchać. Celem niniejszej pracy było określenie minimalnej energii zapłonu (MIE) mieszanin pyłowo-powietrznych pyłów sosnowego i bukowego przy założonej wilgotności pyłu równej 0 % i średnicy ziaren mniejszej od 63 μm. Ponieważ zasadniczy wpływ na wartość minimalnej energii zapłonu pyłu ma stopień jego rozdrobnienia, oznaczono ponadto skład frakcyjny badanych pyłów.

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Quantitative characteristics of the process of sawing logs to lumber Part IV. Effect of taper curve and log length on the process of sawing of small-and medium-sized diameter logs

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Abstract: The paper presents results of a study on the effect of taper curve and log length on the process of sawing of small- and medium-sized diameter logs. The quantitative yield decreases in absolute value with increasing the log length from 2 to 6 m, at taper curve 0.50 and 1.50 cm/m, with 4.46 and 7.93 %, respectively. Yield decreasing by absolute value with increasing the taper from 0.50 to 1.50 cm/m, at log length 2.0 and 6.0 m is 5.58 and 9.05 %, respectively. The effect of double interaction between taper and log length on yield revealed almost equal influence of these factors on yield formation.
Key words: Taper curve, length, logs, lumber, quantitative yield

Introduction

Taper curve and log length together with diameter are among the most important factors affecting the dimensional characteristics of logs. These factors influence the process of sawing and yield of lumber. Determination of precise values and relationships is of crucial importance for planning organizing and optimizing of the sawing process. The lack of such information caused the main objectives of this study:

1. To determine the relationships between log length and quantitative yield within enough wide range for practical purposes. The relationships between log length and yield should be determined for different taper values.
2. To determine the patterns of yield change at simultaneous effect of log length and taper.
3. To evaluate the effect of diameter, cut width, taper curve and log length on the quantitative yield of the process of sawing small- and medium-sized diameter logs.

Material and methods

The effect of log length and taper curve, combined with effects of diameter and cut width [1,2] was studied by means of 4-factorial experimental design. Maximum yields were defined for all points of the experimental design, depending on combinations among the varying characters. The sawing process was optimized for three main operations: setting the thickness, width and length of lumber into two stages. The first stage was performed using specialized computer software and the dimensions mentioned above were determined as functions of diameter, length, taper curve and form of logs, and depending on the sawing method and cut width. Thus, all the factors were considered for the lumber dimensions defined. Additionally, the optimal thickness and length were converted to actual and standard dimensions. A waste-less technology was applied during the second stage, the operation of edging and cross-sectional sawing, and the dimensions were converted from optimum to actual and standard ones.

This experimental design served as a base for developing a model describing quantitative yield as a function of diameter, length and taper of logs, and cut width. The regression coefficients of the model for small- and medium-sized diameter logs were obtained at multiple correlation coefficient R=0.995084, Fisher's criterion F=72.13068, at $F_{crit.}$ = 2.845; degrees of freedom NI_1=14, NI_2=10 and significance level α=0.05. It means the approximation is good enough and the model could be further used. The average absolute error of the model is 0.5979415 and the average percentage error is 1.11 %.

The present paper presents part of the results concerning the effect of taper curve and log length on the yield when sawing small- and medium-sized diameter logs.

Results and discussion

The results of the effect of log length of small and medium-sized diameter logs on the yield of lumber are presented on figure 1. The figure shows that the values are grouped in curve sloped lines expressing the trend of yield decreasing with increasing log length. The group of lines form a family of curves drawn for 20 cm log diameter and 3.2 mm cut width.

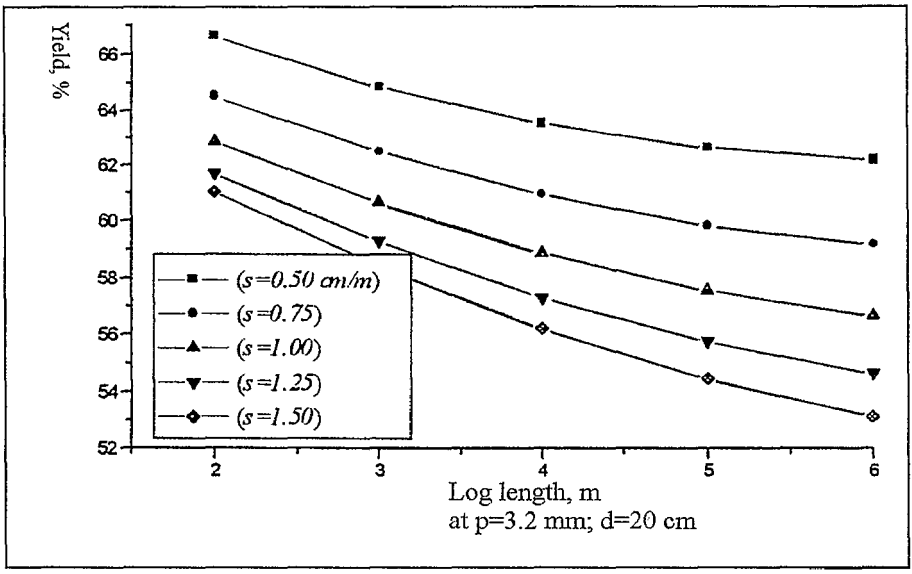


Figure 1. Effect of log length of small- and medium-sized diameter logs on the yield when sawing logs to lumber. Family of curves at different taper values.

Decreasing of yield absolute value when log length increases from 2 to 6 m, at taper curve 0.5 cm/m is 4.46 %, and at taper curve 1.5 cm/m is 7.93 %, respectively. Decreasing of yield in absolute value when the log length increases is better expressed at higher values of taper curve.

Yield decreasing in absolute value, when the taper increases from 0.5 to 1.5 cm/m is 5.58 % at log length 2.0 m, and 9.05 % at log length 6 m. It means decreasing

of yield when the taper curve increases is analogous to that when the log length increases.

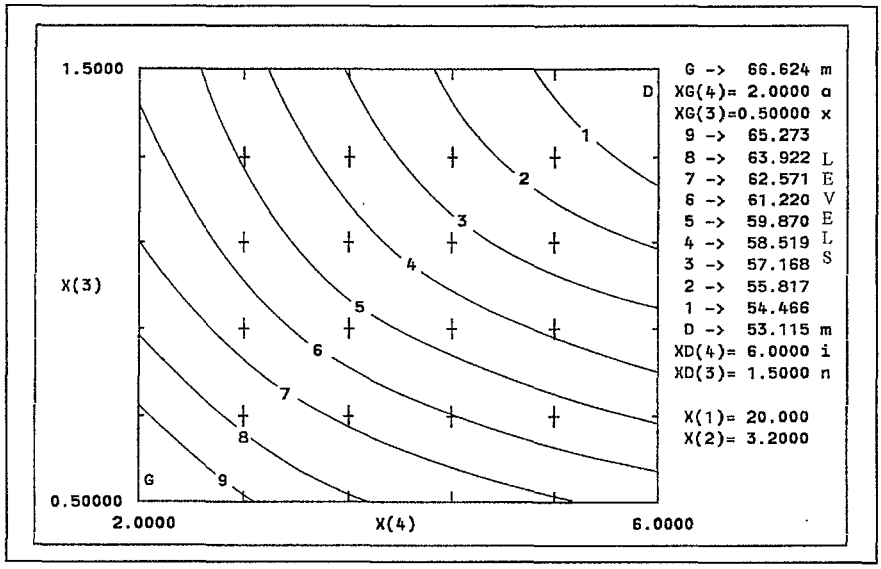


Figure 2. Effect of length X(4) and taper curve X(3) of small- and medium-sized diameter logs on the yield when sawing logs to lumber. The values refer to log diameter 20 cm and cut width 3.2 mm.

The effect of double interaction between the taper and log length on the yield is presented on figure 2. The figure expresses the equal effect of taper and log length on the yield. The maximum yield value 66.624 % has the following coordinates: log length = 2.0 m and taper = 0.50 cm/m. The minimum yield value 53.115 % has the following coordinates: log length = 6.0 m and taper = 1.50 cm/m.

The studies performed on the effect of diameter, taper, log length and cut width allow to define the levels of yield for the extreme points of the ranges studied. These results are presented in table 1.

Table 1. Characteristic levels of the quantitative yield by factors and ranges studied

Quantitative yield – R [%] by factors for the extreme points of the ranges studied							
X_1: Diameter, d [cm]		X_2:Cut width, p [mm]		X_3: Taper curve, S [cm/m]		X_4: Log length, L [m]	
10	30	1.6	4.8	0.5	1.5	2	6
48.27	64.17	48.94 64.74	43.21 59.20	53.37 68.37	45.16 61.95	66.62 61.04	62.16 53.11
Values of constant factors: p =3.2; S=1.0; L=4.0		d=10; S=1.0; L=4.0 d=30; S=1.0; L=4.0		d=10; p=3.2; L=4.0 d=30; p=3.2; L=4.0		S=0.5; d=20; p=3.2 S=1.5; d=20; p=3.2	

R_{max}=72.06 % - at d=30 cm; p=1.6 mm; S=0.50 cm/m; L=2.0 m R_{min}=37.02 % - at d=10 cm; p = 4.8 mm; S = 1.50 cm/m; L = 6.0 m

The results of quantitative yield determined at the extreme points of the factors' ranges (table 1) show both the levels achieved and the effect of the factors studied. Doubtless, the log diameter has the strongest effect on yield, and for the range 10-30 cm, the yield increasing in absolute values at different factors is 15-16.8 %. The effect of the other factors, such as cut width, taper and log length cause changes of 4 to 9 %, with approximately equal effect of the different factors.

The uppermost and lowermost levels of yield for the extreme points of the ranges and factors studied, is 68.37 and 43.21 %, respectively. It must be pointed out that the yields presented in table 1 refer to the extreme points of effect of single factors, among the four factors studied. The remaining factors have values close to the average for the respective ranges and they are listed in table 1. Due to this reason the yield values presented above are not extreme for all factors and ranges studied. The extreme values of yield for all the ranges and factors studied are R_{max}=72.06 % and R_{min}=37.02 %, and the conditions of achieving these values are indicated in table 1. It means by varying of values of the factors and ranges, the maximum difference in yield could reach 35.04 %. This difference is a result of complex influence of the factors studied, after their selection within the ranges.

Conclusions

The studies on the effect of taper curve and log length on the yield when sawing small- and medium-sized diameter logs allow the following more important conclusions:

1. The studies showed the effect of effect of taper curve and log length on the yield when sawing small- and medium-sized diameter logs. The yield decreases with increasing of log length from 2 to 6 m, at taper 0.5 and 1.5 cm/m. The decreasing amounts 4.46 % and 7.93 %, respectively. Analogously, the decreasing of yield in absolute value when increasing the taper from 0.5 to 1.5 cm/m, at log length 2 and 6 m, is with 5.58 and 9.05 %, respectively.
2. The effect of double interaction between taper curve and log length on the yield was also established. The graphic presentation of the results indicated practically equal effect of the factors on yield formation. The double interaction within the ranges studied lead to maximum yield 66.624 %, with coordinates log length 2.0 m and taper 0.5 cm/m. The minimum yield 53.115 % was obtained at coordinates log length 6.0 m and taper curve 1.5 cm/m.
3. Generally, the study of effect of the four factors on the yield revealed the strongest effect of log diameter, causing changes in yield with 15-16.8 %. The effect of the other factors, like cut width, taper and log length caused changes in yield 4 to 9 % and were approximately equal. For the factors and ranges studied the yield could vary from 37.02 to 72.06 %.

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small- and medium-sized diameter logs.Technologies of wood processing. International Scientific Conference, September 10-11, Zvolen.

Tytuł: Ilościowa charakterystyka procesu przetarcia kłód. Cz. IV. Wpływ zbieżystości i długości kłody na proces przetarcia drewna mało i średniowymiarowego.

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Quantitative characteristics of the process of sawing logs to lumber Part V. Effect of taper curve and log length on the process of sawing of large-sized diameter logs

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Abstract: Inversely proportional relationships were established among taper curve, log length and quantitative yield, studied by factors and by double interaction. The taper curve and log length showed almost equal effect on yield formation. The yield values could be expressed as surfaces depending on the factors log length and taper curve, which are situated one above the other with increasing of diameter. The limits of variation of yield depending on the taper curve and log length are determined as well.

Key words: Taper curve, length, logs, lumber, quantitative yield

Introduction

The taper curve, and log length are part of the factors affecting the patterns of dimensional characteristic and form of logs. These two factors, together with diameter, determine the manner of sawing both of external zone and the whole volume of logs and cause direct influence on the quantitative yield. This statement was proved by the studies on small- and medium-sized diameter logs [1]. For practical purposes it is necessary to test the effect of taper curve and log length of large diameter logs, i.e. having diameter range 30 to 60 cm. The above arguments determined the objectives of present study: 1. Determining the relationships between log length and quantitative yield at different values of taper curve, for large sized diameter logs; 2. Determining of double interaction effect of taper curve and log length on the quantitative yield; 3. Quantitative evaluation of effect of taper curve and log length on yield, for the range of large sized diameter logs.

Material and methods

The effect of log length and taper curve on yield is a part of study, aimed to evaluation of the effect of diameter and cut width, together with these factors. All the factors directly influence the yield, and, therefore, general relationships were studied by means of four-factorial experimental design. The factors were set to vary within the ranges: diameter – 30 to 60 cm; cut width – 1.6 to 4.8 mm; taper curve – 0.5 to 1.5 cm/m and log length – 2 to 6 m.

The process of sawing was optimized for the operation of setting of diameter, width and length of lumber, for all the points of compositional plan of the experimental design, and the maximum quantitative yields have been determined.

The model obtained describes the maximum quantitative yield in relation to the values of the factors studied. The regression coefficients of the model have multiple correlation coefficient R = 0.995644,at Fisher's criterion F=81.44819. The critical value of F-criterion is $F_{crit.}$= 2.845, at degrees of freedom NI_1=14 and NI_2=10 and level of significance α=0.05. It means the approximation is good enough and the

model could be further used. The average absolute error of the model is 0.4278534 and the average percentage error is 0.623 %.

The present paper presents results concerning the effect of taper curve and log length on the yield when sawing large-sized diameter logs.

Results and discussion

The results of the effect of log length of large-sized diameter logs on the yield of lumber, at different taper curve values are presented on figure 1. The factors set at constant levels are: cut width = 3.2 mm, and log diameter = 45 cm. The relationship between the log length and yield, at different values of taper curve, is well described by family of curves that are close to straight lines. It means the quantitative yield follows inversely proportional trend of changing as compared to increasing of log length. This trend is better expressed at higher values of diameter and taper curve. For instance, when log length increases from 2 to 6 m, at taper curve 0.50 cm/m, the yield decreases from 72.95 to 70.63 %, i.e. with 2.63 %. For the same values of log length, but at taper curve 1.50 cm/m, the yield decreases from 69.55 to 62.97 %, i.e. with 6.58 %. Analogously, when the taper curve increases from 0.50 to 1.50 cm/m, at log length 2 m, the yield decreases from 72.95 to 69.55 %, i.e. with 3.40 %. For the same taper values, but at log length 6.0 m, the yield decreases from 70.63 to 62.97 % (7.66 % difference).

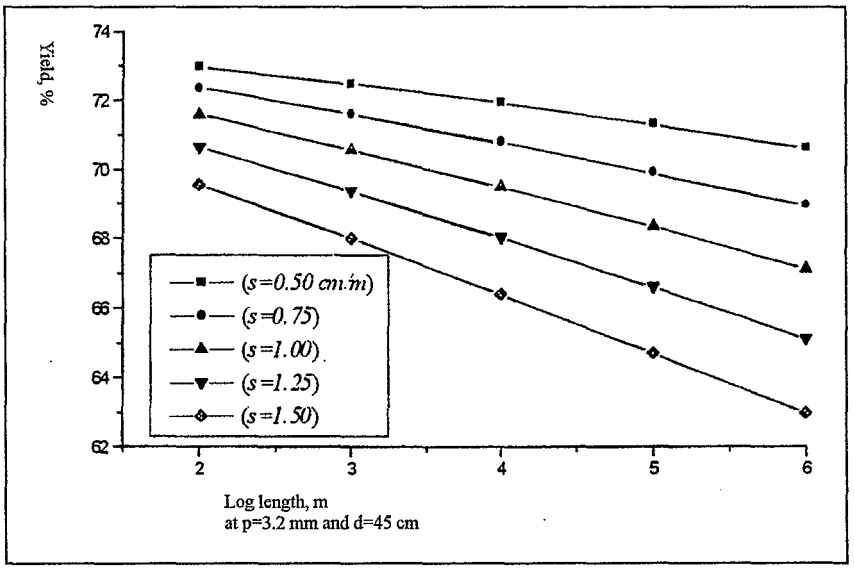


Figure 1. Effect of log length of large sized diameter logs on the quantitative yield when sawing logs to lumber. Family of lines at different values of taper curve.

Figure 2 represents the double interaction effect between log length and taper on quantitative yield. The figure reveals almost equal effect of the two factors, log length and taper, on the quantitative yield formation. Decreasing of interval between the lines of constant levels indicates continuous increasing of the effect of log length and taper with increasing of their values. All the values of yield could be scored from

figure 2. For the log length and taper studied, these values are between lowermost yield level 62,971 % and uppermost yield level 72.953 %.

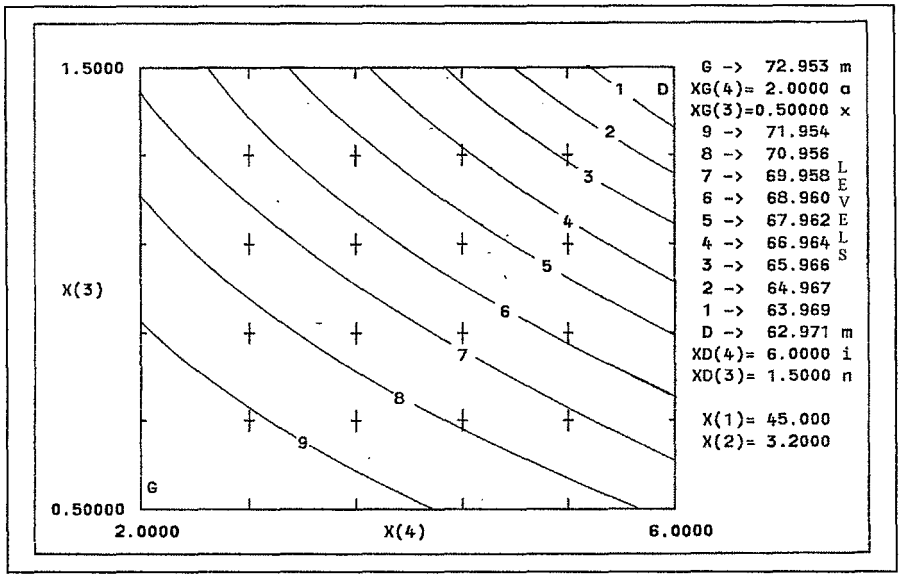


Figure 2. Effect of taper curve X(3) and log length X(4) on the quantitative yield when sawing logs with diameter 45 cm and cut width 3.2 mm.

The whole range of variation of quantitative yield, expressed as a function of the studied values of log length and taper curve, at log diameters 20 and 40 cm and cut width 3.2 mm, are presented in table 1.

Table 1. Quantitative yield as a function of log length and taper curve at log diameters 20 and 45 cm and cut width 3,2 mm

Quantitative yield [%], at log length, L [m}; taper, S [cm/m] and diameters, d[cm]										
L	S=0.5		S=0.75		S=1.00		S=1.25		S=1.50	
	d=20	d=45	d=20	d=45	d=20	d=45	d=20	d=45	d=20	d=45
2	66.62	72.95	64.48	72.35	62.84	71.58	61.69	70.64	61.04	69.55
3	64.85	72.48	62.50	71.61	60.64	70.57	59.27	69.37	58.41	68.01
4	63.52	71.93	60.95	70.80	58.87	69.49	57.29	68.03	56.21	66.40
5	62.62	71.32	59.83	69.91	57.54	68.35	55.74	66.62	54.44	64.72
6	62.16	70.63	59.16	68.96	56.65	67.13	54.63	65.13	53.11	62.97

The values of yield in table 1 draw two surfaces. The first one is described by factors log length and taper curve at diameter 20 cm, while the second surface, situated above the first one is described by the same factors, but at log diameter 45 cm. The values of the factors describing the surfaces are also sections with these

surfaces. The differences between the points of equal taper and log length are the distances between these surfaces. The surfaces and the distances between them are formed by the complex interaction between the log diameter (d), taper curve (S) and log length (L). The range of quantitative yield (R) between the two surfaces is equal to difference between maximum yield value R_{max}=72.95 %, at L=2 m, S=0.5 cm/m for d=45 cm, and minimum yield value $R_{min.}$=53.11 %, at L=6 m, S=1.5 cm/m, and d=20 cm.

The distances between the surfaces are formed also by the complex effect of the three factors. The minimum absolute difference between them is 6.33 %, at L=2 m, and S=0.5 cm/m, and the maximum absolute difference increases up to 10.88 %, at L=5 m and S=1.25 cm/m. The distances between the surfaces increase with increasing both of log length and taper curve. All the distance values at L=6 m and S=1.50 cm/m remain lower than these at the lines of L=5 m and S=1.25 cm/m. However, this difference is too small and has value lower than 0.55 %. The yield could have values, which are points of the two surfaces, but also values situated between these two surfaces.

Conclusons

The studies on the effect of taper curve and log length of large-sized diameter logs on the quantitative yield allow the following more important conclusions:

1. The relationships between the log length and yield, on one hand, and between taper curve and yield, on the other, could be set to be inversely proportional. The yield decreasing is better expressed at higher values of log length and taper.

2. The double interaction effect of log length and taper on the quantitative yield revealed the equal importance of the two factors on yield formation, as well as of increasing the effect with increasing of their values. The lines expressing the constant yield levels allow its determination at desired taper curve and log length.

3. The values of yield could be described by surfaces, depending on the factors log length and taper curve, which are situated above each other with increasing of diameter. The surfaces are close to plains and are slightly sloped to the increasing values of log length and taper curve. The distances between the two surfaces are numerical axes of the yield. For log diameter from 20 and 45 cm, log length from 2 to 6 m and taper curve from 0.50 to 1.50 cm/m, the yield range is characterized with minimum value 53.11 % and maximum value 72.95 %. The distances between the surfaces having maximal and minimal difference by absolute value, is 6.33 % and 10.88 %, respectively.

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Tytuł: Ilościowa charakterystyka procesu przetarcia kłód. Cz. V. Wpływ zbieżystości i długości kłody na proces przetarcia drewna wielkowymiarowego.

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Application of polystyrene for plywood production

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Abstract: The subject of the study was the possibility of applying crumbled polystyrene for bonding veneers in plywood. The source of this material were trays from foamed polystyrene coming from recycling. Nine pressing schemes were developed differing in the amount of spread material and pressure of pressing. Bond quality, compression and density of obtained plywood samples were determined and compared with plywood produced in a „traditional" manner. Plywood samples produced with polystyrene have shown, depending on pressing scheme, a comparable or slightly lower (up to 14%) bond quality. At the same time, these samples had a greater density and thickness, as compression has not taken place.

Introduction

One of the directions in the development of wood-based materials is introduction of new materials into their production, among them also recycled ones. A very interesting group of them is constituted by thermoplastics coming from recycling. Researches having been conducted have proven a possibility of applying polyethylene (LDPE, HDPE), polypropylene (PP) and polystyrene (PS) for bonding wood particles in particleboards and fibreboards (2, 3, 4, 5). These boards usually show lower strength properties in comparison with „traditional" boards. However, their unquestionable advantage is usually higher water resistance and dimensional stability in changing air humidity (4). The studies which have been conducted so far have proven also a possibility of simultaneous veneering the obtained boards. It seems advisable to go further ahead and to conduct researches on the application of the discussed materials to bonding veneers in plywood (2).

Such an application of thermoplastics creates new possibilities of material recycling. The greatest source of the discussed materials are packaging and expendable articles (dishes, cutlery, writing accessories etc.). It is worthy of stressing here that in 1995 in Poland only 1.3% of wastes from packaging were recycled (1).

In the present study, it was attempted to apply polystyrene coming from used trays which are a commonly used expendable packaging of many food products as a bonding agent for production of plywood.

Method

Within the framework of the study, 3-layer beach plywood samples were produced from industrial veneer of nominal thickness 1.5 mm. For bonding the veneers in the plywood, crumbled trays from foamed polystyrene were used which came from recycling (Fig. 1). Plywood samples were produced according to 9 pressing schemes differing in pressure and the quantity of spread polystyrene (Table 1). The time of pressing for all kinds of plywood amounted to about 6 minutes. Additionally, control samples of plywood were produced by means of resins: urea-formaldehyde and phenol-formaldehyde ones.

The following properties of the obtained products were determined:

- bond quality determined on dry samples,
- bond quality determined on wet samples soaked in water of temperature about 20°C for 24 hours,
- compression of plywood,
- plywood density.

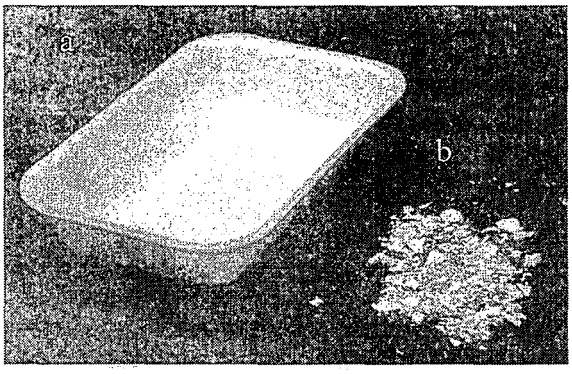


Fig. 1. The tray from foamed polystyrene (a) and its crumbled form (b)

Table 1. Specification of parameters of particular pressing schemes.

Number of pressing scheme	Bonding agent	Specific pressure of pressing	Spread quantity	Pressing temperature
		MPa	g/m^2	°C
I	phenol-formaldehyde resin	1,6	160	110
II	urea-formaldehyde resin	1,6	160	110
III	polystyrene	1,6	200	160
IV			300	
V			400	
VI		2,0	200	160
VII			300	
VIII			400	
IX		2,5	200	160
X			300	
XI			400	

Results and analysis

The results of the conducted researches are specified in Table 2 and Figures 2.

Table 2. Results of researches

Scheme number	Bond quality – shear strength (R_t)		Average thickness	Compression (S) *	Density (g)
	dry samples	after soaking			
	N/mm^2		mm	%	kg/m^3
I	2,9	2,5	4,43	2	676
II	2,9	2,4	4,30	4	689
III	2,5	2,0	4,52	0	701
IV	2,7	2,1	4,82	-7	716
V	2,7	2,2	4,93	-10	744
VI	2,6	2,1	4,58	-2	695
VII	2,9	2,0	4,77	-6	702
VIII	2,9	2,4	4,86	-8	745
IX	2,5	2,1	4,58	-2	693
X	2,9	2,1	4,68	-4	714
XI	3,1	2,3	4,88	-8	753

* „-" thickness increasing after pressing

As visible in Fig. 2, plywood produced by means of polystyrene show, depending on pressing parameters, a comparable or slightly lower (up to 14%) bond quality in relation to plywood samples produced by means of „traditional" glues (based on phenol-formaldehyde and urea-formaldehyde resins). However, it should be emphasised that in the case of polystyrene both pressing temperature and pressure should be higher than in the case of typical plywood production. The applied polystyrene underwent strong plastification only at the temperature of 160°C. It implied a necessity of exerting a higher pressure (about 2.5 MPa) in order to obtain an appropriate adhesion of the material to the veneer. It is also worthy to add that in the course of bonding veneers the plastified polystyrene does not penetrate wood which is the case with „traditional" glues. It is particularly apparent in determination of the quality of glue bonds in samples having been soaked in water (Fig. 2 a). Additionally, the bond quality was influenced also by the quantity of spread polystyrene, especially by the difficulty in its uniform spreading on the surface of veneer. In the course of forming the stock and its transport to the press, the crumbled material was running. In the final effect, especially with small spread quantity (200 g/m^2), the arising bonds could have variable thickness and be not continuous on the whole surface. This threat diminishes with a greater polystyrene spread quantity which implies a higher bond quality (Figs. 2 a, b).

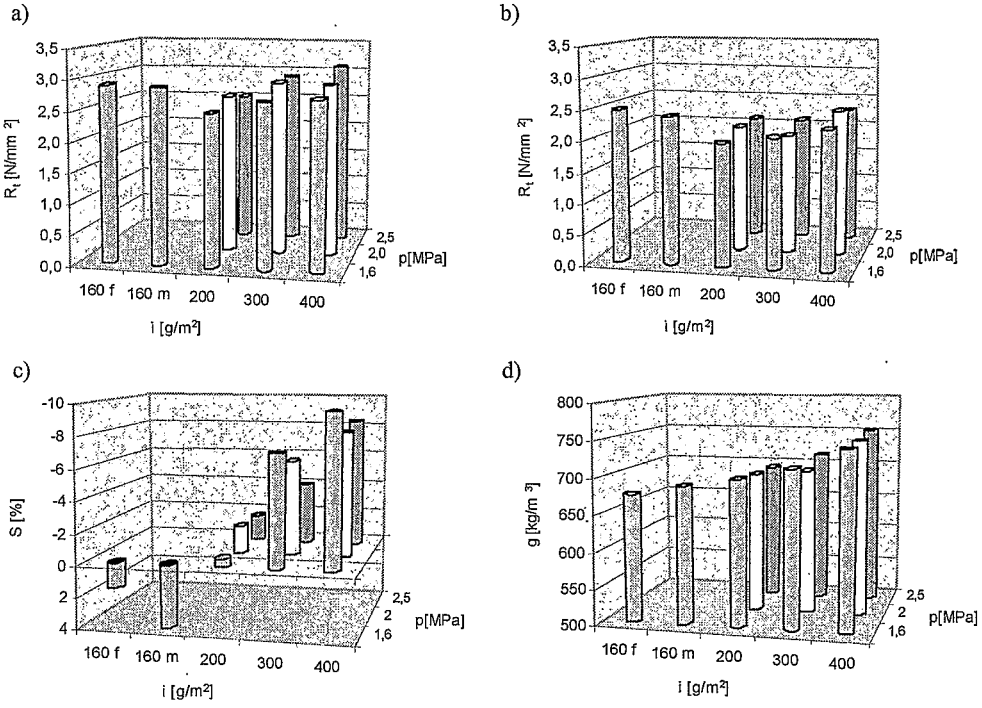


Fig. 2. a) Bond quality – shear strength, determined on dry samples
b) Bond quality – shear strength, determined on samples after soaking
c) Compression of plywood samples
d) Plywood density

R_t – bond quality – shear strength
S – compression
g – density
p – specific pressure of pressing
i – spread quantity
f – phenol-formaldehyde resin
m – urea-formaldehyde resin

The unquestionable advantage of polystyrene as a bonding agent is the fact that no additional water is introduced into a set of veneers which occurs in the case of traditional „glues". It has a direct effect on the thickness of obtained plywood. It was proven by the investigations that in the case of applying polystyrene, no plywood compression took place and the thickness of plywood was greater than the summary veneers thickness before pressing (Fig. 2 c). In the course of pressing, the veneers underwent usually elastic deformation and the final thickness of plywood was influenced mainly by the thickness of bonds. When the quantity of spread polystyrene amounted to 400 g/m^2, the thickness of plywood varied within the range 4.86-4.93 mm while with traditional glues, as a result of compression, it was even by 13% smaller (Table 1). Introduction of polystyrene as a bonding agent to plywood affected also its density (Fig. 2 d). Greater quantity of spread polystyrene, in spite of increased plywood thickness, resulted in a growth of its density.

Summary

The conducted researches have proven a possibility of applying recycled polystyrene for bonding veneers in plywood. Special attention should be paid to the fact that with a comparable or slightly smaller (up to 14%) bond quality plywood of greater density and thickness was obtained. When polystyrene is applied, the phenomenon of compression does not occur. The produced plywood samples had usually a greater thickness (even by 10%) than the total thickness of veneers before pressing.

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Streszczenie: *Zastosowanie polistyrenu do wytwarzania sklejek.* Badano możliwość zastosowania rozdrobnionego polistyrenu do łączenia fornirów w sklejce. Źródłem tworzywa były pochodzące z recyklingu tacki ze spienionego polistyrenu. Opracowano 9 schematów prasowania różniących się pomiędzy sobą ilością naniesienia tworzywa i ciśnieniem prasowania. Określono wytrzymałość spoin klejowych na ścinanie, sprasowanie i gęstość pozyskanych sklejek oraz porównano je ze sklejkami wykonanymi w sposób „tradycyjny". Sklejki wykonane przy użyciu polistyrenu wykazywały (zależnie od schematu prasowania) porównywalną lub nieznacznie niższą (do 14 %) wytrzymałość spoin na ścinanie. Jednocześnie sklejki te charakteryzują się wyższą gęstością i grubością – nie występuje zjawisko sprasowania.

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Development of materials and technology obtaining of items by pressing in the closed moulds from wood scraps without adding adhesive

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Abstract: The outcomes of researches on study technological properties of material from wood particles without adding adhesive and physic-mechanical properties of plastics from these compositions are indicated. The special attention is given to study of influence organic and inorganic modifiers, and also role of water during formation of plastics

In Russia the stock of wood is evaluated in 80 000 million m^3. However, it does not mean, that it can be used not rationally. The degree using of wood raw material makes 65-70 %, and chemical and chemistry-mechanical methods processes only 15-17 % (world level of processing makes 50-70 %). On the hydrolyses enterprises of Russian Federation is accumulated lignin in an amount 1,5 million ton in recalculation on dry substance [1].

One from rational directions of an effective utilization of scraps is the deriving from them molding material - mass wood pressing (MDP) with using phenol- and urea formaldehyde resins [2-4]. However, for want of use in these compositions synthetic resins in an amount from 11 up to 35 %, they become expensive and not ecological pure. Therefore, wood plastics received without adding adhesives represent large interest. Raw material can be not only small-sized wood particles, but also lignin and vegetative residuals of one-year plants (flax, hemp, cotton, straw and etc.).

In articles of the Prof. A.N. Minin (Byelorussia technological university) such material is called pressure termoplastic [5].

At our university since 1961 the works on obtaining plates from wood and other vegetative scraps without adding adhesives in open moulds (between heated plane-parallel plates) are conducted. The material is named lignin–carbo–hydrate wood plastic (LUDP) [6].

On faculty of technology of processing of plastic UGLTU since 1996 the works on deriving wood plastics without adding adhesives and items from them in the closed moulds (wood plastics without adhesives: DP-WA) are conducted [7,8].

The technologies obtaining of plates and items from wood plastics without adhesives do not find broad introduction because of a large cycle of pressing, as the cooling plastics is made in a mould under pressure. Therefore productivity of the equipment low, and cost of heat large. We offer technology of pressing of items based on a principle of remote moulds with using in quality of warm – air. It allows increasing productivity process of pressing more than 5 times, on a comparison with traditional technology for such material, and considerably cost of heat is reduced.

One from defects wood composites without adding adhesives is their low fluidity. The fluidity DP-WA with wood waste utilization (faction of 0-2 mm) on a method of pressing of a flat sample - disk [9] for humidity 10 % is equal 78 mm, and for want of 20 % - 95 mm [10]. The fluidity on Rashig for humidity 10 % is equal 9 mm, and for want of 20 % - 29 mm.

Good raw materials for manufacturing DP-WA are the scraps of productions: a rubbing dust of plywood (RD-P) and rubbing dust of particleboard (RD-PB). For example, the amount formed RD–PB for volume of production particleboard 100 000 m^3 per year makes 7500 ton [11].

In work [12] is shown, that RD–PB is possible to use in production general–purpose phenolic of mark O3-010-02, conforming the requirements GOST 5689-86 on phenolic (see tab.).

The table

Structure and properties phenolic with using of wood flour and grinding dust of PB

Parameters	Filler	
	Wood flour	RD–PB
Composite, %		
1. Phenolfomaldehyde resin	42,8	37,5
2. Wood filler	42,6	42,0
3. Mummy	6,5	7,0
4. Lime (Hydroxide magnesium)	0,9	0,7
5. Stearin	0,7	0,6
6. White bole	—	4,4
7. Paint	1,1	—
Properties		
1. Ultimate bending strength, MPa	69	66-69
2. Shock viscosity, kDj/cm^2	5,9	5,9-7,0
3. Electrical strength, kV/cm	14	16,7-17,2

The purpose of the given work is the development composition from RD-P without adding adhesives and determination modes of pressing items.

The fluidity DP–WA with using of RD–P considerably concedes of phenolic. Therefore, it is possible to produce items of a not complicated configuration. The fluidity of a material on Rashig and on the disk depending on it of humidity is indicated on fig.1a and 1b.

It is known [13], that the modification of wood by ammonia considerably increases it plasticity. The optimum amount of ammonia makes 5 %.

As a source of ammonia offered to use urea, which in conditions of pressing is decomposed under the following scheme:

$$NH_2{-}\underset{\underset{O}{\|}}{C}{-}NH_2 + H_2O \longrightarrow 2\,NH_3 + CO_2$$

Amount of ammonia (m_{am}) and carbon dioxide (m_{cd}), formed for want of decomposition urea (m_u), are possible to calculate under the formulas:

$$m_{am} = m_u / 1{,}765 \text{ and } m_{cd} = 0{,}733\ m_u.$$

Under our judgement, the application urea is more expedient, as the forming carbon dioxide creates a weak acid medium that promotes passing of polycondensation processes lignin and light hydrolyzable of a part cellulose – hemicellulose. It coincides the judgement of the authors of work [14].

The water during obtain a wood plastics without adding adhesives is necessary both plasticizer of wood and as a chemical reactant participating in reactions with components of wood.

Agrees work [6] for courses of chemical processes happening for want of formation a plastic from pine particles for wants of pressure 2,5 MPa, the initial humidity of wood should make 7-9 %. For want of use of deciduous breeds (asp, alder) the initial humidity a little above also makes 10-12 %. For giving to wood of plasticity, the moisture content should be even more and depends on breed of wood and pressure of pressing.

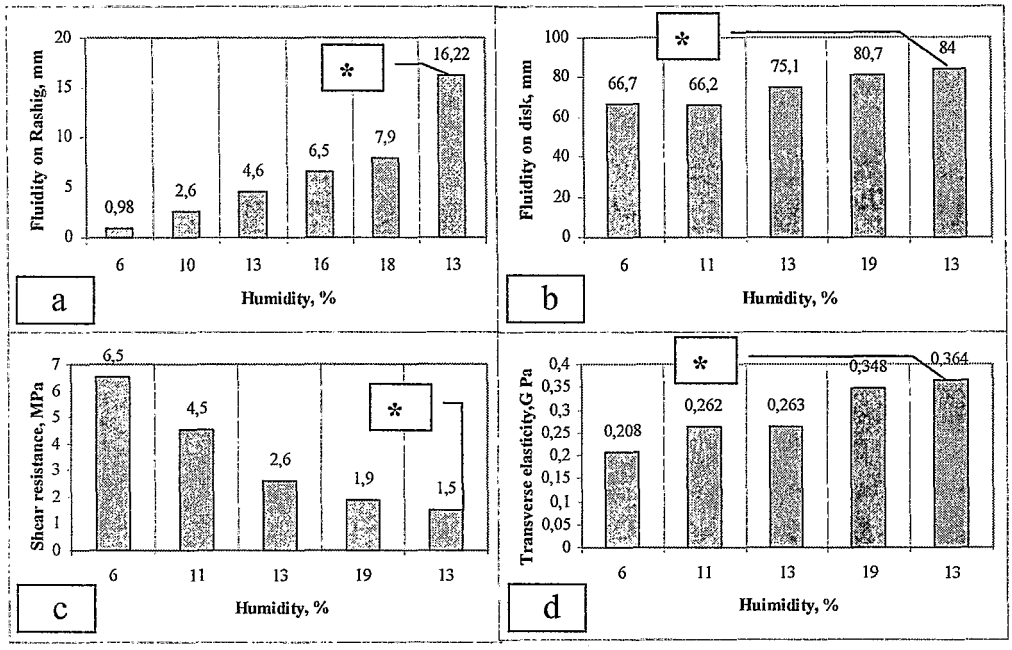


Fig.1. Dependence of properties of a composite material and DP–WA with using RD–P from humidity (* - significance of properties by modification of urea)

Besides for want of use as the modifier of urea, the additional amount of water for its expansion (see scheme) is necessary. The amount of water (m_w) for passing a reaction can be calculated under the formula: $m_w = 0,53\ m_{am}$.

Therefore, for want of formation DP-WA because of RD–P, with use as the modifier of wood water, the optimum contents of it should make about 13 %.

For modification a press-composition because of RD–P 9 % of urea was used. It allows considerably increase fluidity of a press-material. For example, fluidity on Rashig, for want of humidity of an initial material 13 %, will increase in 3,5 times, fluidity on disk with 75 up to 84 mm, and the shear resistance, determined according to work [9], decreases with 2,6 up to 1,5 MPa (fig.1c). The transverse elasticity of plastic is increased with 263 up to 364 MPa (fig. 1d).

With use of a method of mathematical planning of experiment of a kind 3^2 the influence of humidity RD–P ($X_1 = 11 \pm 5$ %) and pressure of pressing ($X_2 = 15 \pm 10$ MPa) on properties DP–WA is investigated. Temperature of pressing made 170^0C. In an outcome of processing of outcomes of experiments the following adequate equations of regression as a polynomial of the second order are obtained:

Ultimate bending strength, MPa

$$Y1 = 34,9 + 6,6\ X_1 + 16,9\ X_2 - 1,4\ X_1^2 - 4,3\ X_2^2 - 3,0\ X_1\ X_2$$

Sorption of water, %

$$Y2 = 34,5 - 21,8\ X_1 - 76,7\ X_2 + 26,3\ X_1^2 - 3,8\ X_2^2 + 75,5\ X_1\ X_2$$

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Tytuł: Rozwój technologii bezklejowego prasowania materiałów drzewnych w formach.

Модификация карбамидо - формальдегидных олигомеров

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Содержание: В работе рассматривается метод повышения качества древесностружечных плит, фанеры направленной модификацией карбамидо – формальдегидных олигомеров. Положительные результаты исследований и апробации в производственных условиях были достигнуты при применении различных составов комбинированного связуемого, состоящего из карбамидоформальдегидной смолы и карбамидомеламинофенолоформальдегидной смолы. Комбинированное связуемое нашло применение для производства клееной продукции высокой водостойкости, со значительным улучшенным механическим свойством и меньшей эмиссией формальдегида, а также без коробления изделий.

Качество продукции – это совокупность свойств продукции, обусловли-вающих её пригодность удовлетворять определённые потребности в соответствии с её назначением. Известно, что показатель качества – количественная характеристика свойств продукции, входящих в состав качества, рассматриваемая применительно к определённым условиям её создания и эксплуатации. В основе измерения качества лежит системный подход , заключающийся в том, что качество продукции рассматривается как некоторая обобщённая (комплексная) характеристика, зависящая от характеристик отдельных свойств качества.

Качество древесностружечных плит (ДСтП), фанеры рассматривается как категория технико-эксплуатационная. В этом случае в понятие качества входит вся сумма показателей, характеризующих пригодность их для определённых назначений. Анализ требований промышленности к качеству ДСтП, фанеры и тенденций развития требований позволил выделить основные показатели качества.

Специальные требования к качеству ДСтП, фанеры предъявляет строительная индустрия. Это гидрофобность, низкотоксичность, прочность, долговечность. Гидрофобность и низкотоксичность следует отнести к их наиболее важным свойствам. Большее значение имеет показатель прочности при растяжении перпендикулярно поверхности, характеризующих прочность склеивания. Указанные характеристики ДСтП, фанеры взаимосвязаны и в значительной мере определяются когезионно-адгезионной прочностью, т. е. прочностью склеивания древесных частиц, отдельных элементов древесины, степенью отверждения связующего.

В работе рассматривается метод повышения качества ДСтП, фанеры, направленной модификацией связующего.

Наиболее распространёнными в настоящее время связующими веществами, применяемыми для изготовления ДСтП, фанеры различного назначения, являются карбамидоформальдегидные олигомеры благодаря ряду преимуществ: способности к быстрому отверждению в присутствии ускорителей, сочетанию сравнительно высокой концентрации с пониженной или повышенной вязкостью. Они обеспечивают высокую прочность ДСтП, фанеры, уступая другим смолам главным образом в стойкости к одновременному и длительному воздействию влаги и повышенной температуры (более 60°С).

Карбамидоформальдегидные смолы примерно в 2 раза дешевле фенолоформальдегидных.

Фенолоформальдегидные олигомеры обеспечивают образование клеевых соединений, способных хорошо сопротивляться переменным воздействиям повышенной влажности и температуры окружающей среды, а также обладающих повышенной термостойкостью.

Однако, фенолоформальдегидные смолы требуют применения более высоких температур прессования или удлинения продолжительности этого процесса.

Кроме того, существенное улучшение показателей водостойкости достигается только при введении более 15% смолы.

Применение фенолоформальдегидных смол для ДСтП, фанеры ограничено санитарно-гигиеническими свойствами, связанными с токсичностью фенола [1,2] имеют повышенную щёлочность, вследствие чего для достижения высоких результатов по гидрофобизации плит требуются дополнительные приёмы.

Меламиноформальдегидные олигомеры обладают всеми преимуществами карбамидо-и фенолоформальдегидных и не имеют их недостатков [3].

Повышенная функциональность меламина по сравнению с карбамидом определяет возникновение в смоле большего количества поперечных связей. Меламиноформальдегидные смолы обладают высокой водо- и теплостойкостью [4]. Однако, из-за ограниченного объёма производства и дороговизны меламина они не нашли широкого применения для изготовления ДСтП, фанеры.

Нами проведены исследования и апробация в производственных условиях различных составов комбинированного связующего, состоящего из карбамидоформальдегидной смолы КФМТ-15, КФС-01-МУУ, карбамидо-меламинофенолоформальдегидной смолы КФФФ. Положительные результаты дали возможность серийного применения комбинированного связующего для производства клееной продукции высокой водостойкости со значительными улучшенными механическими свойствами, более целесообразными с экономической точки зрения, эмиссией формальдегида класса Е-1, Е-0.

Кроме того, вышеуказанные составы позволяют исключить в некоторой степени коробление за счёт снижения температуры прессования [5].

Модификация карбамидоформальдегидных олигомеров способствует увеличению жизнеспособности и улучшает свойства полимера. Известно, что триазины повышают водостойкость, теплостойкость и другие свойства карбамидных смол. В настоящее время ведутся промышленные испытания модификации олигомеров с помощью 1-β-гидроксиэтил-3,5-бис-гидроксиметил-1,3,5-гексагидротриазинон-4, эмпирическая формула $C_7H_{15}O_4N_3$, а также N, N^1 – (диэтиламино) метил-N-оксиметилмочевины, эмпирическая формула $C_{12}H_{28}O_6$ N_4, продуктами конденсации формальдегида, карбамида, моноэтаноламина, диэтаноламина, полученными по разработанного нами одного из промышленных технологических процессов переработки параформа.

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Streszczenie: *Modyfikacja oligomerów mocznikowo – formaldehydowych.* Przeprowadzono analizę sposobów podwyższania jakości płyt wiórowych i sklejek wykonanych z użyciem modyfikowanej żywicy mocznikowo-formaldehydowej. Wyroby wykazały wysoką wodoodporność wraz ze znaczącym polepszeniem właściwości mechanicznych oraz zmniejszeniem emisji wolnego formaldehydu.

Production of particleboards with use of waste from recycled boards glued with PF resin

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Abstract: *Production of particleboards with use of waste from recycled boards glued with PF resin.* The research investigated the possibility of substituting, in the production of particleboards, a part of wood particles with waste from recycled boards glued with the phenolic resin. In the production of experimental particleboards phenolic and urea resins were used. The studies prove that adding the waste material to the centre layer of the boards glued with phenolic resin slightly deteriorates their properties. A much worse effect is obtained when the boards are glued with urea resin. Even a small amount of the waste particles added to the centre layer results in a considerable deterioration of the properties of the boards. This effect becomes even stronger as the amount of the added waste particles increases.

Key words: waste particles, recycling, particleboards

Introduction

The production and consumption of particleboards constantly develop, which results in the growing demand for timber. The limited possibility of increasing the lobbing and supplies of timber as well as a relatively high cost of this material make manufacturers search for substitutes of timber. As a result, the use of industrial wood waste, especially sawdust, recycled timber [Wnuk 1999] and annual plants [Grigoriou 1998; Piotrowski 1999; Czarnecki, Dziurka, Mirski 2001], becomes increasingly effective. Moreover, due to the technological progress concerning the equipment and machinery for wood-based materials industry, the processing of worse quality material has become possible. A considerably good results were obtained using waste particles from particleboards glued with urea (UF) resin, both raw and laminated [Czarnecki, Dziurka, Łęcka 2002]. The waste material required only a reduction to chips and could be successfully used as the addition to the center layer of the experimental boards. Therefore, it seems worthwhile to investigate whether boards glued with phenolic (PF) resins can be treated similarly.

The aim of the present work is study to what extent the waste from particleboards glued with PF resin can be applied to the production of particleboards.

Material and methods

In the production of particleboards, pine particles obtained in industry conditions and recycled particles obtained from particleboards, both raw and laminated, glued with phenol-formaldehyde resin were applied. The particles underwent screen classification: dust and the fraction unable to get through square mesh were removed. The square mesh dimensions were as follows: 2 mm. in a side in terms of pine particles for the top layer and 5 mm in a side in case of pine particles and recycled particles purposed for the center layer. Two series of boards were produced, glued with, respectively, PF and UF resin. The resin level of the particles was 8% in case of the center layer and 12% in case of the top layer. The waste was added only to the center layer of the experimental boards in the amount of 10, 20, 30, 40, 50 and 60%. The weight ratio of the center layer particles to the top layer particles was 2:3. Three-layer particleboards with the density of 700 kg/m^3 and the dimension of 450 x 450 x 19 mm were produced in laboratory conditions using the following pressing parameters: pressure 2.5 MPa, temperature 180°C and time 7.5 minutes..

The following properties of the produced particleboards were investigated :

- modulus of rupture (MOR) according to PN-EN 310 "Wood-based panels – Determination of modulus of elasticity in bending and of bending strength"
- internal bond (IB) according to PN-EN 319 "Particleboards and fiberboards – Determination of tensile strength perpendicular to the plane of the board"
- swelling in thickness after 24 hours according to PN-EN 317 "Particleboards and fiberboards – Determination of swelling in thickness after immersion in water"
- free formaldehyde content according to PN-EN 120 "Wood based panels – Determination of formaldehyde content – Extraction method called the perforator method"

Discussion of results

The influence of the amount of recycled particles added to the particles of the centre layer upon the properties of boards glued with PF resin is presented in Table 1. Results included in the table show that the 10% addition of recycled particles leads to a noticeable, yet slight, decrease in the modulus of rupture by 7.65%. Further growth of the recycled particles amount up to 60% results in an insignificant but systematic decrease in MOR of the investigated boards. The results of studies on internal bond are similar. The 10% addition of the recycled particles decreases this property by 1/3. However, further increase in the amount of the recycled particles does not actually change the value of IB. The addition of waste particles favourably affects swelling in thickness. The free formaldehyde content, however, remains in fact unchanged, at a relatively low level.

The results obtained for the other series of particleboards glued with urea resin are much worse. Only the 10% addition of waste particles can me regarded safe as far as the properties of the produced boards are concerned. When a larger fraction of recycled particles is used, all properties, apart from free formaldehyde content, deteriorate rapidly. When the fraction of waste particles exceeded 40%, the produced particleboards happen to undergo serious damage right after taking them out of the press.

Conclusions

The research results lead to the conclusion that, in the scheduled conditions of producing laboratory particleboards, the use of particles from recycled boards glued with PF resin results in the deterioration of strength properties of the boards. However, in case of particleboards glued with phenolic resin the deterioration is slight, even with the 60% fraction of waste particles. Yet, the use of recycled particles in the production of boards glued with UF resin results in a sudden deterioration of their strength properties, leading even to the destruction of the boards right after the pressing. In case of the 60% addition of the waste particles the destruction was total, and for the fraction of 40 and 50% it was partial. In both cases the free formaldehyde content remains actually unchanged, and swelling in thickness after immersion in water changes slightly. Therefore, particles from recycled particleboards can be used in the production of boards glued with PF resin.. However, using waste particles in the production of boards glues with UF resin is not recommended.

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Streszczenie: *Wytwarzanie płyt wiórowych z wykorzystaniem odpadów uzyskanych z płyt zaklejanych żywicą PF.* Zbadano możliwość substytucji części wiórów drzewnych, w procesie wytwarzania płyt wiórowych, odpadami powstałymi w wyniku recyklingu płyt zaklejanych żywicą fenolową. Do wytwarzania płyt doświadczalnych zastosowano żywice fenolową i mocznikową. Wykazano, iż dodatek odpadów do warstwy środkowej płyt wiórowych zaklejanych żywicą fenolową nieznacznie pogarsza ich właściwości. Dużo gorszy efekt uzyskano stosując do zaklejania płyt doświadczalnych żywicę mocznikową. Już niewielki dodatek wiórów odpadowych w warstwie środkowej płyt znacznie powoduje znaczne pogorszenie ich właściwości mechanicznych. Efekt ten wyraźnie narasta w miarę wzrostu ilości dodawanego odpadu.

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Table 1

The influence of the fraction of recycled particles added to the centre layer upon properties of experimental particleboards glued with PF resin.

Properties		Mass unit	Fraction of recycled particles in the centre layer of boards glued with PF resin, %						
			0	10	20	30	40	50	60
Modulus of rupture		MPa	18.3	16.9	16.6	16.6	16.7	16.0	16.0
Internal bond		MPa	0.42	0.28	0.25	0.26	0.26	0.24	0.26
Swelling in thickness	after 2 h	%	16.0	14.0	14.5	13.7	14.9	12.4	13.0
	after 24 h		17.6	17.2	17.8	16.6	15.9	15.2	15.2
Free formaldehyde content		mg CH_2O/ 100 g d.m.b.	3.67	3.48	3.83	3.15	3.63	3.69	3.53

Table 2

The influence of the fraction of recycled particles added to the centre layer upon properties of experimental particleboards glued with UF resin

Properties		Mass unit	Fraction of recycled particles in the centre layer of boards glued with UF resin, %						
			0	10	20	30	40	50	60
Modulus of rupture		MPa	14.7	14.0	13.1	13.1	12.0	9.6	5.4
Internal bond		MPa	0.41	0.26	0.18	0.15	0.09	0.06	-
Swelling in thickness	after 2 h	%	9.7	13.1	13.1	13.1	15.1	15.5	-
	after 24 h		19.3	19.6	19.5	19.8	19.3	20.1	-
Free formaldehyde content		mg CH_2O/ 100 g d.m.b.	7.85	8.40	8.35	8.21	8.26	8.06	8.48

Properties of OSB/3 boards in dependence upon the environment humidity

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Abstract: *Properties of OSB 3 boards in dependence upon the environment humidity* Studies were made upon the influence of the action of air with increased humidity content and the cyclic changes in the humidity upon properties of OSB/3 boards glued in the centre layer with PMDI resin. The research results prove that the OSB/3 boards used in the studies were characterised by very high modulus of rupture and modulus of elasticity. The action of the air with humidity of 90% as well as cyclic changes in the humidly result in only slight decrease in these values. The boards meet the requirements of PN-EN 300 standard in terms of internal bond, however their moisture-resistance measured with a boil test does not comply with the standard even in the control board. Both long-lasting action of water with increased humidity and the cyclic changes in the humidity lead to permanent deformation in the thickness of OSB/3 boards reaching 12%.

Key words: OSB/3, humidity, cyclic tests

Introduction

Recently in Europe, the production of oriented strandboards has been developing intensively. The development results from the wide range of possible uses of OSB in especially skeleton building structures and interior furnishings. Due to their properties, they successfully replace the used so far particleboards of increased water-resistance, plywood and timber. Oriented strandboards are used mainly as roofing, inner and outer walls, floors, ceilings and structure elements of girders, I-beams and trusses. Also in Poland, in 1997, the manufacturing of OSB started in the production line with the effectiveness of over 35,000 m^3/year. In the described manufacturing plant, for the first time in the world, the boards are produced in a continuously operating press and the centre layer is glued with isocyanate resin (PMDI). The studies made so far on the influence of the bonding agent upon the properties of OSB concerned mainly boards glued with phenolic resin [Kim et al. 1994; Andersen, Troungton 1996; Pu et al. 1992a, 1992b; Wu, Suchsland 1996, 1997]. None of these works regarded oriented strandboards made of pine particles glued in the center layer with PMDI resin, and in the outer layer with MUPF resin.

The aim of the present work is investigate to what degree the humidity of the environment affects the properties of thus glued OSB/3, i.e. boards purposed for use in humid conditions.

Material and methods

OSB/3 produced in industrial conditions with thickness of 22 mm were used in the studies. In order to determine the influence of humidity upon properties of the boards, samples were subjected to the following tesys:

- the action of air with humidity content of 90% RH (12 weeks)
  the measurements of the boards properties were made after 3, 6, 9 and 12 weeks
- the cyclic action of air with humidity content of 30% RH and 90% RH (3 cycles x 2 weeks of 90% RH + 2 weeks of 30% RH)
  the measurements of the boards were made after each cycle

The tests were made right after taking the samples out of a conditioning chamber and after a repeated air-conditioning of the samples in the standard conditions. The following properties of the boards were determined: swelling in thickness, humidity content, internal bond (IB), moisture resistance, modulus of rupture (MOR) and modulus of elasticity (MOE).

Discussion of results

The influence of increased humidity content and the time of humidity action upon the properties of OSB/3 boards is shown in Tables 1 and 2. Data presented in Table 1 show that the value of modulus of rupture, along both longer and shorter axis, which characterized the investigated oriented strandboards significantly exceed the requirements of PN-EN 300 standard. As the seasoning progressed in the air with humidity of 90%, the MOR value of the boards decreased, and the samples determined right after taking them out of the conditioning chamber showed slightly smaller value of MOR than those which, before the investigation, were air-conditioned in standard conditions. The decrease in MOR results probably from the loosening of the board structure due to the deformation of the pressed particles caused by high humidity of the environment. Minor differences in the modulus of rupture of samples both subjected and not subjected to the air-conditioning (not exceeding 3MPa) prove the mechanical character of the changes, since the rupture of the chemical bonds would result in a permanent and more significant decrease in the modulus of rupture. Also the results of studies on MOR after the cyclic tests prove such a character of the action of the air humidity. In this case, boards investigated directly after taking them out of the conditioning chamber, in which the humidity content was 30%, were characterized by higher values of MOR than those which, before the studies, were air-conditioned in standard conditions. The mechanical character of the destruction of the boards is also confirmed by the analogical results of studies on modulus of elasticity. Although the oriented strandboards subjected to cyclic changes of humidity showed decrease in the MOR value along the longer axis by approx. 8% and in the modulus of elasticity by 10%. However, in the analogical period of the action of the air with humidity of 90%, the decrease in the values of MOR and MOE amounted to, respectively, 29% and 40%. Nevertheless, in both cases the numerical values of MOR as well as MOE, after the completed studies, considerably exceeded the requirements of PN-EN 300.

The results of studies on internal bond of the boards are different. The boards which were tested cyclically met the requirements of PN-EN 300 in the whole scope of the study. Yet, OSB/s boards subjected to the constant action of the humidity of 90%, after 9 weeks showed smaller internal bond than the IB value required by the standard. It ought to be emphasised that the studied boards do not comply with the standards of moisture-resistance and the humidity conditions only slightly affected this parameter. After each cycle of the tests in the changeable humidity conditions, the humidity of the boards met the requirements of the standard specification. However in the humidity conditions of 90%, the humidity of the boards increased systematically and exceeded the acceptable standard after the sixth week. The increase in the humidity content of the boards was accompanied by the increase in their thickness (by as much as 11.8% after 12 weeks). Presumably, these deformations are to a certain extent of a permanent character. The measurements of the boards thickness after the cyclical tests, i.e. after the reconditioning from 90% RH down to 30% RH, when the increase in the thickness amounted to 3.7% after the third cycle, prove the permanent nature of the deformations.

Table 1

The influence of the time and relative humidity of the air on the modulus of rupture and modulus of elasticity of OSB/3

The conditions of air-conditioning	Measurement after [weeks]	Modulus of rupture [MPa]				Modulus of elasticity [MPa]			
		Non-conditioned		After air-conditioning		Non-conditioned		After air-conditioning	
		Larger axis	Smaller axis	Larger axis	Smaller axis	Larger axis	Smaller axis	Larger axis	Smaller axis
Value according to PN-EN 300		18,0	9,0	18,0	9,0	3500	1400	3500	1400
Control board		38,1	26,1	38,1	26,1	7892	4872	7892	4872
90% RH 12 weeks	3	34,7	23,8	36,2	25,0	6686	4045	7166	4958
	6	32,3	21,7	35,9	22,1	6062	3431	6992	4820
	9	30,7	19,1	34,1	21,3	4906	3130	6835	3907
	12	27,0	17,0	29,8	19,9	4551	2924	5450	3736
3 x [2 weeks 90% RH + 2 weeks 30% RH]	4	38,7	25,9	36,2	25,0	7595	3902	7166	4958
	8	36,2	22,9	35,9	22,1	7114	3737	6992	4820
	12	35,2	20,9	29,8	19,9	7075	3640	5450	3736

Table 2

The influence of the time and relative humidity of the air upon water-resistance of OSB/3

The conditions of air-conditioning	Measurement after [weeks]	Tensile strength perpendicular to the plane of the board [MPa]		Moisture content [%]	Swelling in thickness [%]
		After air-conditioning (internal bond) 20^0 C, 65% RH	After a boil test (moisture-resistance)		
Value according to PN-EN 300		0,30	0,12	5-12	-
Control board		0,38	0,08	7,7	-
90 % RH 12 weeks	3	0,37	0,05	8,4	1,6
	6	0,35	0,05	12,6	5,2
	9	0,29	0,05	12,9	7,6
	12	0,27	0,05	15,8	11,8
3 x [2 weeks 90% RH + 2 weeks 30% RH]	4	0,38	0,06	8,1	1,0
	8	0,32	0,05	9,4	3,2
	12	0,30	0,04	10,7	3,7

Conclusions

The research proves that the investigated OSB/3 boards are characterized by very high modulus of rupture and modulus of elasticity. Both long-lasting action of air with the humidity of 90% as cyclic changes in the humidity very slightly reduce these values. The studied boards meet the requirements of PN-EN 300 in terms of internal bond; yet, the moisture resistance dies not comply with the standard even in the control board. The long-lasting action of the air of increased humidity as well as of cyclically changing humidity lead to the permanent deformation of the thickness of the boards up to 12%.

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Streszczenie: *Kształtowanie się właściwości płyt OSB/3 w zależności od wilgotności otoczenia* Zbadano wpływ oddziaływania powietrza o podwyższonej wilgotności oraz jej cyklicznych zmian na właściwości płyt OSB/3, zaklejanych w warstwie wewnętrznej PMDI. Badania wykazały, iż płyty OSB/3 użyte do badań charakteryzowały się bardzo wysoką wytrzymałością na zginanie statyczne i modułem sprężystości, przy czym zarówno długotrwałe oddziaływanie powietrza o wilgotności 90% jak i cykliczne zmiany wilgotności w niewielkim stopniu powodują obniżenie tych właściwości. Wprawdzie płyty odpowiadają normie PN-EN 300 w zakresie wytrzymałości na rozciąganie prostopadłe do płaszczyzny lecz ich wodoodporność mierzona tym parametrem po próbie gotowania nie spełnia wymagań normy nawet w płycie odniesienia. Zarówno długotrwałe oddziaływanie powietrza o podwyższonej wilgotności jak i cyklicznie zmieniającej się powodują trwałe odkształcenie grubości płyt OSB/3 sięgające 12%.

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Properties of polycondensed UF resins modified by compounds containing acetoacetate groups

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Abstract: *Properties of polycondensed UF resins modified by compounds containing acetoacetate groups.* Studies were made on the influence of compounds containing acetoacetate groups upon properties of polycondensed UF resin used in the production of particleboards. The research proves that, along with the increase in the amount of acetoacetate groups introduced into the resin, the hydrophobic properties of the resin considerably increase., which is expressed by the decrease in the absorbability, swelling in thickness and formaldehyde content. These phenomena intensify, as the amount of acac groups added to the resin grows.

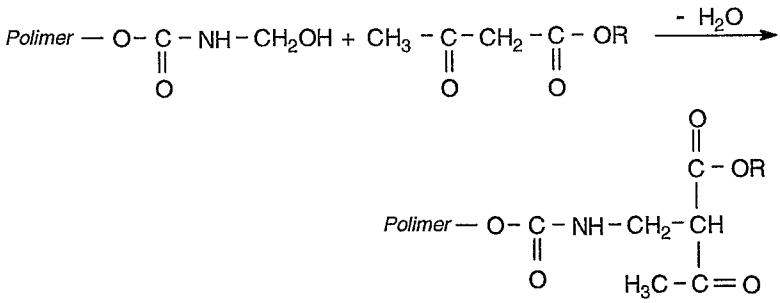
Key words: UF resin, acetoacetate group, modification

Introduction

The properties of particleboards greatly depend on the kind of bonding agents used in the production. Currently, about 90% of the world production of particleboards are manufactures with use of urea-formaldehyde (UF) resins [Sellers 1992], mainly because of their good technological properties and relatively low price. However, among the disadvantages of this kind of boards there are the free formaldehyde content and low resistance to changeable environmental conditions; these factors considerably limit the range of UF resin uses.

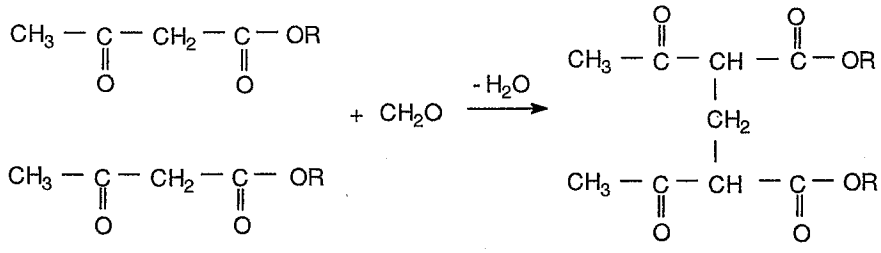
Although, the results of contemporary studies on hygienic properties of particleboards make it possible to reduce the formaldehyde emission by 80-90% [Pizzi 1989], researchers still have not succeeded in increasing the water resistance or improving the mechanical properties of the boards. The need for expanding the use range of the boards as well as increasing demands concerning further reduction of CH_2O emission lead to the intensification of research aiming at improving properties of particleboards by means of modifying UF resin. The modification of UF resin is supposed to make it possible to produce resins that meet the above requirements.

One of possible ways of reducing the emission of CH_2O and improving the mechanical properties of the boards may be the use of compounds containing acetoacetate groups (acac), the derivatives of 3-oxobutyric acid – CH_3-CO-CH_2COOH [Clemens 1986]. Studies made so far [B. Thomalla, J. Thomalla 1997] prove that the emission of formaldehyde from amine varnish resins can be reduced by means of introducing acac groups, which react with hydroxymethylene groups of the resin [Del Rector, Blount, Leonard 1989, Witzeman, Crain, Clemens 1992]:



(1)

Moreover, the free formaldehyde can be bonded with α carbon atoms of methylene groups $-CH_2$ in acetoacetate chains according to the below reaction :



(2)

Therefore, the reactions of amino plastics and CH_2O with compounds containing acetoacetate groups (reactions **1** and **2**) lead to the formation of cross-linked structures. Moreover, in the former methylene group (presently methine in an acac group) there remains an active hydrogen atom, which is able to react with free formaldehyde ocurring when the particleboards are used. What is more, as a result of the reaction of acac groups with hydroxymethylene groups of the resin (reaction **1**), carbon-carbon bonds are formed, which hamper the polymer hydrolysis, when, caused by high temperature or humidity, CH_2O is emitted [Dutkiewicz 1983].

The purpose of the present study is to investigate the structure and properties of cured UF resins, in dependence of the number of the introduced acetoacetate groups.

Material nad methods

Properties of the polycondensed UF resin, in dependence on the amount of the added acrylic emulsions and the degree of acac groups content, were determined by mean of measuring:

- the amount of substances eluted by water
- pH of the water extracts of the cured UF resin
- formaldehyde content in the polycondensed UF resins with use of the perforator method
- absorbability and swelling in thickness of the polycondensed UF resins

In order to explain the influence of the applied modifiers on the chemical structure of the cured resin, IR spectroscopy was used. An IR spectrum is a very characteristic feature of a substance and therefore it can be treated as an analytic tool for identifying structural groups present in the investigated compounds as well as for studying the occurring chemical processes. The IR spectral studies were made for the UF resin before and after the

modification with compounds containing acetoacetate groups. The IR spectra were recorded with Fourier transformation spectrophotometer in the range of 4000-500 cm^{-1}.

Discussion of results

Table 1 shows the influence of the kind and amount of acrylic emulsions introduced into UF resin upon the properties of the cured resin. Data included in the resin prove that the presence of acetoacetate groups does not significantly affect the pH value of the cured resin, which is important from the perspective of the possible ageing process in the polycondensed resins while they are used. As expected, a decrease in the formaldehyde emission, measured with the perforator method, was observed probably due to the fact that acac groups are capable of bonding free CH_2O present in the UF resin (reaction **2**). The increase in the formaldehyde amount was proportional to the amount of emulsion added to UF resin and to the number of acac groups: for the 10% addition of the emulsion with the maximum number of acac groups the decrease reached 20%. The determined amount of elutable substances in water indicates that the used modifiers take an active part in the polycondensation process of the resin; as the amount of the emulsion added to the resin increases, the elutable fraction content increases as well, which may imply that the acrylic emulsion to a certain degree acts as a steric hindrance, which makes the formation of the strongly cross-linked resin structures difficult. However, the decrease in the formaldehyde content which accompanies the increased elusion proves also that the reaction of hydroxymethylene groups of UF resin with acetoacetate groups included in the emulsions is competitive towards the cross-linking reaction between mers of the UF resin. And this is the phenomenon responsible for the formation of structures with smaller polycondensation degree, and, consequently, with greater elutability. Moreover, such a course of the polycondensation process of modified UF resins is indicated by the increase in the amount of substances eluted by water as well as the increase in the acac groups number. Emulsions introduced into UF resin significantly affect the hydrophilic properties of the cured resin measured by absorbability and swelling in thickness. These values considerably decrease, as the amount of the added emulsions and acac groups content grow. In an extreme case, for the 10% addition of acrylic emulsion containing the maximum number of acac groups (gram-equivalent of acac groups 962g/mole), the absorbability decreases from 16.71% (for the non-modified resin) down to 6.91%, that is by almost 60%; at the same time the swelling in thickness decreases by 26%. Also in this case it is probably caused by the simultaneous hydrophobic action of the emulsion itself, reinforced by the overreaction of the included acac groups with the hydrophilic hydroxymethylene groups of the UF resins.

FTIR analysis of the polycondensed UF resin shows that, in the conditions of particleboards production, acetoacetate groups react with hydroxymethylene groups of UF resin forming ester an ether systems, which is proved by changes in the resin spectra before and after the addition of acac groups. In the spectrum of the UF resin containing acac groups, presented in Figure 1, a shift of the amide band from 1539 cm^{-1} to 1562 cm^{-1} is observed. However, I amide band (C=O) shifts from 1647 cm^{-1} to 1640 cm^{-1}. The shifts of amide bands prove there are changes in the polarity of bonds, especially the NH bond. Important changes are also observed in the intensity of the band at the wavelength of 1035-960 cm^{-1}, attributed to CH_2OH before and after introducing acac groups into the resin. In this region, therefore, in the resin spectrum there is a wide band that after the modification with ethyl acetoacetate narrows considerably; simultaneously, on the slope of I amide bond at 1640 cm^{-1} an absorption band appears which comes from the vibrations of a carboxyl group of the aster. Moreover, the decrease in the relation of the A_{1640}/A_{3351} absorption degree from 0.77 down to 0.66 shows that there is also a small decrease in the OH groups content in relation to the amount of these

groups in UF resins. Supposedly, the reduction of the number of OH groups in the modified resin is caused by their reaction with acetoacetate groups.

Conclusions

The results of the research on properties of polycondensed UF resins lead to the conclusion that introducing acrylic emulsions containing acetoacetate groups results in the decrease of the polycondensation degree of the resins, but it also significantly reduces the absorbability and swelling in thickness, as well as formaldehyde content. The extent to which these phenomena occur widens as the number of acac groups introduced into the resin increases.

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Streszczenie: *Właściwości spolikondensowanych żywic UF modyfikowanych emulsjami akrylowymi o różnej zawartości grup acetylooctowych.* W pracy zbadano wpływ związków zawierających grupy acetylooctowe na właściwości spolikondensowanej żywicy UF, stosowanej do wytwarzania płyt wiórowych. Właściwości spolikondensowanych żywic w zależności od ilości wprowadzanej emulsji akrylowej oraz stopnia jej zacetylooctowania, określono poprzez pomiar: ilości substancji wymywanych wodą, pH wodnych ekstraktów utwardzonej żywicy UF, zawartości formaldehydu metodą perforatora, nasiąkliwości i spęcznienia. Przeprowadzone badania wykazały, że wraz ze wzrostem ilości wprowadzanych do niej grup acetylooctowych, znacznie wzrasta jej hydrofobowość, wyrażająca się spadkiem nasiąkliwości i spęcznienia oraz obniża się zawartość formaldehydu. Zjawiska te zachodzą w tym większym stopniu, im większa jest ilość wprowadzanych grup acac. do żywicy.

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Table 1

The influence of the kind and amount of acrylic emulsion containing acac groups upon properties of cured UF resin.

Amount of emulsion	Elutable substances H_2O	Absorbability after 24 h	Sweling in thickness after 24 h	pH of the cured resin	CH_2O content
%	%	%	%		mg /100 g of dry mass
Control sample	2.61	16.71	4.14	3.98	99.3
gram-equivalent of acac groups – 0 g/mole					
2.5	3.09	14.68	4.05	4.18	96.3
5.0	3.72	12.68	3.90	3.91	94.8
7.5	3.45	11.68	3.81	3.68	94.1
10	4.78	10.55	3.65	3.73	93.7
gram-equivalent of acac groups - 2412 g/mole					
2.5	3.13	12.50	4.01	3.63	93.6
5.0	3.21	10.75	3.91	3.71	91.8
7.5	3.74	9.88	3.59	3.55	90.6
10	4.52	9.10	3.29	3.61	88.9
gram-equivalent of acac groups - 1212g/mole					
2.5	3.42	11.11	3.95	3.70	91.3
5.0	3.82	9.25	3.69	3.51	89.2
7.5	4.04	8.44	3.41	3.69	87.6
10	4.60	7.95	3.14	3.96	86.2
gram-equivalent of acac groups - 962 g/mole					
2.5	3.68	9.46	3.91	3.86	88.1
5.0	3.92	8.28	3.70	3.72	85.7
7.5	4.10	7.69	3.40	3.62	83.1
10	4.64	6.91	3.06	3.58	79.6

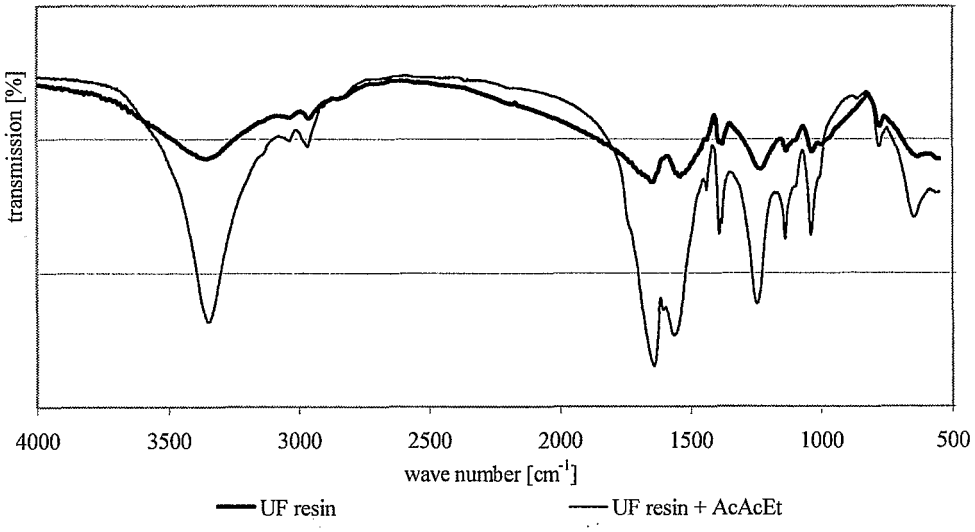


Figure 1. FTIR spectra of UF resin cured with or without the addition of ethyl acetoacetate.

Properties of liquid UF resins modified by compounds containing acetoacetate groups

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Abstract: *Properties of liquid UF resins modified by compounds containing acetoacetate groups*. Studies were made on the influence of compounds containing acetoacetate groups upon properties of liquid UF resin used in the production of particleboards. The research proves that introducing acrylic emulsions containing acetoacetate groups into the liquid UF resin results in the increase in the reactivity in the pressing conditions: that is expressed by shortening of the gel time and decrease in the activation energy of the polycondensation.

Key words: UF resin, acetoacetate group, modification

Introduction

Urea-formaldehyde resins are commonly used in the production of particleboards. From the perspective of the production technology, such features of urea resins as viscosity, curing time and free formaldehyde content are of special importance.

The present work instigates the influence of compounds containing acetoacetate groups upon the those properties of urea resins that make it possible to produce boards fulfilling technological and health standards.

Material and methods

For the purposes of the study, UF resin of the following characteristics was used:

- density 1.282 g/cm^3
- dynamic viscosity 610 mPa·s
- conventional viscosity, #4 Ford cup 123 s
- dry mass content 67%
- gel time at 20°C over 6 h
- gel time at 100°C 86 s
- miscibility with water 1.2

Acrylic emulsions with various degrees of acetoacetate groups content were produced in the synthesis process; acetoacetoxyethyl methacrylate (AAEM) was used as the carrier of the acetoacetate groups. The emulsions contained, respectively, 0, 2414, 1212 and 916 gram-equivalents of acetoacetate groups (acac), where a gram-equivalent of an acac group represents the number of grams of a polymer containing 1.0 mole of acetoacetate groups. The appropriate emulsions were added to the resin in the amounts from 2.5 to 10% in relation to dry resin solids.

The pot life of the UF resin modified at 20°C was determined on the basis of the measurements of the dynamic viscosity of the glue solutions made with use of a Höppler rheoviscometer. The dynamic viscosity was determined every two hours for 12 hours, and then every 12 hours. The measurements were completed after 60 hours.

The studies on the gel time were made at 100°C. Moreover, the results of investigations of the gel times in the temperatures ranging from 80 to 110°C were used to estimate the relative activation energy of the cross-linking process. As assumption was made that the curve illustrating the curing process in time, for the particular temperatures of 80, 90, 100, and 110°C, is a linear function till the curing point is reached. Since the reaction rate increases along with the growth of the temperature, and the curve illustrating the curing rate in

dependence of the absolute temperature converse shows the linear dependence, therefore the activation energy can be calculated based on Arrhenius equation:

$$k = A \cdot \exp(-E_a/RT)$$

where k means the curing reaction rate constant at the temperature T, A is the pre-exponential factor, E_a is the activation energy, R is the gas constant and T is the absolute temperature.

Discussion of results

The influence of acrylic emulsions containing acac groups upon the UF resin stability at 20°C is shown in Table 1. The included data indicate that, at first, as the number of acac groups in the emulsions grows, the dynamic viscosity of the mixed glue decreases. In the initial 10 hours the viscosity of the solutions changes slightly. A considerable diversification of the viscosity of the modified and non-modified UF resin is observed after 24 hours. After this time the dynamic viscosity of UF resin modified with acrylic emulsions increases rapidly; the increase is the greatest in case of emulsions containing the largest number of acac groups. It seems that after 24 hours the cross-linking process of the UF resin containing acac groups intensifies and that results in the increase in the resin viscosity. The decrease of the viscosity observed initially has also been noticed by other researchers [Clemens, Del Rector 1989, Li, Graham 1993]. In their studies, the researchers prove that the presence of acac groups in amine varnish resin significantly decreases its viscosity and, simultaneously, shortens its gel time in the ambient temperature. The initial decrease in the viscosity of the modified UF resins can be explained by the introduction of AAEM, as the carrier of acac groups, into the resin structure; AAEM makes the individual chains of urea polymers more distant from one another. This steric hindrance, as well as the fact that AAEM does not include hydroxyl groups, minimizes the possibility of forming hydrogen bond between the individual chains of the polymer. As a result, the mobility of polymer chains increases and, therefore, the viscosity of the solution decreases [Eastman Kodak Company 1988].

The influence of the kind and amount of emulsions introduced into UF resin upon the gel time of the resin is illustrated by Table 2. the data included in the table prove that the applied modifiers slightly decrease the gel time at 100°C. It has been found out that the fraction of acac groups in the acrylic emulsion is more significant than the amount of the emulsion introduced into the solution. Nevertheless, the greatest shortening of the gel time, by almost 50%, was obtained for the maximum (10%) addition of the modifier, containing the largest number of gram-equivalents of acac groups. This fact confirms the chemical reactivity of acac groups towards the UF resin.

Table 3 illustrates how the amount of acac groups introduced along with the acrylic emulsion into the resin and the presence of wood dust affect the gel time of the UF resin in the temperatures ranging from 80 to 110°C. Data included in the table prove that introducing acac groups into the UF resin considerably shortens the gel time of the resin, especially in lower temperatures. The maximum shortening of the gel time of the UF resin with the addition of acac emulsion at 80°C reaches 30%, and at 110°C only 19%. Introducing pine dust into the resin also significantly shortens the gel time of the resin; also in this case the effects are less apparent as the temperature grows. The shortening of the gel time is most apparent when pine dust and acrylic emulsion are simultaneously introduced into the resin; best results are obtained for emulsions with the largest number of acac groups. Nonetheless, the addition of pine dust decreases the gel time of UF resin in a more effective way (Table 3). The substantial influence of pine dust upon the polycondensation of the PF and UF resins is confirmed by other research results [Proszyk, Zakrzewski 1992, Zakrzewski, Proszyk 1979]. The authors prove that the presence of wood dust significantly affects the activation energy of the cross-linking process of the resin. Also Levendis, Pizzi and Ferg [1992] show clearly that the bonding energy of wood-glue components is lower than that of glue-glue components.

Table 4 shows the influence of emulsions containing acetoacetate groups and wood dust upon the activation energy of the polycondensation process of UF resin, calculated on the basis of the gel time measurements. The data included in the table show that introducing wood dust along with the used modifiers into the resin makes it possible to decrease the activation energy of the process by as much as 30%.

Conclusions

The research results lead to the conclusion that introducing acrylic emulsions containing acetoacetate groups into the liquid UF resin results in the decrease of the resin stability at the ambient temperature and the increase in the reactivity in the pressing conditions. The latter is expressed by the shortening of the gel time and the decrease of the activation energy of the polycondensation process. Best results were obtained for emulsions with the greatest gram-equivalent of acetoacetate groups.

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Streszczenie: *Właściwości płynnych żywic UF modyfikowanych emulsjami akrylowymi o różnej zawartości grup acetylooctowych.* W pracy zbadano wpływ związków zawierających grupy acetylooctowe na właściwości płynnej żywicy UF, stosowanej do wytwarzania płyt wiórowych. Właściwości płynnej żywicy UF w zależności od ilości wprowadzanej emulsji akrylowej oraz stopnia jej zacetylooctowania, określono poprzez pomiar: żywotności modyfikowanych żywic UF, czasu żelowania i kinetyki sieciowania. Przeprowadzone badania wykazały, iż wprowadzanie do płynnej żywicy UF emulsji akrylowych zawierających grupy acetylooctowe, powoduje wzrost reaktywności w warunkach prasowania płyt wiórowych, wyrażający się skróceniem czasu żelowania i obniżeniem energii aktywacji procesu polikondensacji.

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Table 1

The influence of time upon the viscosity of UF resin modified with acrylic emulsions containing acetoacetate groups.

Amount of modifier, %	Kind of modifier	Dynamic viscosity, mPa·s									
		Measurements made in time, h									
		0	2	4	6	8	10	12	24	36	48
0	Control sample	610	610	610	610	615	620	635	650	676	720
2.5	Emulsions containing no acetoacetate groups	465	465	465	470	510	565	605	780	930	1135
5		450	450	450	460	500	555	595	765	910	1175
7.5		420	420	420	430	470	525	565	750	890	1220
10		415	415	415	425	465	520	560	730	875	1240
2.5	Gram-equivalent of acac groups in emulsion 2412 g/mol	390	390	390	420	510	620	975	1090	1930	2950
5		370	370	370	400	495	605	965	1115	2150	3180
7.5		350	350	350	380	470	560	950	1185	2280	3295
10		335	335	335	365	455	545	920	1210	2390	3315
2.5	Gram-equivalent of acac groups in emulsion 1212 g/mol	325	325	330	380	470	560	905	1125	2160	3385
5		310	310	320	375	455	540	885	1200	2300	3445
7.5		300	300	315	365	440	525	875	1230	2385	3490
10		280	280	300	350	430	505	850	1350	2490	3595
2.5	Gram-equivalent of acac groups in emulsion 962 g/mol	240	245	260	310	390	460	860	1295	2405	5350
5		220	225	245	285	365	450	855	1320	2450	5460
7.5		190	195	220	270	350	425	815	1395	2560	5570
10		170	175	205	260	340	420	820	1465	2690	5690

Table 2

Gel times of UF resin modified with acrylic emulsions of various number of acac groups at 100°C.

Amount of modifier in relation to dry resin solids, %	Investigated formula				
	UF resin	UF + emulsion 0 acac groups	UF + emulsion 2412 acac groups	UF + emulsion 1212 acac groups	UF + emulsion 962 acac groups
	Gel time, s				
0	83				
2.5		87	75	69	64
5.0		85	69	65	59
7.5		83	66	62	49
10		81	65	60	47

Table 3

Influence of the wood dust addition and the kind of acrylic emulsion upon gel times of UF resin at temperatures ranging from 80 to 110^{0}C.

Curing temperature, ^{0}C	Investigated formula									
	UF resin	UF resin+dust[x]	UF resin + emulsion[xx] 0 acac groups	UF resin + emulsion 0 acac groups + dust	UF resin + emulsion 2412 acac groups	UF resin + emulsion 2412 acac groups + dust	UF resin + emulsion 1212 acac groups	UF resin + emulsion 1212 acac groups+ dust	UF resin + emulsion 962 acac groups	UF resin + emulsion 962.acac groups + dust
	Gel time, s									
80	410	208	395	186	368	182	318	178	282	172
90	202	101	186	90	164	88	141	88	121	86
100	87	48	83	42	80	41	76	40	70	41
110	54	42	54	38	50	36	48	36	44	37

[x] – the amount of the added pine dust was 10% of dry mass in relation to dry resin solids

[xx] – the amount of he added emulsion was 10% in relation to dry resin solids

Table 4

Kinetic parameters of the curing process of UF resin modified with acrylic emulsions with various acac groups content and wood dust

Curing temperature	^{0}C	80	90	100	110	Activation energy, kJ/mol	ln A
	K	383	393	403	413		
1000/T	K^{-1}	2.61	2.54	2.48	2.42		
Formula		ln k					
UF resin		5.43	5.84	6.74	7.30	**80.58**	**33.34**
UF resin + emulsion. 0 acac groups		5.43	5.81	6.66	7.21	**76.73**	**32.00**
UF resin + emulsion 2412 acac groups		5.45	6.00	6.76	7.40	**76.54**	**32.10**
UF resin + emulsion 1212 acac groups		5.46	5.93	6.70	7.26	**72.95**	**30.81**
UF resin + emulsion 962 acac groups		4.99	5.93	6.54	7.26	**72.78**	**30.71**
UF resin + dust		5.66	5.93	6.70	7.26	**73.29**	**30.93**
UF resin + emulsion. 0 acac group + dust		5.37	5.82	6.54	7.01	**65.06**	**28.02**
UF resin + emulsion 2412 acac group+ dust		5.40	5.96	6.61	7.09	**61.76**	**27.03**
UF resin + emulsion 1212 acac group+ dust		5.37	5.93	6.54	6.59	**55.60**	**24.91**
UF resin + emulsion 962 acac group + dust		5.40	5.83	6.51	6.83	**55.08**	**24.65**

The influence of polyethylene glycols on the properties of particleboards glued with the phenolic resin

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Abstract: *Influence of the polyethylene glycols on the properties of particleboards glued with the phenolic resin.* Studies were made upon the influence of the modification of PF resin with polyethylene glycols with various polycondensation degree upon the properties of the modified resin and particleboards produced with its use. The research results prove that the applied polyethylene glycols shorten the gel time of the resin and do not affect its stability. The particleboards glued with the resin modified with polyethylene glycols showed greater dimensional stability and better mechanical properties. As a result of introducing polyethylene glycols into the resin, the amount of free formaldehyde grows as the molecular weight of PEG increases.

Key words: particleboard, phenolic resin, modification

Introduction

Apart from the kind of wood and technological conditions of the production, the properties of particleboards greatly depend on the kind of the applied bonding agent. A mixed glue ought to make it possible to produce, in a possibly short pressing time and at not very high temperatures, joints of good mechanical strength, high water-resistance and good health properties. Joints of such properties can be obtained when phenol-formaldehyde (PF) resins are used. Therefore, PF resins are commonly used in the production of particleboards of increased water-resistance. However, the relatively long pressing time and high curing temperature are the drawbacks of these resins. That is why, both manufacturers of wood-based materials and research centres attempt to increase their reactivity and modify the resins in order to improve properties of boards produced with their use. The research made so far proves that the reactivity of the phenolic resins of the resol type can be increased by means of introducing various additives into the resin. Among substances that increase the reactivity of the resin, there are lactanes, hydroxy acids or their esters, keto acids and their esters [Fidelus 1983, Elbert 1984], isocyanates, formamide, resorcinol [Proszyk, Pajdosz 1993], ethylene carbonate or propylene carbonate [Stephanou et al. 1993, Tohmura et al. 1995]. Czarnecki, Łęcka [2002] claim that introducing hydrogen peroxide solution into the resin improves the properties of particleboards and, at the same time, shortens the pressing time. The addition of polyethylene glycols into PMDI or UF resins resulted in the increase of internal bond and modulus of elasticity, and favourably affected the dimensional stability of the particleboards [Milota, Wilson 1985, Sakuno, Canadido 1988, Chen, Wu 1993].

The present work investigates whether, and to what extent, the amount and kind of polyethylene glycols (PEG) introduced into the PF resin affect the properties of thus modified resin and particleboards glued with the resin.

Material and methods

For the research purposes, PF resin used in the production of particleboards of increased water-resistance was used. The resin was of the following characteristics: dry mass – 45.7%, density – 1.112 g/cm^3, free phenol content – 0.02%, free formaldehyde content – 0.026%, viscosity according to #4 Ford cup/20°C – 106 s, gel time at 130°C – 46 s, pH – 12.52.

Polyethylene glycol 200, polyethylene glycol 300 and polyethylene glycol 400 were added to the resin in the amount of 0.025 to 0.15 mole per 1 mer of the resin.

The properties of the liquid PF resin modified with PEG were determined by means of measuring the gel time at 130°C, the viscosity and the stability at 20°C.

Single-layer particleboards with the dimensions of 600 x 500 x 12 mm and density of 700 kg/m^3 were produced from pine particles with use of the modified resin. The experimental particleboards were produced using the following pressing parameters: gluing degree 8%, pressing time 5 minutes, temperature 180°C and pressure 2.5 MPa.

Thus produced particleboards were subjected to the following tests:

- swelling in thickness after 24 h according to PN-EN 317
- internal bond according to PN-EN 319
- moisture-resistance according to PN-EN 1087-1
- modulus of rupture according to PN-EN 310
- modulus of elasticity at bending according to PN-EN 310
- formaldehyde content with perforator method according to PN-EN 120

Discussion of results

Table 1 presents the results of determining the gel time at 130°C of the resin modified with polyethylene glycol. Data included in the table prove that, with the modifier amount of 0.025 mole, only PEG 400 considerably affects the gel time of the PF resin, shortening it by over 10%. Adding a large amount of modifiers result in shortening the gel time. Moreover, the greatest shortening of gel times is observed in case of modifiers with larger molecular weight. The most remarkable shortening of the gel time, by as much as 21%, was obtained for PEG 400 introduced in the amount of 0.15 mole/mer.

The modification of PF resins with polyethylene glycols influences also the dynamic viscosity of the resins. The addition of polyethylene glycol with the smallest molecular weight, PEG 200, resulted in the decrease in the viscosity regardless of the amount of the added modifier. In case of polyethylene glycols with larger molecular weight, PEG 300 and PEG 400, initially an increase in the viscosity is observed. Yet, later the viscosity decreases as the amount of the modifiers grows. This phenomenon can be explained by the fact that the addition of a small number of polar particles of the modifier results in the formation of hydrogen bonds between PEG and PF molecules. Yet, as the amount of the modifier grows, the steric hindrance effect of PEG molecules becomes prevailing and leads to a decrease in the number of hydrogen bonds in the resin. Such a way of reasoning is also confirmed by the results of studies on the stability of the resin at 20°C (Table 3). Data presented in Table 3 prove that the resin with the greatest amount of PEG 400 was characterized by the lowest value of the viscosity after 48 hours. Nevertheless, the polyethylene glycols, regardless of the polycondensation degree, did not significantly affect the stability of the resin.

Table 1

The influence of the modification of the phenolic resin with polyethylene glycols upon the gel time at 130°C.

	Kind of ester		
amount mole/mer	PEG 200	PEG 300	PEG 400
	Gel time [s]		
0.000	**211**		
0.025	209	200	186
0.050	194	190	174
0.100	181	179	170
0.150	175	170	166

Table 2

The influence of the modification of the phenolic resin with polyethylene glycols upon dynamic viscosity.

amount mole/mer	Kind of ester		
	PEG 200	PEG 300	PEG 400
	Dynamic viscosity [mPas]		
0.000	**745**		
0.025	690	800	975
0.050	645	780	885
0.100	545	715	780
0.150	475	575	665

Table 3

PF resin stability at 20°C in dependence on the kind and amount of polyethylene glycol added to the resin

Kind of PEG	**Amount mole/mer**	**Measurement period [h]**						
		0	**4**	**8**	**12**	**24**	**36**	**48**
		Dynamic viscosity [mPas]						
0	0	745	745	745	745	925	1100	1170
PEG 200	0.025	690	695	700	815	945	1015	1440
PEG 300		800	815	825	900	1165	1370	1655
PEG 400		975	980	980	1115	1410	1765	2100
PEG 200	0.050	645	675	675	735	780	885	1315
PEG 300		780	795	875	875	1060	1200	1485
PEG 400		885	965	1025	1035	1250	1445	1790
PEG 200	0.100	545	550	620	640	730	820	1155
PEG 300		715	745	790	815	895	1025	1445
PEG 400		780	845	940	955	1020	1135	1630
PEG 200	0.150	475	505	505	505	610	650	905
PEG 300		575	565	645	645	745	790	1105
PEG 400		665	700	715	770	875	985	1240

The results of studies on properties of particleboards produced with use of PF resin modified with various amounts of polyethylene glycols are shown in Table 4. Data included in the table indicate that the addition of polyethylene glycols in the amount of 0.025 mole does not significantly affect swelling in thickness after 24 hours of immersion in water; the obtained values are about the same as those obtained for the control board. Yet, as the amount of the added modifier grows up to 0.15 mole/mer of PF resin, the value of swelling in thickness decreases. The decrease in the hydrophilic properties is greater for PEG with larger molecular weight. The lowest value of swelling in thickness was observed for boards glued with resin modified with PEG 400 added in the amount of 0.15 mole; the value was lower by 27% than that of the control board.

Table 4

Properties of particleboards in dependence on the kind and amount of ester added to PF resin.

Kind of ester	Amount of ester	Swelling In thickness 24 h	Internal bond	Moisture-resistance	Modulus of rupture	Modulus of elasticity at bending	Formaldehyde content
	mole/mol	%	MPa				mg CH_2O/100g board d. m.
0*	0	28.7	0.57	0.47	19.0	2420	1.98
PEG 200	0.025	28.5	0.86	0.44	19.3	2510	1.98
	0.05	26.1	0.89	0.37	19.7	2690	2.25
	0.01	24.1	0.76	0.29	21.2	2930	2.87
	0.15	21.6	0.73	0.21	21.5	2990	3.25
PEG 300	0.025	28.9	0.71	0.29	20.7	2820	2.21
	0.05	26.2	0.83	0.26	21.2	2850	2.47
	0.10	23.4	0.69	0.22	21.5	3060	3.07
	0.15	21.4	0.56	0.20	20.5	2900	5.21
PEG 400	0.025	29.6	0.64	0.29	21.2	2990	2.26
	0.05	24.6	0.65	0.24	22.5	3120	2.68
	0.10	22.4	0.55	0.22	19.5	2720	4.83
	0.15	20.9	0.52	0.17	16.2	2420	8.36

0* - control board

The values of internal bond of boards glued with both modified and non-modified resin are very high (Table 4). Data presented in table prove also that the kind of modifier as well as the amount of PEG significantly affect the internal bond. The greatest increase in internal bond was obtained by introducing the modifier in the amount of 0.15 mole/mer of the resin. Adding such an amount of PEG 200 increased the internal bond by 0.32 MPa. Further increase in the amount of the added polyalcohols resulted in the decrease in the discussed value; nevertheless, the value of IB was still higher than that of the control board.

Data included in table 4 show that the use of modified resin in the production of particleboards leads to a decrease in the moisture-resistance of the boards determined in the boil test (V-100 test); the decrease depended upon both the amount and the polycondensation degree of the introduced polyethylene glycol. Boards glued with the PF resin modified with PEG 200 showed the smallest decrease in moisture-resistance. Introducing this modifier into the resin in the amount of 0.05 mole results in the 20% decrease in the moisture-resistance. However, a larger amount of PEG 200 as well as adding other kinds of polyethylene glycols decreases moisture-resistance by 40%. Apparently, introducing the PEG modifiers into the resin, due to the steric hindrance, leads to the a decrease in the degree of cross-lining and therefore in the moisture-resistance of the particleboards subjected to the boil test. Moreover, the decrease in the moisture-resistance is also caused by the fact that the thermal energy supplied in the boil test may result in the cleavage of relatively weak hydrogen bonds between hydroxyl groups of wood, the resin and polyethylene glycols. That is probably why water-

resistance measured by swelling in thickness differs from that measured by moisture-resistance after a boil test. Such an interpretation is also supported by the results of studies on the influence of the kind and amount of PEG added to the resin upon the modulus of rupture. These results show that for PEG with the largest molecular weight the maximum value of MOR could be obtained by adding smaller amounts of the modifier. The highest MOR value for PEG 200 was obtained when the modifier amount was 0.15 mole/mer and for PEG 400 the amount was 0.05 mole/mer. A similar trend is observed in the results of studies on modulus of elasticity at bending. Also in this case, the increase in the modulus of elasticity is observed and the maximum values of MOE are obtained for PEG 200 in the amount of 1.15 mole/mer, for PEG 300 in the amount of 0.10 mole/mer and for PEG 400 in the amount of 0.05 mole/mer.

The modification of the phenolic resin with polyethylene glycols leads to an increase in free formaldehyde content in the investigated boards. The content of this compound increases as the amount of the added PEG grows and as the molecular weight of the modifier increases. In case of PEG 400 introduced into the resin in the amount of 0.15 mole/mer the free formaldehyde content determined in the first hygienic class was exceeded. The observed increase in the free formaldehyde content confirms the theory stating that the molecular weight of polyethylene glycols added to the PF resin affects the dross-lining process of the resin.

Conclusions

The research results prove that the modification of PF resin used for the production of particleboards with polyethylene glycols results in the shortening of the gel time; yet, it does not considerably affect the pot life of the resin. With larger amounts of PEG added to the resin, a decrease in the viscosity is observed; the greatest decrease in this property was observed for PEG with large molecular weight.

The conducted studies prove also that the used modification leads to a significant increase in such mechanical properties of the produced boards as internal bond, modulus of rupture and modulus of elasticity at bending. However, when a certain amount of the added modifier, depending on the kind of PEG, is exceeded, a decrease in the discussed properties is observed. As expected, the modification of PF resin with polyethylene glycols considerably improves the dimensional stability of the particleboards.

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Streszczenie: W*pływ polietylenoglikoli na właściwości płyt wiórowych zaklejanych żywicą fenolowo-formaldehydową.* Zbadano wpływ modyfikacji żywicy PF polietylenoglikolami o różnym stopniu polikondensacji na właściwości zmodyfikowanej żywicy oraz wytwarzanych przy jej udziale płyt wiórowych. Badania wykazały, iż zastosowane polietylenoglikole skracają czas żelowania żywicy PF, oraz nie wpływają istotnie na jej stabilność. Zaklejane zmodyfikowaną polietylenoglikolami żywicą PF płyty wiórowe wykazywały wyższą stabilność wymiarową oraz lepsze właściwości mechaniczne. W wyniku wprowadzenia do żywicy fenolowej polietylenoglikoli następuje wzrost ilości wolnego formaldehydu i jest on tym większy im większa jest masa cząsteczkowa wprowadzanych PEG.

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The possibility of shortening the pressing time of particleboards glued with the phenolic resin modified by esters with different substituents in the acid alkyl group

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Abstract: *The possibility of shortening the pressing time of particleboards glued with the phenolic resin modified by esters with different substituents in the acid alkyl group.* Studies were made on the influence of the kind of acid that forms the ester introduced into the phenolic resin upon the properties of liquid resin and the mechanical and physical properties of thus modified resin. The results of the studies prove that the applied esters significantly shorten the gel time of PF resin and decrease the stability. These effects intensify in case of esters with shorter acid chains appearing in larger amounts. The research results prove also that all kinds of esters added to the resin considerably improve properties of the boards. The use of ethyl butyrate as the modifier makes it possible to shorten the pressing time of the boards by 30% without deteriorating their physical and mechanical properties.

Key words: particleboard, phenolic resin, modification

Introduction

The properties of particleboards affecting the range of their applications greatly depend upon the kind of resin used in their production. Particleboards glued with phenol-formaldehyde (PF) resins are characterized by good mechanical properties and high water-resistance. Yet, the use of PF resin results in a considerable increase in the costs of production due to the relatively long pressing time and high temperature required to cure the boards. The curing rate is a very important factor that restrains the time of the pressing procedure and determines the efficiency of the production line. That is why studies are made aiming at improving the economic aspects of producing particleboards with use of PF resin, mainly by means of increasing their reactivity. The literature devoted to this subject suggests that promising results can be achieved using some esters of organic acids and propylene carbonate as the curing agents [Stephanou, Pizzi 1993, Pizzi, Stephanou 1994, Tohmura, Higuchi 1995]. Also earlier studies carried out by the authors of the present paper prove that using esters as the modifiers of PF resin makes it possible to obtain particleboards of much improved physical and mechanical properties, while the pressing parameters remain unchanged [Łęcka, Mirski, Morze 2001]. Based on the results of this research we decided to investigate how the length of alkyl chain of organic acid that forms the ester affects the possibility of shortening the pressing time of particleboards glued with the modified PF resin.

Material and methods

In the course of the research we used phenol-formaldehyde resin for the production of particleboards purposed to be used in humid conditions. The resin was of the following characteristics:

- dry mass 45.8 %
- density 1.208 g/cm^3
- free phenol content 0.02 %
- free formaldehyde content 0.05 %
- viscosity, #4 Ford cup/20°C 96 s
- gel time in 130°C 143 s
- pH 12.47

The following esters were used as modifiers of the phenolic resin: ethyl acetate, ethyl propionate and ethyl butyrate in the amount of 0.01 to 0.15 mole/mer of the resin

The properties of the modified resin were determined by the measurements of gel time at 130°C, viscosity and stability at 20°C.

With use of PF resin modified with esters added in the amount of 0.025 mole/mer, particleboards were produced from pine particles in laboratory conditions. The dimension of the boards was 600 x 500 x 12 mm, the density was 700 kg/m^3 and the resin level was 8 %.

The boards were pressed in a semi-automatic press manufactured by "Simpelkamp" with the heating panels having the dimension of 1000 x 800 mm. The following pressing parameters were applied:

- temperature 180°C
- pressure 2.5 MPa
- times: 3.5, 4.0, 4.5, 5.0 minutes

Thus produced boards were subjected to the following tests:

- swelling in thickness after 24 hours according to PN-EN 317
- internal bond (IB) according to PN-EN 319
- moisture resistance (test V 100) according to PN-EN 1087-1
- modulus of rupture (MOR) according to PN-EN 310
- modulus of elasticity (MOE) according to PN-EN 310
- free formaldehyde content according to PN-EN 120

Discussion of results

Table 1 presents the results of determining the gel time at 130°C of the resin modified with the esters. Data included in the table show that even a small amount of the modifier significantly shortens the gel time; and as the amount of ester grows, the rate of the curing process increases. Adding the ester into the resin in the amount of 0.01 mole shortens the gel time by 11 to 21%, and in the amount of 0.15 mole by 37 to 40%. The influence of the kind of ester is most distinct when smaller amounts of the modifier are introduced into the resin. The addition of ethyl acetate in the amount of 0.01 mole/mer results in a 10% greater shortening of the gel time than the addition of ethyl butyrate. With the amount of 0.15 mole/mer the kind of acid radical of the added ester does not actually affect the gel time of PF resin at 130°C.

Table 1

The influence of the modification of PF resin with esters of organic acids upon the gel time at 130°C

Amount mole/mer	Kind of ester		
	Ethyl acetate	Ethyl propionate	Ethyl butyrate
	Gel time [s]		
0.000	165		
0.010	130	143	146
0.025	123	140	144
0.050	120	131	135
0.100	113	122	122
0.150	99	103	100

As expected, introducing esters into PF resin results in the decrease in dynamic viscosity (Table 2). As the amount of the modifier increases the dynamic viscosity decreases and the influence of the added ester becomes more distinct. The addition of ethyl propionate in the amount of 0.15 mole/mer decreases the viscosity by 190 mPa·s, and ethyl butyrate by only 115 mPa·s.

The analysis of the results presented in Table 3 proves that both the kind and amount of the introduced ester considerably influence the stability of the resin at 20°C. The changes in the viscosity are most strongly affected by ethyl acetate. The addition of this ester in the amount of 0.01 mole/mer after 48 hours results in a threefold increase in the viscosity; with the ethyl acetate amount of 0.05 mole/mer such an increase is observed after 8 hours, and when the amount of the ester is 0.15 mole/mer the viscosity increases by over 5,000 mPa·s. The smallest influence on the stability of the resin is observed in case of ethyl butyrate.

Table 2

The influence of the modification of phenolic resin with esters of organic acids upon dynamic viscosity.

	Kind of ester		
amount mole/mer	**Ethyl acetate**	**Ethyl propionate**	**Ethyl butyrate**
	Dynamic viscosity [mPa·s]		
0.000	635		
0.010	605	580	600
0.025	580	525	585
0.050	550	490	565
0.100	490	475	545
0.150	455	445	520

Table 3

Stability at 20°C of PF resin modified with esters of organic acids.

Kind of ester	**Amount mole/mer**	**Measurement times [h]**						
		0	**4**	**8**	**12**	**24**	**36**	**48**
		Dynamic viscosity [mPa·s]						
0	0	635	635	645	655	830	895	980
Ethyl acetate	0.01	605	735	855	995	1125	1295	1785
Ethyl propionate		580	660	825	960	1075	1275	1690
Ethyl butyrate		600	690	725	910	1000	1250	1545
Ethyl acetate	0.05	550	1160	1625	2520	2905	3565	over 5000
Ethyl propionate		490	1060	1410	1970	2180	2725	3775
Ethyl butyrate		565	655	710	965	1195	1740	2215
Ethyl acetate	0.15	455	1785	3080	over 5000	-	-	-
Ethyl propionate		445	1310	2785	4500	over 5000	-	-
Ethyl butyrate		520	670	715	1010	1350	2320	4590

Table 4 shows the results of studies upon the physical and mechanical properties of the produced particleboards. The data included in the table indicate that esters applied as modifiers as well as the used pressing times do not affect the swelling in thickness after 24 hours of immersion in water. Only boards glued with PF resin modified with ethyl butyrate were characterized by a lower value of swelling in thickness when compared with the board glued with non-modified PF resin; the decrease of swelling was not dependent upon the pressing time.

Table 4

Properties of particleboards glued with PF resin modified with esters in dependence of the pressing times

Kind of ester	Time	Properties of particleboards					
		Swelling in thickness after 24 hours of immersion in water	Moisture resistance after V-100	Internal bond	Modulus of elasticity	Modulus of rupture	Formaldehyde content
	min	%	MPa				mg CH_2O/100g d.m.b.
-	3.5	31.3	0.43	0.67	1900	15.1	1.78
	4.0	32.5	0.49	0.75	2090	16.0	1.37
	4.5	28.0	0.57	0.83	2110	16.2	1.23
	5.0	29.5	0.60	0.91	2320	16.3	1.29
Ethyl acetate	3.5	32.0	0.41	0.66	2190	16.5	2.96
	4.0	33.2	0.46	0.76	2310	16.8	2.06
	4.5	31.9	0.57	0.82	2490	18.2	2.03
	5.0	32.2	0.64	0.91	2600	19.0	1.48
Ethyl propionate	3.5	30.0	0.47	0.89	2350	17.9	1.70
	4.0	31.3	0.51	0.93	2580	20.6	1.62
	4.5	30.2	0.59	0.92	2610	20.8	1.62
	5.0	28.5	0.69	1.03	2850	21.9	1.28
Ethyl butyrate	3.5	26.9	0.67	0.97	2320	18.5	1.54
	4.0	26.5	0.68	1.01	2530	19.8	1.54
	4.5	24.9	0.74	1.05	2590	20.6	1.14
	5.0	26.9	0.97	1.18	2970	22.9	1.22

The measurements results of moisture resistance of the experimental particleboards determined with V 100 test prove that boards glued with non-modified resin are characterized by relatively high moisture resistance. Only the use of ethyl acetate as the modifier of the PF resin decreased the moisture resistance of the boards. In other cases, the modification resulted in the increase in the moisture resistance of the particleboards. The highest values were

obtained for the boards modified with ethyl butyrate which, in the pressing time of 3.5 min., showed higher resistance than the control board pressed in the time of 5 min.

The internal bond of both modified and non-modified boards is very high (Table 4). Data included in the table show also that the kind of modifier as well as the pressing time greatly influence the internal bond. Lengthening of the pressing time and using as the modifier the ester with longer carbon chain in the acid group results in the increase of internal bond. Only boards modified with ethyl acetate were not characterized by higher internal bond in comparison with the control board.

Data shown in Table 4 prove also that the applied modifiers of PF resin lead to the increase in the modulus of rupture and the modulus of the elasticity, regardless of the pressing time. With the pressing time of 3.5 min. the value of modulus of rupture in the boards made with use of PF resin modified by ethyl acetate was the same as that of control boards produced in the pressing time of 5 min. The use of ethyl propionate and, especially, ethyl butyrate makes it possible to produce, in the time shorter by 1.5 min., particleboards characterized by modulus of rupture increased by 10 to 13 per cent. The correlations of modulus of elasticity in the produced particleboards are of similar kind in dependence of the applied ester and pressing time. A considerable increase in the modulus of elasticity of the boards produced with use of modified resin shows that the esters greatly accelerate the cross-linking process in the resin. Effects of this kind appear mostly in the top layers of the boards, which are responsible for obtaining high values of modulus of rupture in shorter pressing times.

The investigated boards were characterized by very low formaldehyde content due to the kind of used resin. The applied modification does not significantly affect free formaldehyde content in the boards (Table 4).

Conclusions

The kind of acid that forms the ester greatly affects the effectiveness of the action of the ester as a modifier of phenol-formaldehyde resin. As the length of the carbon chain in the acid radical of the applied ester increases, the mechanical and physical properties of the boards increase. The best of the investigated modifiers was ethyl butyrate; its use made it possible to shorten the pressing time of particleboards glued with PF resin by 30%.

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Streszczenie: *Możliwość skrócenia czasu prasowania płyt wiórowych zaklejanych żywicą PF modyfikowaną estrami o różnym podstawniku alkilowym w grupie kwasowej.* Zbadano wpływ rodzaju kwasu tworzącego ester wprowadzanego do żywicy fenolowej na właściwości

płynnej żywicy oraz fizyczne i mechaniczne właściwości zaklejanych zmodyfikowaną w ten sposób żywicą płyt wiórowych. Badania wykazały, iż zastosowane estry istotnie skracają czas żelowania żywicy PF oraz zmniejszają stabilność. to tym bardziej im o krótszym łańcuch kwasowym jest ester i im większa jest wprowadzana jego ilość. Badania wykazały, iż wszystkie rodzaje dodawanych do żywicy estrów znacznie poprawiają właściwości płyt, a zastosowanie jako modyfikatora butanianu etylu pozwala na skrócenie czasu ich prasowania o 30 % bez pogorszenia właściwości fizycznych i mechanicznych.

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Laccieren und Laccierte Arbeit

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Abstract: *Laccieren und Laccierte Arbeit.* In der Arbeit wurde ein Beitrag aus einem Lexikon zitiert,das Anfang des 18. Jahrhunderts erschienen ist und in dem der Begriff und die Technologie der Lackarbeiten, die Geschichte und der Handel mit lackierten Möbeln beschrieben werden.

Schlüsselwörter: Lack, Möbel, Holz, Tischler

Lackarbeiten entstehen durch Uberziehen von Gegenständen aus Holz, Ton, Metall u.a. mit einer Schicht von Lack zum Schutz oder zum Schmuck. Den Rohstoff liefert der gummiartige Saft des Lackbaumes (Rhus vernicifera) aus den Bergwäldern von China, Japan oder Korea [Lexikon der Kunst 1971]. Eine um 100 Jahre altere Beschreibung lautet: Der japanische Lack (Urusinoci) wird durch Einschnitte aus dem Firnis-Sumach (Rhus vernicifera) gewonnen; er ist eine grauweiße, dickflüssige Masse, die an der Luft bald in Braun oder Schwarz übergeht. Zur Verwendung wird er mit dem Öl der Bigonia tomentosa versetzt. Der chinesische Lack (Tsi) ist ein harziger Stoff, der aus den Tsichon oder Lackbaum (Augia chinensis) fließt und mit den Früchten der Vernicia montana gemischt wird [Brockhaus 1898] . Die Lackkunst gehört zu den entwickelten künstlerischen Techniken, die von O-Asien, bes. China, ihren Ausgang genommen haben. Bereits in der späten Shang-Zeit (1384-111 v.u.Z.) war in China die Verwendung von Lack bekannt, zunächst als Überzug für Grabbeilagen aus Bambus und Holz... teils auch als dekoratives Klebemittel für Einlagen... Ab 17.Jh. stieg der Export chinesischer Lackgeräte... nach Europa (bes. unter Kaiser Kangxi, 1662-1722 von der Quing Dynastie). Er ließ in Peking viele Hofwerkstätten einrichten. Auch aus dem japanischen Neolithikum (bis 3.Jh. v.u.Z.) stammen Bogen, Schalen und Gebrauchsgegenstände, die mit Lack überzogen waren [Lexikon der Kunst 1971] . Nach Europa wurden ostasiatische Lackarbeiten im späten 17.Jh. eingeführt und bald auch nachgearbeitet. In Paris hatte die Familie Martin seit 1730 ein königliches Patent, alle Arbeiten in Lack im Geschmack Japans und Chinas herstellen zu dürfen [Lexikon der Kunst 1971]. Darum auch ist im Realen Staats=Conversations- und Zeitungs=Lexici von Gleiditsch Johann Friedrich I. (gest. 1716) Leipzig. Buchhändler, Verleger. 1681- 1715. Nachf. Sohn Johann Gottlieb Gleiditsch (als Johann Friedrich Gleiditsch Sohn) Buchhändler 1712-1715, Braunschweig [Paisley 1988] und noch bevor die Familie Martin das oben erwahnte Patent erhielt, die verhältnismäßig umfangreichen Stichwörter Laccieren und Laccierte Arbeit enthalten, woraus ersichtlich ist, daß in Europa lackierte Möbel hergestellt wurden, deren Qualität den importierten nicht nachstand.

Laccieren, oder lackieren heißt, die hölzernen Gefäße und Mobilien, als Tische, Stühle, Gueridons, Schreib-Contoirs, Schränke, Schüsseln, Schachteln, etc. dergestallt mit Farben künstlich bemahlen, und als denn mit einem saubern Firnis überziehen, daß man es für Marmor, oder Ost-Indische Arbeit, oder als wenns mit Glas überzogen wäre, ansehen sollte, wie denn heutiges Tages, dergleichen Arbeit sehr gemein, sonderlich seit dem, daß die Ost-Indischen=Compagnien so viel lackiertes Zeug aus Ost=Indien mitgebracht, und theuer verkauft haben, da sich denn viel beflissen, dergleichen Kunst=Werck allhier in Europa

nachzumachen, solches auch schon so hoch getrieben, daß es dem Ost=Indischen nichts nachgiebet, und wir also solches, eben wie ihr Porcelan, gar wohl entbehren können. Es kommt aber das meiste bey dieser Arbeit auf einen guten und schönen Firniß an. [1727]

Laccierte Arbeit, so in **Tonquin** gemacht wird, giebt keiner andern etwas nach, ausser der Japanischen, welche für die schönste in der Welt gehalten wird, welches Zweifels ohne daher kommt, daß das Holtz allda viel besser ist, als in Tonquin, denn sonsten siehet man in der Mahlerey und im Firnis keinen Unterschied. Das Tonquinische Lacc ist eine Art fliessendes Gummi, welches aus dem Stamme und den Aesten gewisser Bäume dringet. Das Land=Volk sammlet dessen eine so große Menge, daß sie alle Tage auf dem Marckt zu Cachao gantze Tonnen voll zu verkauffen bringen, sonderlich wenn sie wissen, daß, die Arbeits=Leute viel zu thun haben. Von der Art ist es weisser Farbe, und so dicke, als etwa Milchrahm, in der Lufft, aber verändert es sich, und wird schwärzlich, dannenhero die Leute, ehe sie es in die Stadt bringen, ein paar Bögen Papier drüber decken, damit es frisch bleibe, und seine natürliche Farbe behalte. Die Schräncke, Schreibe=Tische, und dergleichen, welche gevernisset werden sollen, sind meistentheils von tänennen oder Pone=Holtz gemacht, allein der dasigen Tischler Arbeit ist mit der Europäer ihrer gar nicht zu vergleichen, und geschiehet gar offt, wenn sie den Firniß auf die schönsten und zierlichsten Sachen aufgetragen wollen, daß sie die Ecken und Fugen an den Schubladen und anderswo zerbrechen und verderben. Über dieses ist auch das Geräthe, oder die Sachen selbst, von ganz anderer Art und Gemächte, als bey uns. Man hält die Häuser, worinne das Lack gearbeitet wird, für sehr ungesund, weil ein gewisses Gifft in diesem Gummi seyn soll, welches den Arbeitern durch die Nasenlöcher ins Gehirn steiget, da es doch weder einen allzustarcken noch unangenehmen Geruch hat. Diejenigen, die damit umzugehen gelernet, können nur in der trockenen Jahrs=Zeit, oder wenn die Nord=Winde, so sehr trocken, wehen, darinnen arbeiten, denn sie müssen das Lack mehr als einmahl auftragen, und da muß der vorige Anstrich allemahl vorher wohl getrocknet seyn, ehe man es wieder überstreichet. Schwarz wird es von sich selbsten, wenn man es an die Lufft leget, und den Glanz giebt, und vermehrt das Oel und andere eingemischte Dinge. Wenn nun endlich der letzte Anstrich trocken ist, wird es geglättet, und so blanck als ein Spiegel gemacht, wozu sie gemeiniglich nur die flache Hand gebrauchen, indem sie das Holtz starck damit reiben. Sie können dem Lack eine Farbe geben, was für eine sie wollen; machen auch einen sehr guten Leim, als immer einer zufinden, daraus. Dieser wird zwar sehr wolfeil gegeben, sie machen auch den Firniß damit an, es ist auch verboten ihn aus dem Lande zu führen.

Dass die Lackkunst in Europa schon zu dieser Zeit ein hohes Niveau erreicht hatte, kann folgendes Stichwort belegen.

Tischer=Arbeit, *de la Menuiserie*, kommt bey Kauffleuten in ihrem Handel selten vor, außer was sie an Kisten und Regalen zu ihrem eigenen Gebrauch nöthig haben, darein sie die Waaren, sonderlich die feinen, einpacken, und die ausgepackten ordentlich zu legen pflegen. Oder was von vornehmen Leuten an kostbaren und künstlichen Meublen von Eben, Cypressen, Oliven, Brasilien und Indianischen, Zucker= Tannen= Wurzeln, Nußbaum, Masern, Cedern und Königs=Holtz bey ihnen gesuchet wird, ingleichen was an schönen Spiel=Tischen, Pulten etc. bey den so genannten Kunst= oder Galanterie=Händlern zu finden ist, und zwar mehrentheils seit der Zeit, da die Chinesische und Japanische Holtz=Arbeit von den Ost=Indischen Compagnien so häuffig nach Europa gebracht worden, und die Kunst zu lackieren bey uns sehr hoch gestiegen, da sie der Ost=Indischen wenig oder nichts mehr nachgiebet.

Hübner Johann, ein Schulmann, der durch seine „auserlesenen biblischen Historien" und seine auf Verbreitung historischer und geographischer Kenntnisse berechneten Schriften in den weitesten Kreisen bekannt geworden ist, geb. den 15. April 1668 zu Türchau in der sächs. Oberlausitz, gest. den 21. Mai 1731 in Hamburg - Enkel eines aus Böhmen ausgewanderten Protestanten, der um den Glauben zu bewahren, viel irdisches Gut verlassen hatte, Sohn eines doch wieder zu Wohlstand gelangten Vaters, wurde er früh für die Studien bestimmt, und am Gymnasium in Zittau gewann er... jene Vielseitigkeit des Wissens und jene Gewandtheit der Darstellung, die ihn später zu einem so beliebten Schriftsteller machten. ... 1689 ging er nach Leipzig um Theologie zu studiren ... Bereit 1691 wurde er Magister... und... schon 1694 als Rektor an das Gymnasium in Merseburg berufen... Anfang 1711 wurde er in das Rectorat des dortigen Johanneums als Nachfolger von J.A. Fabricius berufen. ... Die aus der Zerfahrenheit des Lehrerkollegiums hervorgegangenen Mißstände in Unterricht und Zucht abzustellen, gelang ihm bei der Schwierigkeit das Scholarchat, und die Lehrer von der Notwendigkeit einer Reform zu überzeugen, um so weniger, als er selbst durch seine leidenschaftliche Art manches verdarb, so daß zuletzt das Johanneum in gänzliche Zerrüttung zu gerathen begann. Um so erfreulicher waren für Hübner die Erfolge, welche er fort und fort als Schriftsteller davon trug. Es erschienen von ihm rasch nach einander ... viele Bücher. Das „reale Staats= Zeitungs= und Conversations=Lexicon" (Leipzig 1715) und das „Curieuse Natur= Kunst= und Handelslexikon" (Leipzig 1712) sind von ihm eigentlich nur durch die Vorreden eingeführt. [ADB 1879]

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Curieuses und Reales Natur=Kunst=Berg=Gewerk= und Handlungslexicon, Darinnen nicht nur Die in der Physic, Medicin, Botanic, Chymie, Anatomie, Chirurgie und Apothecker=Kunst, wie auch in der Mathematic, Astronomie, Music, Mechanic, Bürgerlichen und Kriegs=Bau=Kunst, Artillerie, Schiffarten etc. ferner bey den galanten und Ritterlichen Exercitien; bey Bergwerckern, Jägerey, Fischerey, Gärtnerey; wie auch in der Kauffmannschaft, bey Buchhalten, und in Wechsel=sachen, bey Künstlern und Handwercken gebräuchliche Termini technici oder Kunst=Wörter, nach Alphabetischer Ordnung ausführlich beschrieben werden: Sondern auch alle in Handel und Wandel, ingleichen in Jure und vor Gerichten vorfallende, und aus allerhand Sprachen genommene, unentberliche Wörter, den Gelehrten und Ungelernten zu sonderbaren Nutzen gründlich und deutlich erkläret, auch an vielen Orten nützliche Realien mit eingemischet seyn. Alles dergestalt eingerichtet, daß man dieses als einen andern Theil des Realen Staats= Conversations= und Zeitungs=Lexici mit grossem Vortheile gebrauchen kann. Die fünfte Auflage mit allem Fleiß verbessert, und mit etlichen hundert Articeln vermehret. Nebst einer ausführlichen Vorrede Herrn Johann Hübners. Mit Churfürstl. Sächs. Allergnädigsten Reichs=Vicariats=Privilegio. Verlegt von Joh. Friedr. Gleiditschens sel. Sohn. Anno 1727.

Deutsche Encyklopedie oder Allgemeines Real=Wörterbuch aller Künste und Wissenschaften von einer Gesellschaft Gelehrten. Fünfzehender Band (Heil- Holz.) Frankfurt am Mayn bey Varrentrapp und Wenner 1790.

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Paisley David, L. Deutsche Buchdrucker, Buchhändler und Verleger 1701-1750, 1988: Otto Harrassowitz. Wiesbaden

Streszczenie: *Zdobienie mebli laką.* Meble zdobione laką rozpoczęto sprowadzać do Europy w XVII wieku. W roku 1730 rodzina Martin otrzymała we Francji patent na produkcję mebli wykończonych laką. W pracy umieszczono krótką historię stosowania laki do wykańczania mebli , następnie opisano metodę produkcji laki i sposób wykańczania nią mebli , jaki znajduje się w piątym wydaniu wydanej w roku 1727 w Saksonii nakładem Johana Fryderyka Gleidischa encyklopedii. Z opisu wynika że w Europie już przed patentem Martina meble wykańczane laką nie różniły się jakością od importowanych do Europy z Chin i Japonii przez Wschodnio-indyjskie Towarzystwo.

Die in der Arbeit zitierten Positionen befinden sich in der Universitatsbibliothek Warschau, Abteilung Alte Drucke.

The effect of wood species and density on propagation velocity and damping coefficient of ultrasonic wave

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Abstract: The paper reports results of measurements of ultrasonic wave propagation velocity and attenuation coefficient in wood of pine, oak and beech wood in three anatomical directions. It has been shown that in mature wood of pine and beech wood the speed of ultrasonic wave propagation along the fibres decreases with increasing wood density. For oak tree samples the reverse tendency has been observed in the samples covering the annual rings from 25 to 60. In the transverse directions no significant effect of the wood density on the ultrasonic wave propagation velocity has been noted. Within particular wood species studied, the wood density does no affect the value of the attenuation coefficient. The mean value of this coefficient depends on the species and the anatomical direction of wave propagation. Irrespective of the wood species the sound attenuation is the strongest in the tangent direction and the weakest along the fibres.

Introduction

The researches on velocity of ultrasonic wave propagation in wood have been continued for over 150 years, since Wertheinm and Chevandier published their pioneer works (1846). In the last decade there has been observed significant increase of the interest in those problems. They are focused mainly on the closer recognising of the rules of ultrasonic wave propagation in wood, as a tool for assessment of the quality of wood treated either as the raw material, or solid wood products as well as wood-based materials (Sandoz 1989, 1993; Steiger 1991; Bucur i Chivers 1991; Greubel i Plinka 1995; Kolesnikova 1996; Mishiro 1996; Han 1996; Nimz i in. 1997; Marcok i in.1997). Nevertheless a lot of aspects of wood structure effecting the ultrasonic wave propagation in wood are not quite well recognised, and even results of some research are controversial. The most controversial seems to be the effect of wood density on ultrasonic wave propagation. From the formula $C^2=E/\rho$ it appears that increase of wood density should result in decrease of ultrasonic wave velocity. Paradoxical it emerges from the most of the research, with some doubts however, that the increase of wood density results in increase of velocity of ultrasonic wave propagation (*e.g.* Kollmenn and Krech 1960; Burmester 1965; Dzbeński 1984). The positive correlation between wood density and ultrasonic wave velocity was presented also in research of Yiannos and Taylor (1967) as well as the one of Burmester (1965), which was carried out, separately on early and late woods of South pine. Those authors revealed that the ultrasonic wave velocity in zone of the early wood was from 10 till 25% lower while compared to the late wood. Whereas the similar tests carried out by Gerhards (1978) did not confirm those conclusions.

The results of the above-mentioned studies are showing the needs of continuation of the research on the effect of wood density on ultrasonic wave propagation. Those investigations is also important while taking into consideration how useful can be the ultrasonic method for the assessment of technical quality of the timber (*e.g.* Dzbeński, 1984). This paper is limited only to determine of the effect of the density of the mature wood, *i.e.* the

wood of stable dimensions of its anatomic elements, on velocity of ultrasonic wave propagation as well as on the ultrasonic wave damping coefficient.

Methods

It was decided to perform the measurements of ultrasonic wave propagation and damping coefficient on wood of pine (*Pinus sylvestris* L.), oak (*Quercus robur* L.) and beech (*Fagus sylvatica* L.) in all anatomical directions. For the test purpose the centre planks had been sawn from the round wood, and then seasoned on the open air in period of 2 years. The two pairs of pair matching samples were produced of them. The thickness of the pair-samples was 15 and 30 mm as well as 20 and 40 mm, and had the annual increments orientation as shown at Fig. 1. The surface of the samples on which the measuring heads were coupled with equalled 50x50 mm^2. The samples of pine and beech woods were made out of outer zones of the planks, while the oak samples were made of outer zones of heard wood, which were located more then 25th annual ring of distance from the pith. The test samples were afterwards seasoned in room conditions in period of 2 months. After that time the moisture content of the all samples stabilised at the level of 8%. The next stage was to sand precisely the samples, and then the density with stereometric method was determined. The average width of annual increments ranged from 1,4 till 2,2 mm for pine samples, 0,9 till 2,38 mm for oak and 1,8 till 3,2 mm for beech ones. The percentage of late wood in pine and oak samples comprised in ranges from 37 till 48% and from 57 till 81%, respectively.

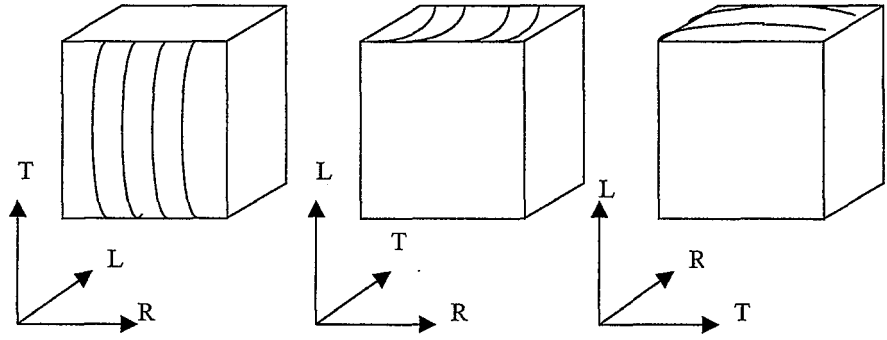


Fig.1. Shape and orientation of annual increments in the samples destined for velocity of ultrasonic wave and damping coefficient measurements: a – along-to-the-grain direction, b-tangential direction, c-radial direction.

To determine the wave velocity and damping coefficient the impulse method of through-coming wave without a delay line was chosen. The samples of two lengths were used for experiment (the signal taken from testing of the one sample was treated as the signal of reference for the other). That method do not require multiply transmission through the tested samples which is the important advantage while the porous materials or the material of strong damping ultrasonic propagation properties are being subject of testing. The signal initialising the transmitting head was short impulse signal. The experimental track consisted of generator 5058 PR and measuring heads V-318 of frequency 0,5 MHz each, produced by Panametrics, generator MATEC TB 1000 and computer with DSO-digital storage osciloscope. To assure the proper coupling of measuring head with the tested sample surface the silicone grease was

applied. The determining of damping coefficient and phase velocity of the wave was obtained with means of spectral analysis based on Fast Fourier Transform (FFT). Those experiments were conducted in Institute of Environmental Mechanics and Applied Computer Science in Bydgoszcz.

Results

The direct results of the experiments of velocity measurements of ultrasonic wave propagation in various anatomic directions in relation to wood density of the tested samples of pine and beech woods are presented at Fig. 2 and 3. The evident tendency towards decreasing of wave velocity in along-to-the-grain direction, with density increase, is observed. One should notice here, that the tested samples were taken from outer zones of the tree stems aged of approximately 100 years. The tested samples comprised the mature wood tissue in which the dimensions of anatomic elements are stabilised at approximately constant level. The results of those experiments are in conformity to the basic formula joining the sound velocity with material density and its elastic properties. Additionally the measurements of ultrasonic propagation were repeated using the material tester type 543, with measuring heads of frequency 0,5 MHz, and the results achieved there were identical.

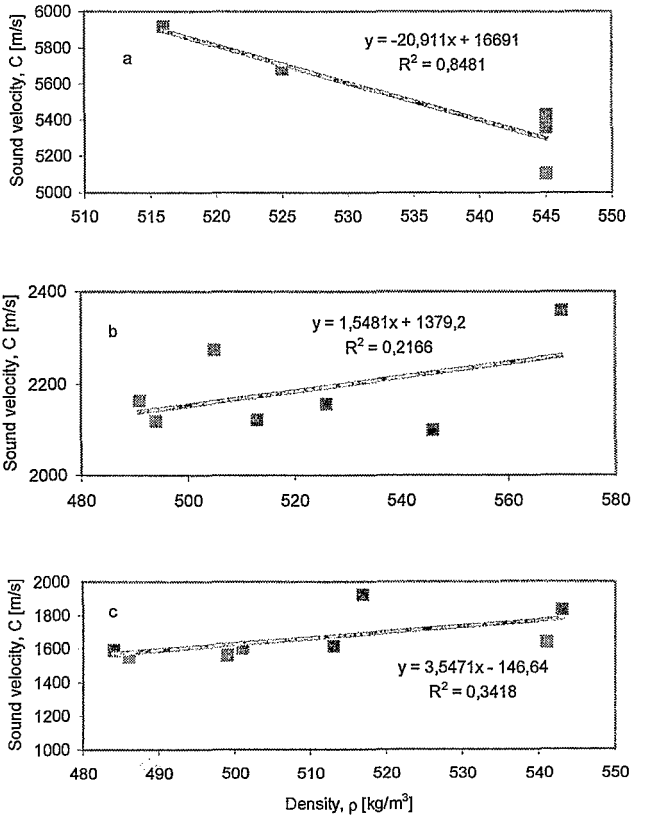


Fig.2. The effect of pine wood density on velocity of ultrasonic wave propagation: a- along-to-the grains, b- in radial direction, c- in tangential direction.

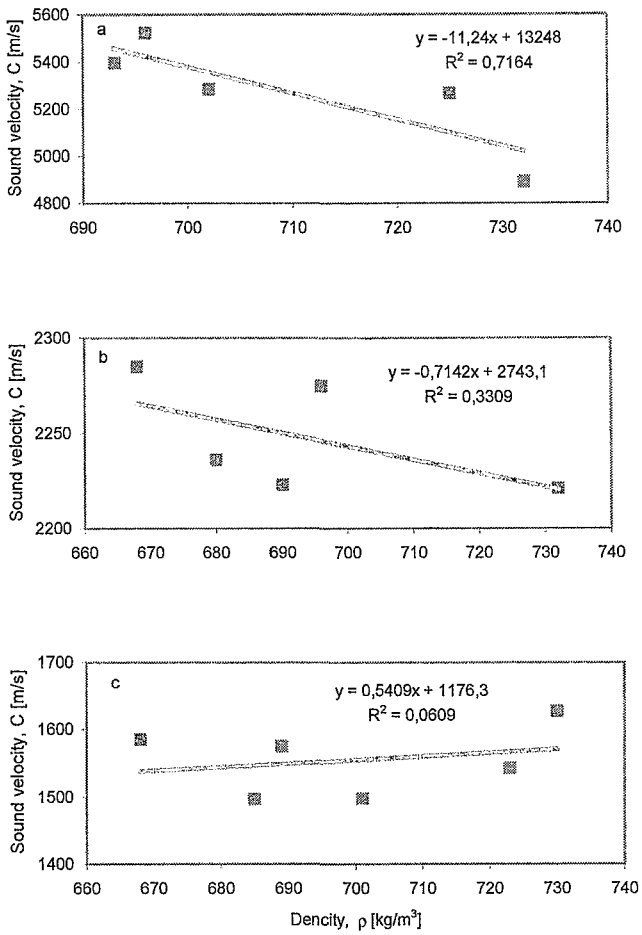


Fig.3. The effect of beech wood density on velocity of ultrasonic wave propagation: a- along-to-the grains, b- in radial direction, c- in tangential direction.

The tendency to decrease the velocity of ultrasonic wave in along-to-the-grain direction with increase of the density of pine and beech woods above a defined threshold, was observed by Burmester (1965). For the oak wood samples, showing the density level from 603 till 748 kg/m^3, very weak trend to increase of the wave velocity with the growth of the density of the wood was recorded. More precise explanation of those relationships requires however the further investigation on the more numerous test materials, with simultaneous

determination of the effect of anatomical elements dimensions on the characteristics to be analysed.

While comparing the average levels of ultrasonic wave velocity along-to-the-grain of the tested wood species, it can be observed that the velocity of wave propagation is the highest in pine wood (5500 ms^{-1}), medium in beech wood (5270 ms^{-1}), and the lowest velocity is developed in oak wood (4940 ms^{-1}). Those results conform to the data presented by Kollmann and C□té (1984).

The density of the wood, in limited range, does not effect on velocity of ultrasonic wave propagation in along-to-the-grain direction, as it is evident from the figures presented above. The average values of ultrasonic wave velocity in radial direction for pine (2180 ms^{-1}), and oak (2100 ms^{-1}) woods are approximately 30% higher than in the ones in tangential direction which amounted to 1660 and 1590 ms^{-1}, respectively. For beech wood samples the difference in both anatomical direction is even higher and reaches 45% (2270 and 1550 ms^{-1}).

The measurements of ultrasonic waves damping coefficient revealed that its value increased with increase of ultrasonic signal frequency. Analysing the density effect on damping coefficient for frequency of 0,4 MHz any relation was not found. The source of that situation was probably the very high variability of the measured parameter. The average values of damping coefficient for the tested wood species in various anatomic directions are shown at figure 4.

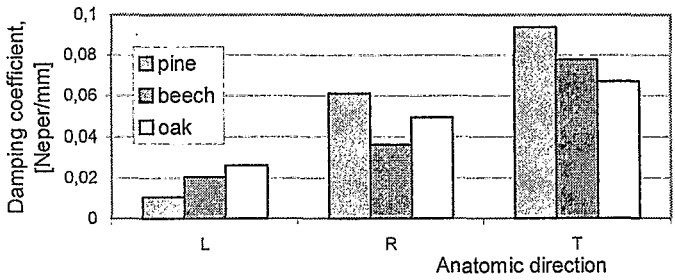


Fig. 4. Wood species and anatomic direction effect on ultrasonic wave damping coefficient.

It is evident from the figure 4, the lowest damping of the ultrasonic wave is observed for along-to-the-grain propagation, medium for radial and the highest for tangential direction. While comparing the damping coefficient for along-to-the-grain propagation of ultrasonic wave, the tested species one can classify according to the factor increase as follows: pine, beech and oak. In transverse directions the highest value of damping coefficient is observed for pine wood samples. The more precise analyse of the tests results is not possible now, as the number of the samples was insufficient and the variability of the measured factor very high. In the Department of Wood Science of Agricultural University in Poznań the new samples are being in preparation process now. After that the next series of experiments are going to be conducted to develop the introductory results of the research which are presented above and to give more precise interpretation and deeper study of the problem.

Conclusions

To summarise the results of the research it can be stated that the velocity of ultrasonic wave propagation along-to-the-grain direction of mature wood tissue decreases together with increase of wood density. That relationship was revealed for pine and beech woods. In transverse directions any significant effect of density of the tested wood samples on ultrasonic wave velocity was not observed. The lowest damping of ultrasonic wave was registered for its along-to-the-grain propagation, medium in radial direction and the highest in tangential direction of wood tissue.

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Streszczenie. *Wpływ gatunku i gęstości drewna na prędkość i propagacji i współczynnik tłumienia ultradźwięków.* W pracy przedstawiono wyniki pomiarów prędkości propagacji i współczynnika tłumienia fal ultradźwiękowych w drewnie sosny, dębu i buka w trzech podstawowych kierunkach anatomicznych. Wykazano, że w drewnie dojrzałym sosny i buka wraz ze wzrostem jego gęstości obniża się prędkość rozprzestrzeniania się fali ultradźwiękowej wzdłuż włókien. W przypadku zaś próbek dębowych, obejmujących przyrosty roczne od 25 do 60, zaobserwowano tendencję odwrotną. W kierunkach poprzecznych nie stwierdzono wyraźnego wpływu gęstości badanych gatunków drewna na prędkość propagacji ultradźwięku. Gęstość drewna, w obrębie poszczególnych gatunków, nie wpływa na współczynnik tłumienia fal ultradźwiękowych. Przeciętna wartość współczynnika tłumienia zależy od gatunku drewna i kierunku anatomicznego. Niezależnie od gatunku drewna tłumienie dźwięku jest największe w kierunku stycznym a najmniejsze wzdłuż włókien.

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Influence of knots to mechanical stress grading of spruce wood timber

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Abstract:*Influence of knots to mechanical stress grading of spruce wood timber.* Spruce wood timber is applied for wood engineering structures. Wood defects (knots, grain angle and other) have significant influence to its strength and elasticity and from it resulting grading into the equivalent strength class. The characteristic values are determined in STN EN 338 and EUROCODE 5. The experiment was oriented to the investigation of the defects influence to MOE of spruce wood timber. The recorded force-deformation diagrams were used for determination of the characteristic values and from it resulting grading into the equivalent strength class.

Introduction

Wood is material with high variability of the physical and mechanical properties. Many factors can be reason of its variability. For instance density and defects of wood are very interesting from the viewpoint of the mechanical stress grading. The density influence to the mechanical properties is known. It can be applied as a direct proportional linear function. The influence of the wood defects is much more complicated and less investigated. Knots, which have dominant position in the softwood species, have negative influence to the mechanical properties especially.

The mechanically stress graded timber is preferred in the area of the wooden structures which have tendency of the intensive increasing at the present time. One of the most often applied method of the mechanical stress grading is application of the bending loading, Dubovský [1993] and Rohanová [2000]. From this point of view the non-destructive characteristics, i. e. modulus of elasticity (MOE) or the influence of knots to the modulus of elasticity, are very interesting. Afterwards the suitable grading of the timber, based on the known relationship of modulus of elasticity and modulus of rupture (MOR), for require aims is possible.

The aim oh the contribution is evaluation of the influence of the knots to the variability of MOE at the bending loading. This relationship is possible to apply at the quality evaluation of timber for the purposes of the wooden structural elements.

Material and method

The spruce wood timber of the regularised cross section 32×240 mm (2 pieces) and 32×220 mm (4 pieces) of the length 2 500 mm was tested. Specimens of the board length were tested to the 3-points bending test with the support span 1 000 mm. The standard STN EN 384 was applied for the bending test. The specimens were conditioned to 12 % moisture content at the air condition humidity φ = 65 % and temperature t = 20 °C. This moisture content is required in the standard STN EN 384. Ten testing points were chosen on the each specimen in relation to the knots distribution, Fig. 1. Afterwards the specimens were loaded in these points as from the face (side) A as the face B. The loaded force F = 2 949 N was applied to the specimen with the breadth b = 240 mm and F = 2 703 N for the breadth b = 220 mm. The applied force was lower than the supposed proportional limit. Further the points with the highest and smallest deflection were chosen for the repeat loading to the ultimate limit. The recorded force-deformation diagrams are shown in Fig. 2 (for specimens S-1 and S-3). The deformations (in our case deflections) and forces determined from the force-deformation diagrams were applied for MOE calculation. The variability of MOE in the board length for specimens S-1 and S-3, taking in account the both faces (A and B), is shown in Fig. 3.

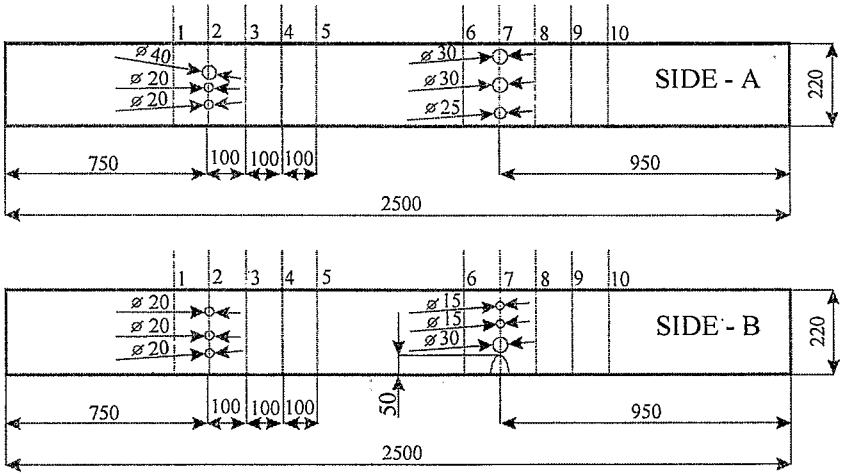


Fig. 1 The data sheet for specimen - board No. 3. Method of the knots identification on the board faces (sides A, B) and the testing point arrangement in the board length.

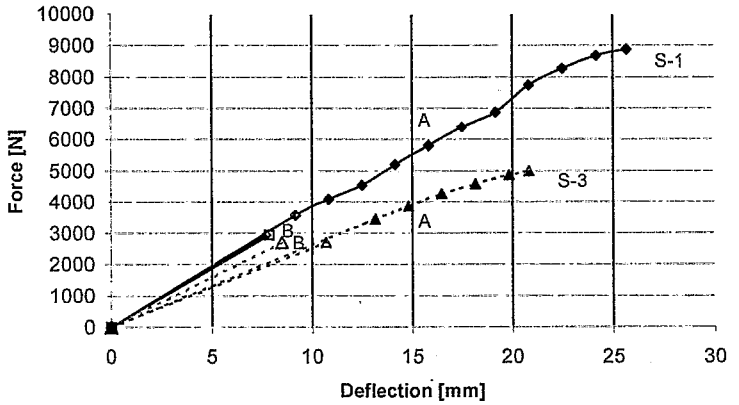


Fig. 2 The force-deformation diagram in the selected point in the board No. 1 (S-1) and in the board No. 3 (S-3). A - loading to the face A - force-deformation curve in the point 2 (in S-1) and in the point 7 (in S-3) at the loading to the ultimate limit. B - loading to the face B, the points (force, deformation) at the loading to the assumed proportional limit in the point 2 (in S-1) and in the point 7 (in S-3).

Results and discussion

The negative influence of knots to MOE of the spruce wood timber results from the experimental tests. It is possible to states base on the Fig. 1, 2 and 3, which represent the specimens with the extreme results. The specimen with the highest MOE (S-1) and with the lowest MOE (S-3) were used for the result analysis. All figures is necessary to take into

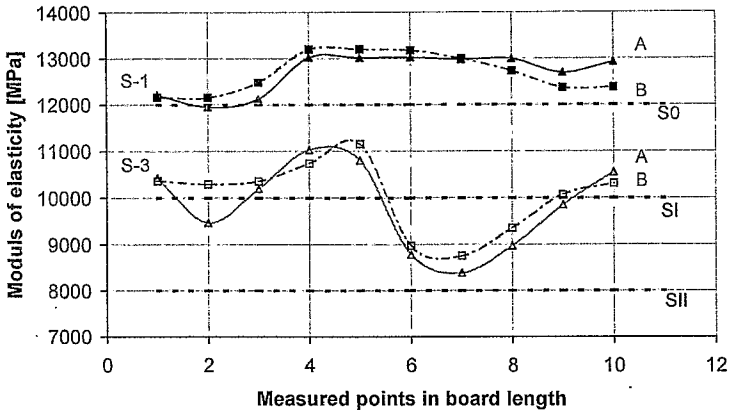


Fig. 3 The continuous variability of the modulus of elasticity in the tested points in the board length at the bending loading.

consideration at the evaluation as a complex. Fig. 1 represents a data sheet and gives information about the distribution of the identified knots. Fig. 2 gives information about the specimens reaction to the loading from the side A and B. The loading to the side A in both cases is represented with the force-deformation diagram into the ultimate limit. The loading to the side B is represented only with one point B which position is very closed to the diagram curve for the side A.

For final application of our results the Fig. 3 is most important. In the first, gives information about the continuous variability of MOE in the relation to the knots distribution as for loading to the side A as to the side B. In the second, base on the standards STN 49 1531, ČSN 49 1531-1 and EUROCODE 5 values of MOE for the qualitative classes S0, SI and SII we can do the evaluation of our specimens. The Fig. 3 enable to grade the tested specimens to the qualitative classes. S-1 into the class S0 (the best) and S-3 into the class SII (the worst). This diagram can be also applied for the weakest points determination (i. e. point No. 7 in the specimen S-3), what is the basement of the mechanical stress grading.

Conclusion

The results of the experimental tests give reliable information about the influence of knots to MOE of the spruce wood timber. The distribution of MOE in the board length is suitable information for application in the methods of the mechanical stress grading. It is the most suitable for methods with the bending application. This kind of grading is the most suitable for the timber applied in the wood structure elements. Base on the above mentioned knowledge, wood defect elimination and new longitudinal joining in the weakest points is possible to apply. For example, application of the fingers joins gives possibility of new grading into higher qualitative class.

The contribution is part of the results from the project VEGA No. 1/9362/02, which is financially supported by the Ministry of Education of Slovak Republic.

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Tytuł: Wpływ sęków na wyniki mechanicznego sortowania tarcicy świerkowej.

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Wood-ahdhesive-carbon-lamella at static and heat stress

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Abstract: *Wood-ahdhesive-carbon-lamella at static and heat stress.* Wooden membrs built in timber structures are exposed to fire load during their service life. The fire resistance of wooden members strengthened with carbon lamellas increases because the carbon lamella as well as the epoxy resin adhesive are not damaged due to high temperatures. The wooden members were experimentally tested at static and heat stress. When comparing the unstrengthened and strengthened members with the same cross-sections, the strengthened members exposed to the above stresses showed a lower deflection (approximately 10%) and also a longer time of burning until failure occurs (20% - 40%).

Introduction

The wooden members loaded only by mechanical load have durability of several years. In case of the wooden members are exposed to fire the durability is decreased to several minutes. Different strengthened materials are used to increase of carrying capacity of wooden members - steel, glass fibres and high effective carbon lamellas. Influence fire to stability and degradation of strengthened wooden members is different. The fire resistance of wooden members strengthened with some materials can be increased. Application of carbon lamellas to timber members is known in abroad as well as in our place (on various building materials as concrete or ferroconcrete). At wooden members strengthened with carbon lamellas is needed take account of specific properties of wood (as moisture content, anisotropy, density a. o.). Carrying capacity of wood members is determined by the tests of static loading. Wooden member built in timber structures is exposed at fire the mechanical loading as well as the thermal loading. The function of strengthening is effective only then there don't come about degradation of adhesive.

The aim of this work is to study the behaviour of wooden members strengthened with carbon lamellas when beam loaded by constant mechanical load is exposed to radiation heat source.

Carbon lamella

Carbon lamellas are composite materials from one direction orientated carbon fibres that are combined by the epoxy resin. Advantages of the carbon lamellas are following (Rohanová 2001):

- high tensile strength, high modulus of elasticity
- low dead weight, anticorrosive material, simple installation

Method

The experimental testing was realized to Faculty of Wood Science and Technology Technical University in Zvolen intro-scientific project 1/9362/02 " Vystužovanie drevených prvkov v stavebných konštrukciách ".

In experiments spruce wood (Picea abies, Karst.) was used. The dimensions of the specimens were following:

- 25 x 50 x 500 mm - unstrengthened - thin without lamella (**Tn**),
- 35 x 50 x 500 mm - unstrengthened - thick without lamella (**Hn**),
- 25 x 50 x 500 mm - strengthened - thin with lamella (**Tv**),
- 35 x 50 x 500 mm - strengthened- thick with lamella (**Hv**).

The dimensions of the lamellas were 1,2 x 50 x 500 mm (thickness of adhesive gap). The moisture content of wood members from experiment was 12 % (reference moisture content according to STN EN 384). The scheme of the bending load is shown in fig.1 and the scheme of the measuring apparatus is shown in fig.2.

Mechanically the unstrengthened and strengthened members were loaded in bending in radial direction. The specimen was placed on two supports and loaded by a constant force. Two levels loading were specified from the characteristics bending strength of wood:

- $\mathbf{T_n} + \mathbf{T_v}$ - 20% - $F_1 =$ 600 N (number specimens: 7 + 6),
- $\mathbf{T_n} + \mathbf{T_v}$ - 40 % - $F_1 =$ 1 000 N (number specimens: 7 + 6),
- $\mathbf{H_n} + \mathbf{H_v}$ - 20 % - $F_1 =$ 1 400 N (number specimens: 5 + 6),
- $\mathbf{H_n} + \mathbf{H_v}$ - 40 % - $F_1 =$ 2 800 N (number specimens: 7 + 6).

The characteristics bending strength of wood is $f_{m,k}$ = 22 MPa (C 22)- STN EN 338 . For the measurement of the member deformation we used the measuring device with the precision of 0,01 mm fixed in a metal stand.

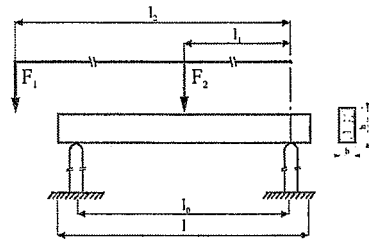


Fig.1: The scheme of the bending load

As the source of radiation heat we used two IR radiators T-5 wit a ceramic heating body. They irradiate the radial surface at the distance 1,5 cm from both sides of wooden member. The temperature in the specimen was measured by a Cu-Ko thermocouples of the thickness 0,15 mm. The thermocouples were connected to the LINE RECORDER TZ 4100. The temperature values were obtained from the values of voltage according to the calibration table (according to already invalid norm STN 35 67 10).

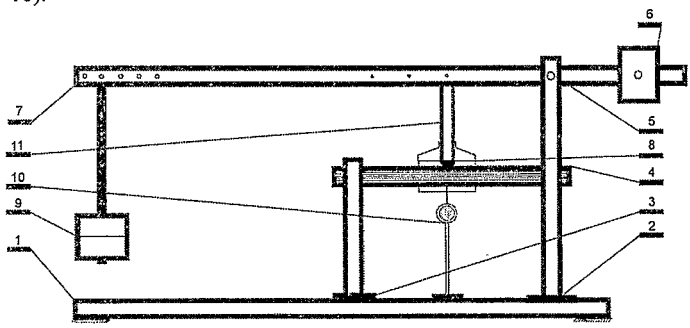


Fig.2: Scheme of the measuring apparatus

1 – framework; 2 – fixed support; 3 – adjustable support; 4 – specimen; 5 – journal of a shaft; 6 – equilibrating weight; 7 – arm; 8 – radiator; 9 – loading weight; 10 – deformation measurement; 11 – loading spike

Results and discussion

The experimental measurements of unstrengthened and strengthened members are only orientation (concerning number specimens) however they give the reliable results on their interpretation.

The influence of radiant heat on the deflection of wooden members

According to obtained results the thickness of specimen has influence on the size of deflection when the specimen is broken. This influence is higher for thin wooden members and difference between the unstrengthened and strengthened members is more obvious. Individual deflection curves are different also from point of viewl of load level (see fig.3 and fig.4). At level of load of 20 %, leading curve is run till 14 minutes and size of deflection is not exceeding of 1 mm for the thin strengthened members. Deflection of the unstrengthened members increase faster in compare with the strengthened members and the unstrengthened members resist to radiant heat shorter time. At level of load of 40 %, the strengthened members have higher resistance against to radiant heat as the unstrengthened members. The time was higher at level of load of 40 % when the wooden member was broken. Thick wooden members have similar behavior as the thin wooden members at level of load of 20 % and also at level of 40 % (see fig.5 and fig.6). The relationship between deflection and time of heating can be described by a exponential function for the all groups of members.

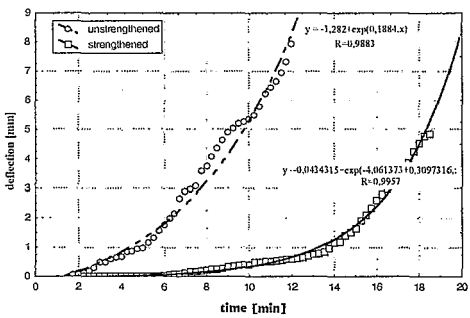


Fig.3: The relationship between the deflection of thin members at level of load of 20 % and time of heating.

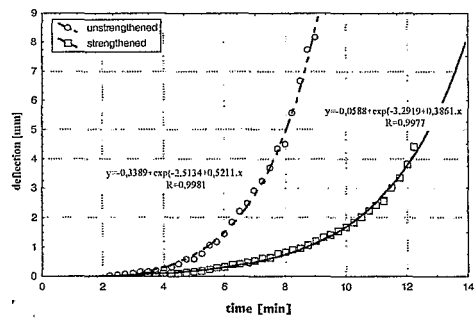


Fig.4: The relationship between the deflection of thin members at level of load of 40 % and time of heating.

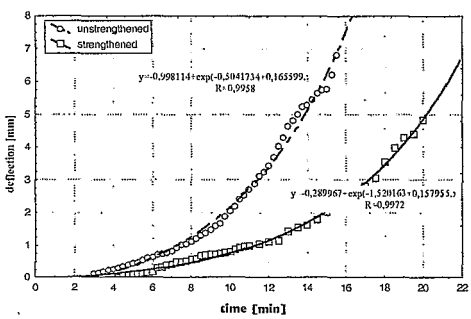


Fig.5: The relationship between the deflection of thick members at level of load of 20 % and time of heating.

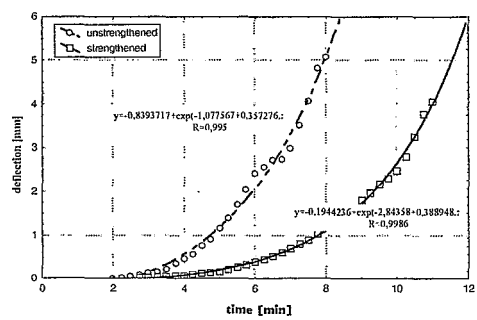


Fig.6: The relationship between the deflection of thick members at level of load of 40 % and time of heating.

The dimensioning of wooden members is established on the method of boundary states

- I. boundary state of carrying capacity
- II. boundary state of applicability

STN EN 338 determines the characteristic values of strength of spruce wood for the individual categories of strength. These values are modified by coefficients (kmod, kdef, gm). From above knowledges the value of loading of 20 % is real from aspect of dimensioning. In tab.2 are shown bending stresses for individual levels of load when members were broken. The values of the bending stresses decrease when the level of load is increasing. The value of bending stress for the unstrengthened member at level of load of 40 % is lower as the value presented for category of strength fm = 22 MPa.

Tab.2 The values of bending stresses when specimens were

Specimens		σ_{OH} [MPa]	
		20 % load	40 % load
thin	unstrengthened	12,48	13,82
	strengthened	30,03	22,76
thick	unstrengthened	27,80	21,37
	strengthened	39,72	38,07

Temperature in the wooden members

The termocouples were placed in all specimens and the temperature was measured during testing. Average temperature in the center of the specimens as function of time is plotted in fig.7.

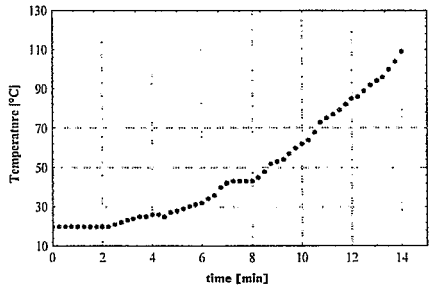


Fig.7: Temperature in the center of the specimens as function of time

Conclusions

Wooden members built in timber structures are exposed to fire load during their service life. The wooden members were experimentally tested at static and heat stress. When comparing the unstrengthened and strengthened members with the same cross-sections, the strengthened members exposed to the above stresses showed a lower deflection (approximately 10%) and also a longer time of burning until failure occurs (20% - 40%). The relationship between deflection and time of heating can be described by an exponential function for the all groups of members.

Achievement results confirm the assumption that spruce wood strengthened with carbon lamella has higher resistance against to radiant heat as the unstrengthened spruce wood. The experiments are results of scientific project VEGA 1/9362/02 – "Vystužovanie drevených prvkov v stavebných konštrukciách".

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Tytuł: Odporność na obciążenia statyczne kompozytu drewnowęglowoepoksydowego w wysokich temperaturach

Отверждение карбамидоформальдегидных смол в присутствии различных катализаторов

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В российской промышленности древесностружечных плит (ДСтП) в качестве отвердителя карбамидоформальдегидных смол (КФС) в основном используют хлорид аммония. Вместе с тем мировая практика показывает неуклонное сокращение применения в технологических процессах веществ, содержащих хлор, из-за способности его к образованию токсичных веществ, например, хлорированных производных органических соединений.

Исследовали возможность замены хлорида аммония на аммонийную соль с другим анионом. Для этого выбрали соли аммония неорганических кислот, которые имеют крупные промышленные объемы производств, - серной, азотной и ортофосфорной, Сравнение их действия проводили с хлоридом аммония и более дорогим и дефицитным, но высокоэффективным отвердителем пероксодисерным аммонием, применяющимся в отдельных случаях в производстве ДСтП[1].

Для приготовления связующего использовали КФС марки КФ-МТ-15 производства АО "Метафракс" (г. Губаха Пермской обл.), которую разбавляли водой до концентрации 55%, отвердители применяли в виде 20%-ных водных растворов. Время желатинизации связующих при 100°С приведено в табл.1.

Таблица 1

Время желатинизации при 100°С КФС с латентными катализаторами

Содержание отвердителя, %	Время желатинизации, с, с отвердителем					
	NH_4Cl	$(NH_4)_2S_2O_8$	$(NH_4)_2SO_4$	NH_4NO_3	$NH_4H_2PO_4$	$(NH_4)_2HPO_4$
0,50	83,3	77,4	92,8	117	139	131
0,75	75,8	58,1	86,6	104	110	112
1,00	68,3	40,3	81,9	97,1	99,8	103
1,50	64,2	25,2	79,6	86,2	88,9	108
2,00	62,8	-	75,1	82,7	84,3	120

Экспериментальные данные показывают, что скорость поликонденсации смолы зависит от вида соли, применяемой в качестве катализатора. Известно, что отверждение КФО происходит в кислой среде. Латентные катализаторы, к которым относятся аммонийные соли, образуют кислоту при взаимодействии с формальдегидом. +Характеристикой силы кислоты в разбавленных водных растворах является константа её диссоциации или константа кислотности K_a. Вместо величины K_a по аналогии с

водородным показателем pH чаще используют соответствующее значение $pK_a = - lgK_a$. Кислоты можно разделить на очень сильные ($pK_a < 0$), сильные ($0 < pK_a < 4,5$), средней силы ($4,5 < pK_a < 9$), слабые ($9 < pK_a < 14$) и очень слабые ($pK_a > 14$) [2, стр. 395]. Аммонийные соли образуют после взаимодействия с формальдегидом кислоты, которые выстраиваются в следующий ряд: очень сильные - $H_2S_2O_8$, HCl, H_2SO_4 ($pK_a = -2,8$), HNO_3 ($pK_a = -1,32$); сильная H_3PO_4 ($pK_a = 2,12$) и средней силы $H_2PO^-_4$ ($pK_a = 7,20$) [2]. В соответствии с их константой кислотности меняется скорость процесса поликонденсации КФС, - чем ниже величина pK_a, тем быстрее идет отверждение смолы.

Для замены хлорида аммония может быть использован сульфат аммония, однако в этом случае несколько увеличивается время желатинизации смолы. Применение пероксодисерного аммония сдерживается низкой жизнеспособностью связующего при 20^0C, равной 0,7...4,0 часа, и может быть использовано в технологических потоках с раздельным нанесением компонентов связующего на стружку.

При изготовлении ДСтП в состав связующего или на древесные частицы вводят специальные добавки, которые связывают формальдегид. Наиболее широко для этой цели применяют аммиак или соединения, образующие его при горячем прессовании плит, например, карбамид. Однако в присутствии аммиака эффективность латентных катализаторов резко снижается. Так, при содержании аммиака 0,5% от массы смолы время отверждения КФС увеличивается более, чем в 2 раза.

Исследовали процесс отверждения КФС с добавкой аммиака в присутствии различных прямых катализаторов – кислот (табл. 2). Для этого отобрали очень сильную минеральную соляную кислоту и органические: щавелевую ($pK_a = 1,26$), муравьиную ($pK_a = 3,45$) и уксусную ($pK_a = 4,76$). Сравнение их действия проводили с хлоридом аммония. Содержание отвердителей – 1% от массы абс. сух. смолы.

Таблица 2

Время желатинизации при 100 ^{0}C КФС с прямыми катализаторами и хлоридом аммония в присутствии различного количества аммиака

Содержание аммиака, %	Время желатинизации, с, с отвердителем				
	NH_4Cl	HCl	$(COOH)_2$	HCOOH	CH_3COOH
0	68,3	15,2	59,7	116	315
0,50	141	69,3	85,4	91,0	330
0,75	182	83,4	103	94,5	377
1,00	228	127	124	95,9	410
1,50	370	170	139	130	546
2,00	591	217	175	158	655

Полученные данные показывают, что минеральная кислота не может быть использована в качестве отвердителя из-за низкой жизнеспособности связующего при 20^0 C (от нескольких минут до 2 ч). Среди органических кислот наибольший интерес представляют щавелевая и муравьиная кислоты, которые при содержании аммиака 0,5...1,0 % сокращают время отверждения КФС в 1,6...2,4 раза по сравнению с хлоридом аммония.

На основании проведенного исследования разработали рецептуры новых отверждающих систем, названных нами композитными отвердителями, т.к. они состоят из смеси латентных и прямых катализаторов. Композитные отвердители серии МПС содержат в своём составе катализаторы со средней и повышенной скоростью отверждения, а также катализаторы, эффективно работающие в присутствии аммиака. Отвердители серии МПС не содержат хлора. Результаты испытаний предлагаемых отвердителей представлены в табл. 3.

Таблица 3

Время желатинизации при 100^{0}С КФС с композитными отвердителями серии МПС и хлоридом аммония в присутствии различного количества аммиака

Содержание		Время желатинизации, с, с отвердителем			
отвердителя, %	аммиака, %	NH_4Cl	МПС-5	МПС-10	МПС-15
1	-	68,3	73,3	71,8	62,9
2	-	63,9	60,2	57,9	51,1
3	-	62,2	59,5	49,6	39,5
1	0,5	228	258	242	214
2	0,5	214	213	201	178
3	0,5	207	186	172	146

Композитные отвердители при содержании их 2...3 % позволяют сократить время отверждения КФС на 10...35 % по сравнению со связующим, в составе которого применяется традиционный хлорид аммония. Это может дать повышение производительности линии ДСтП за счёт сокращения цикла горячего прессования и способствовать значительному уменьшению брака от расслоения плит. Кроме того, при применении композитных отвердителей возможно дальнейшее снижение токсичности ДСтП за счёт увеличения содержания акцептора формальдегида в стружечно-клеевой смеси. Компоненты для приготовления композитных отвердителей являются недефицитными и относительно недорогими.

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Tytuł: Utwardzanie żywic mocznikowo-formaldehydowych różnymi katalizatorami.

Investigation of mechanical properties in bending thin structural pine timber

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Abstract: About 200 pieces of air dry, double edged structural timber from II North-east Poland nature forest region /Mazurian/ and general use timber from commercial sawn wood yard were tested. Their moduli of elasticity (MoE, mechanical control) are significantly correlated with bending strength, density and knot area ratio (KAR=Us, visual observation) after PN-82/D-94021. The highly significant correlation between characteristic bending strength values and modulus of elasticity of thin side boards (19-22 mm thickness, 100-115 mm width) is particularly helpful as the base of machine grading on the principle of timber elastic deflections under quasi-static loads.

Key words: Pine side boards, stress grading, visual and machine methods, structural timber, mechanical properties

Introduction

The production of pine timber in Poland in 2000 amounted according to Polish Official Statistics 2,8 million m^3, which is not tantamount with the whole of received assortments. By analogy to 1997 it is possible to estimate the real production value at about 4,5 million m^3 [Dzbeński, Korczewski 1997], what means that the thin timber of thickness 19-22 mm makes according to Polish Economic Chamber of Wood Industry at least 25%, so officially not less than 706, 4 thousand m^3 and after verification 1125 thousand m^3. Because of its limited usefulness (due to decrease of wood packages production, wood base board used in building industry etc.) this kind of timber lies unsold, although it can be used to laminar gluing or nailing structural elements under condition of previous decrement of its mechanical properties especially during bending. In hitherto existing norms relating to structural timber, only the timber of thickens above 25mm had been taken under consideration for example in PN-82/D-94021, in international regulations (ECE Standards) even above 38mm and in BS 4978 from 1973 - above 35mm; it was the version from the year 1996 when for the first time a reference to minimal thickness of 20mm occurred.

The aim of these investigation is so the experimental relating the knotting and modulus of elasticity as the factor determination the mechanical classification and expected durability of the thin timber.

Material and methods of investigation

The pine timber was obtained by two ways:

a)by sawing of 100 years old trunks of Mazurian pines from II North-east Poland nature forest region (from fresh mixed forests; forest inspectorate Strzałowo, forest district Babięty) of wood density 469-489 kg/m^3 [Krzosek 1998]

b) by purchase of 170 commercial timber pieces from "Paged S.A" in consignments of average annual rings 1,1mm.

The investigated timber was characterized by:

- estimation of annual rings and knottiness (U_s, U_{ms}) and allocation to appropriate material strength quality class (KW, KS, KG), using visual method according to PN-82/D-94021;

- determination of wood density of Mazurian timber using prototypical isotopic densimeter with americium (^{241}Am) as the source of gamma radiation of energy 59,5 keV [Krzosek 1998];
- determination of mechanical properties of timber with thickness 'g' and breadth 'b' width using two load points (like in PN-EN 408: 1998 but with some concessions concerning the fastening the arrangement for measuring the elasticity in bending) with supports spacing l=48g=96cm which corresponds with the distance between supporting rollers in common grading machines e.g. Computermatic or Rau-te Timgrader [Dzbeński 1984a]:

modulus of elasticity was measured by the arrangement with dial indicator of accuracy ±0,01 mm based on supports (so the pure bending occurred only between the load points of spacing l/3) using formula:

$$E = \frac{23\, l^3 \Delta P}{1296\, I\, \Delta f} \quad [\text{MPa}] \tag{1}$$

where:

ΔP – increment of load

Δf – increment of deflection

I - moment of inertia of cross-section

static bending strength was determined using a formula:

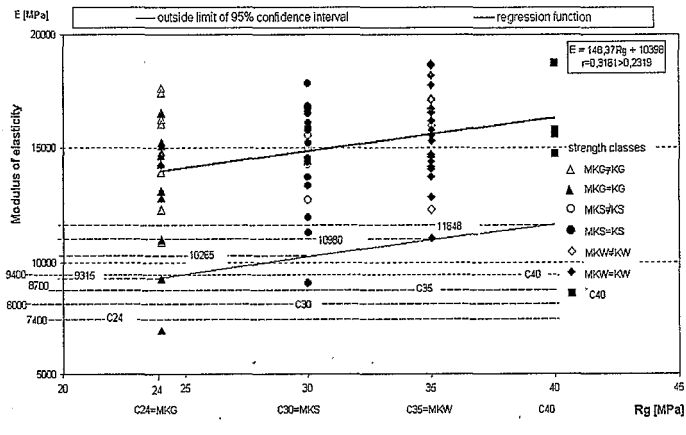
$$R_g = \frac{Pl}{bg^2} \quad [\text{MPa}] \tag{2}$$

The results of measurements were elaborated statistically using computer software: Excel and Statgraphics for analysis of variance ($\bar{x} \pm 2s$) and coefficients of regression and correlation (r) which significance was fixed according to Fisher tables [1948] for the significance level $\alpha = 0,05$ so for the confidence level 95%.

Results of investigation and analysis

In the consignment of timber graded by the visual method there were [Żur 2002]: 37% first-class (KW), 30% middle class (KS) and 33% second-class assortments (KG). Different results were obtained after mechanical grading using the modulus of elasticity measured in the half of length - here 55% of assortments belonged to MKW (so first class), 28% to MKS (middle class) and only 17% to MKG (second class). The reason of divergence of grading is occurrence of critical concentration of knots (as the criterion of visual stress grading) rather near the ends of timber and quite rarely in the half of it.

This is the reason why in the *picture 1* among timber of respective quality classes determined mechanically (MKW, KG) there are units, marked MKS, M by not blackened points, which are characterized by higher modulus of elasticity than it appears from their strength class determined by visual methods (KW, KS, KG). As a result of this, after analysing the confidence interval, its bottom limit shows the following (higher of about 20% than given by PN-EN 338: 1999)



Picture 1. System of the strength clacces

characteristic values of modulus of elasticity of timber thinner than 38mm according to PN-82/D-94021: MKG (=C24)→ 9315MPa, MKS (=C30) → 10265 MPa, MKW (=C35) → 10980 MPa and C40→ 11648 MPa. But it is necessary to add, that the real minimal experimental values are much closer to requirements given in PN-EN 338:1999, for example on the level 7000 < 7400 MPa in the MKG class, and in MKS only slightly exceeding 8000MPa. It seems that the modulus of elasticity for timber below 38 mm (*picture* 1) corresponds to the class lower timber of thickness below 25 mm.

From the *picture 2* where the variability of the modulus of elasticity in the function of knottiness (U_s = KAR) of KW class Mazurian timber is shown, also arises the overstated characteristic value of the modulus of elasticity 11108 MPa > 8700MPa, which may testify its first-class quality, but also may outcome from the small amount (about 20 pieces) of examined materials.

Commonly available, commercial timber of unknown origin shows worse properties than Mazurian timber; one of the investigated consignment (*picture 3*) has the characteristic value of the modulus of elasticity on the level 9212 MPa, so only slightly higher than standard values for KW=C30 (8700MPa) class, and some other investigated coincidently [Żur 2002] reached even 8608 MPa, so much under standard values according to PN-EN 338: 1999.

Mazurian timber (*picture 4*) graded visually according to PN-82/D-94021, shows high bending strength, reaching in the KW class characteristic value 30 MPa so corresponding to C30 strength class according to PN-EN 338:1999. This timber graded on the basis of modulus of elasticity (*picture5*) is characterized by similar bending strength also on the level 29,12 ≈ 30 MPa. Unfortunately, using the measurements of the modulus of elasticity it is difficult to distinguish between edge- and plane knots [Żur 2002].

Conclusions

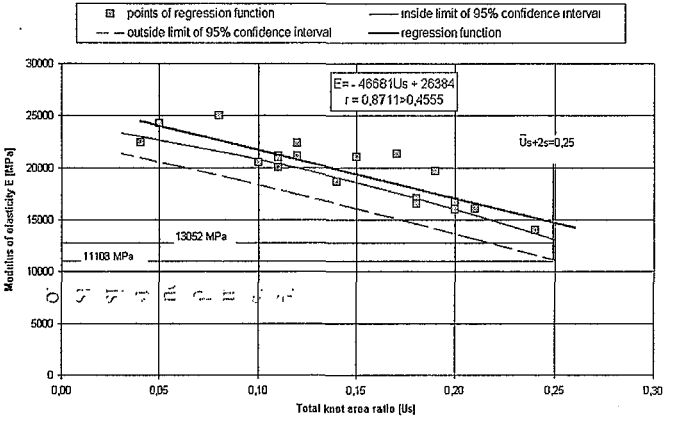
1,It is possible, with some limitations resulting from placement and kind of occurring knots, to sort the thin timber by bending machines in the ranges of wood elasticity.

2.Mechanical grading basing on elastic deflections of thin structural timber needs some correctional activities because of occurrence of critical concentration of knots and also other defects beyond of measurements zone (for example near the ends of bend assortments).

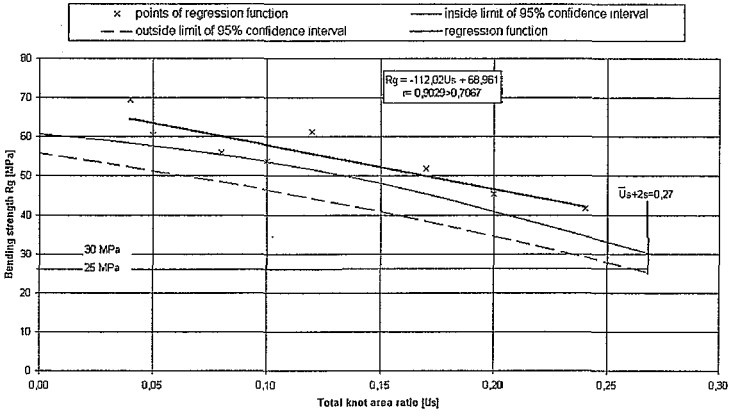
3.Characteristic static bending strength, reckoned both by amount of knots (Us=KAR) and modulus of elasticity of timber on KW class was on the level 29,12 ≈ 30 MPa, what corresponds to the C30 class according to PN-EN 338:1999. Timber of other classes undergoes suitable quality shifts: to 24MPa in KS class and to 20MPa in KG class.

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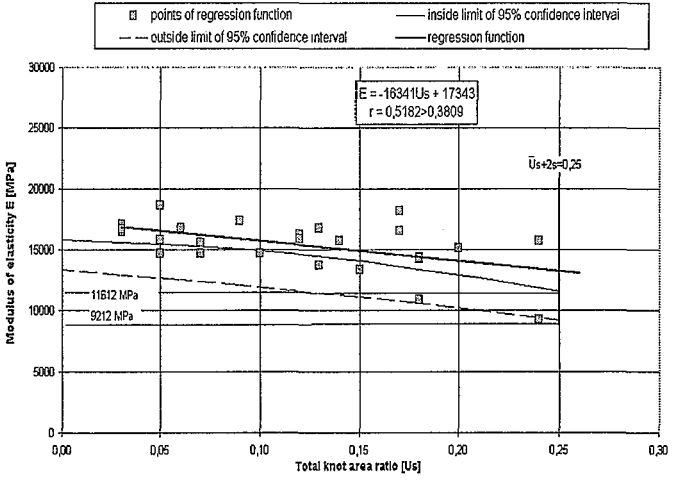
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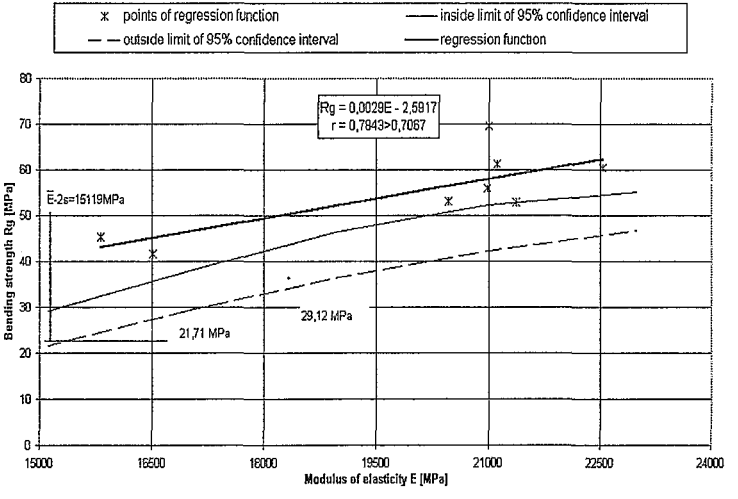
Picture 2. Characteristic modulus of elasticity in correlation to knottiness of Mazurian timber KW class



Picture 4.Knot influence on strength of bending KW class timber



Picture 3. Characteristic modulus of elasticity in correlation to knottiness of KW class timber moisture 12,5-16%



Picture 5. Correlation between beding strength and modulus of elasticity in KW class timber

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Streszczenie: *Badanie mechanicznych właściwości przy zginaniu najcieńszej tarcicy sosnowej.* Przebadano 200 sztuk tarcicy powietrzno-suchej, dwustronnie obrzynanej, pochodzącej z: II krainy przyrodniczo-leśnej (mazursko – podlaskiej) oraz tarcicę handlową. Otrzymane moduły sprężystości (MoE, klasyfikacja mechaniczna) są istotnie skorelowane z wytrzymałością na zginanie, gęstością oraz współczynnikiem sękatości ($KAR=U_S$, klasyfikacja wizualna). Wysoce istotna, znacząca zależność pomiędzy charakterystyczną wartością wytrzymałości na zginanie i modułem sprężystości tarcicy najcieńszej dwustronnie obrzynanej (o grubości 19-22 mm, szerokości 100 – 115 mm) będzie z pewnością pomocna przy sortowaniu maszynowym tarcicy, pod obciążeniem quasi-statycznym w zakresie odkształceń sprężystych.

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Charcoal production in Poland

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Abstract: Charcoal in Poland has been produced at 4 plants of wood destructive distillation as well as in field retorts. Estimated annual production in Poland is about 50 thousand tons. Annual charcoal export between 1994 and 1999 was 36 thousand tons, mainly to West Europe. Average annual import of charcoal is about 1,5 thousand tons mainly from Middle-East Europe.

Introduction

A constant development of charcoal production in Poland is being observed on the recent years. It is mainly manufactured at destructive distillation of wood factories as well as in field retorts.

Charcoal is the material of a wide range of industrial application. It has been known in ancient years – 5 thousand years ago it was used for bronze heat in Egypt.
In Poland, the increase of charcoal production has been observed in XVI century, as a result of development of metallurgical industry, especially in the regions of Świętokrzyskie Mountains and Tatra Mountains. Large amount of charcoal has been also used in forges. (Aleksandrowicz 1855, Paschalis 1973).

In modern years, until the application of coke (end of XIX century) charcoal was the only product used for metal and glass heat. 12 tons of charcoal has been used for production of 1 ton of iron.

Until the end of XIX century, the charcoal in Poland used to be produced in charcoal pits. Afterwards, the factories of destructive distillation of wood have been established. Charcoal production in pits was reactivated in the sixties of XX century in Bieszczady Mountains; production in field retorts started in the eighties, also in Bieszczady.

At present, Poland exports 36 thousand tons of charcoal yearly. However, there is a lack of information concerning total amount of annual production of charcoal in Poland.

Short characteristic of charcoal

The following products are obtained during the destructive distillation of wood: gaseous products (18%, e.g. methanol), liquid products (44%, e.g. water, wood tar, acetic acid) and solid products (38%, eg. charcoal) (Krzysik 1974).

The intensive process of carbonisation proceeds at the temperature of 350 – 450°C. Density of charcoal is between 1,38 and 1,49 g/cm^3.

Depending on the percentage of volatile fractions, two sorts of charcoal are selected: temper carbon (up to 10% of volatile fraction) and generator carbon (over 10% of volatile fraction). Generator carbon is the row material for the production of activated carbon (after glowing at the temperature of 750 – 850°C).

Two factors impact on the output of charcoal production in field retorts: Wood humidity and air temperature. From moist wood we can get up to 23% of charcoal, from dry wood (0% of humidity) – up to 35%. The lower is the air temperature, the lower is output of burn-out process; at the temperature below –20°C process in unprofitable (Głowacki 1988, Laurow 1983). According to Polish standards, maximum humidity of pit charcoal is 12%; while retort charcoal should not exceed 8%.

Charcoal production methods

1. Charcoal pits.

The technology of charcoal burn-out in pits has not been changed for centuries. The different types of pits have been used in Poland: German (most often), Slavonic and Italian; since the sixties of XX century – domestic "Bieszczady" type of retorts has been applied. Average volume of pit was about 100 stacked cubic metre of wood; the height of pits was up to 2,5 m. Yield of burn-out process, depended on tree species, wood assortment and humidity, was about 45% 45 (Aleksandrowicz 1855, Głowacki et.al. 1988, Paschalis 1973). To get 1 ton of charcoal 13 stacked cubic metre of timber was needed. The period of the process was 8 to 10 days.

2. Field retorts

Low output, long period of burn-out process and dangerous work with charcoal pits, caused the improvement of technology. As a result, the field retorts appeared at the middle of XX century. On 1978 – 1983, the new construction of steel retorts was worked out at the Department of Forest Utilisation and Engineering, Warsaw Agricultural University; new burn-out technology was elaborated as well.

Big retorts are of 3 tons weight and 10 – 11 stacked cubic metre capacity. Small retorts are of 250 kg weight and 1,5 stacked cubic metre capacity. Retorts are of cylindrical shape, locked on the top, inlet and exhaust holes are placed at the bottom part. To get 1 ton of charcoal 10 stacked cubic metre of timber is needed (Tab. 1.). Total period of burn-out process is 2,5 days on average (Głowacki 2000, Głowacki et.al. 1981, 1988, Laurow 1983).

Tab. 1. Average yield of charcoal production.

Charcoal produced in:	Wood used per ton of charcoal		Yield (in kg) from:	
	m^3	stacked cubic m	1 m^3	1 stacked cubic m
pits	9,1	13	110	75
field retorts	7,0	10	145	100
factories	5,6	8	180	125

3. Plants of destructive wood distillation.

Charcoal production process at modern industrial plants proceeds according to different technologies and uses different equipment; among others technology of fluidisation system, which allows the constant process of production.

The first plant of destructive wood distillation in Poland was build in Ostrowiec in 1873. At present there exist several factories in Poland: Hajnówka, Zawiercie, Fosowskie and Gryfino. Total potential productivity of these factories is about 30 thousand tones of charcoal annually. Average use of timber is 1 stacked cubic metre per 125 kg of charcoal; to get 1 ton of charcoal 8 stacked cubic metre of timber is needed (Tab. 1., 2.).

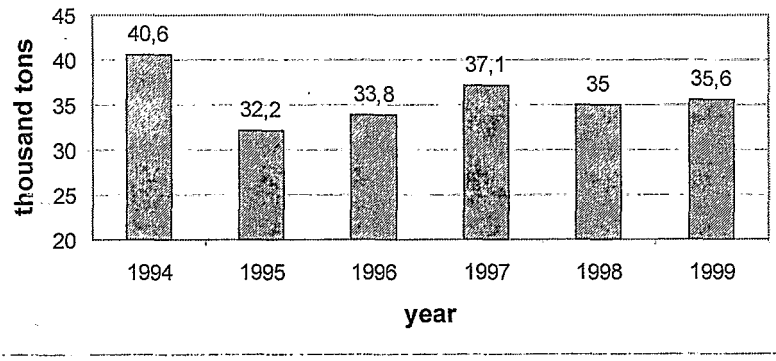
Tab. 2. Total production of charcoal at plants of wood destructive distillation in Poland between1975 and 1978.

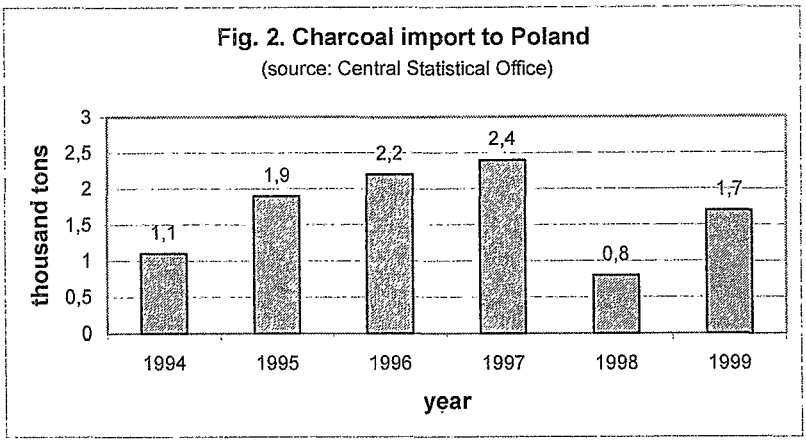
Factory	Production [thousand ton]						Avg. yield [kg per 1 stacked cubic m]
	1975	1976	1977	1978	avg.	%	
Hajnówka	13,4	13,3	13,4	13,1	13,3	49	122,7
Zawiercie	2,2	2,2	2,2	2,2	2,2	8	121,9
Fosowskie	3,8	3,3	2,7	4,0	3,4	13	131,6
Gryfino	8,1	8,0	7,8	7,9	8,0	30	126,2
Total:	27,5	26,8	26,1	27,2	26,9	100	125,7

Conclusion

The charcoal production in Poland takes place at plants of destructive wood distillation as well as in steel field retorts. There is no efficient data concerning total amount of annual production available; we can only estimate, that it is about 50 thousand tones. Only information of charcoal export and import are published: between 1994 and 1999 Poland exported 36 thousand tons of charcoal yearly, mainly to Germany (over 60%) and to Sweden (about 20%, see Fig. 1.). Average annual import of charcoal is about 1,5 thousand tones (Fig. 2), mainly from middle-east Europe. The constant growth of charcoal prices on European market is being observed.

Fig. 1. Charcoal export from Poland
(source: Central Statistical Office)





While burn-out process in retorts in Poland, the only product is charcoal, however in Chech Republic the special construction of retorts was elaborated, which allow to energetic utilisation of gaseous fraction and wood tar.

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Streszczenie: *Produkcja węgla drzewnego w Polsce.* Węgiel drzewny produkowany jest w Polsce w zakładach suchej destylacji drewna w: Hajnówce, Zawierciu, Fosowskim i Gryfinie oraz w stalowych retortach polowych.

W latach 1978-1983 w Instytucie Użytkowania Lasu i Inżynierii Leśnej (obecnie Katedrze Użytkowania Lasu) SGGG w Warszawie opracowano konstrukcję czterech stalowych retort polowych (przestawnej, segmentowej, pierścieniowej i zrębowej) oraz opracowano technologię zwęglania drewna.

Obecną roczną produkcję węgla drzewnego w Polsce szacuje się na 45-50 tys. ton. Na 1 tonę węgla drzewnego w zakładach przemysłowych zużywa się średnio 8 mp surowca drzewnego, a w retortach polowych około 10 mp.

W Polsce w latach 1994-1999 średni eksport węgla drzewnego wynosił 36 tys. ton, a import 1,5 tys. ton.

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Introduction to early fault detection and breakdown prediction of electric chain saws

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Abstract: *Introduction to and breakdown prediction of electric chain saws.* The measurement of vibration can indicate machine condition. That method of machinery monitoring, most likely, can be used for early fault detection of electric chain saws. Level-increases in certain frequency components of vibration can indicate which machine part is deteriorating.

Key words: electric chain saw, vibration monitoring

Introduction

Traditional method of chain saw machinery maintenance is method known as „Run-To-Breakdown". Nowadays it is obvious that measurement of vibration can indicate machine condition [Cempel 1989; Basztura 1996; Górski, Staroszczyk 1998]. Most likely even simple vibration monitoring system can be used for condition-based maintenance of chain saws. It is the most important that level-increases in certain frequency components of vibration can indicate which part of chain saw machinery is deteriorating [Wibracje i wstrz¹sy 1988]. The paper presents fundamentals of the relationship between frequency of vibration and nature of fault. This relationship results from kinematic scheme of standard electric chain saw and state of knowledge about vibration monitoring of machinery.

Kinematic scheme of standard electric chain saw

Getting sufficient efficiency of monophase, series, commutator motor (used in standard electric chain saw) needs high speed of rotor. Reduction, usually intersecting axis, gear is necessary. The rest of machinery is very similar to chain saw with petrol engine. Typical kinematic scheme of electric chain saw (Husqvarna 1600E) is shown in Fig.1 [Górski 2001].

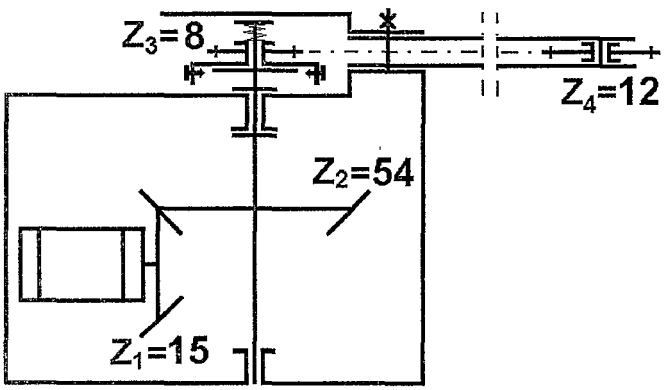


Fig. 1. Kinematic scheme of electric chain saw Husqvarna 1600E.

Relationship between frequency of vibration and nature of fault

There are a few potential, basic sources of forced vibration of electric chain saw machinery [Górski 2001]:

- damaged rolling elements bearings,
- unbalance of rotor (as a result of wear of electric motor),
- wear of gear tooth,
- wear of chain transmission elements.

Tab.1 contains vibration trouble-shooting chart for standard electric chain saw (Fig 1). The basic assumption is idle running and nominal speed of chain (15 m/s).

Tab.1

nature of fault		frequency of dominant vibration
damaged rolling bearings of motor (ball bearings)	outer race defect	2526 Hz
	inner race defect	3579 Hz
	ball defect	2290 Hz
damaged rolling bearing of driven shaft (ball bearings)	outer race defect	471 Hz
	inner race defect	769 Hz
	ball defect	448 Hz
damaged rolling bearing of guide (needle bearing)	outer race defect	923 Hz
	inner race defect	977 Hz
	needle defect	2658 Hz
rotor out of balance		407 Hz
damaged or worn intersecting axis gear		6102 Hz
damaged or worn chain transmission		908 Hz

Conclusion

Measurement and frequency analysis of vibration can be useful source of information about condition of electric chain saw machinery. It is evident, that this paper makes only introduction to condition-based maintenance of electric chain saws. Further experiments are necessary.

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Streszczenie: *Wprowadzenie do wczesnego wykrywania defektów i predykcji poważnych stanów awaryjnych elektrycznych pilarek łańcuchowych.* Drgania mogą być dobrym wskaźnikiem stanu technicznego maszyn. Dlatego właśnie monitorowanie drgań może być, najprawdopodobniej, wykorzystywane do wczesnego wykrywania defektów elektrycznych pilarek łańcuchowych. Wzrost amplitudy drgań o pewnej częstotliwości może wskazywać która część maszyny zaczyna się psuć.

The relationship between height of kerf and specific cutting resistance in chain saw woodworking process

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Abstract: *The relationship between height of kerf and specific cutting resistance in chain saw woodworking process.* The paper presents the results of experimental investigation on the above-mentioned relationship. The pine and beech samples were cross-cut during investigation. With an increase in kerf height an increase in the specific cutting resistance was observed.
Key words: chain saw, cutting resistance

Introduction

The effect basic parameters of woodworking on the cutting resistance is a traditional subject of experimental investigation [Orlicz 1982, Loth 1988, Górski 2001]. Such investigation can be useful from practical point of view - the cutting resistance is a very closely connected with energy-consuming.

Procedure of experimental research

The pine and beech samples were cross-cut during investigation. The kerf height amounted to: 35, 60, 100 and 200 mm. The chain saw operator performed 30 cuttings for 8 sample types (2 kinds of wood). Some limitation connected to the feeding force were imposed. The elements being cut were fixed with the use of rigid steel post. On the post body there were installed the contact sensor of acoustic emission (Kistler 8152B221) and piezoelectric force gauge (Kistler 9601A2). The acoustic emission signal was used in the precise determination duration of cross-cutting. The speed of chain saw was recorded with the use of photoelectric sensor, specially developed for this purpose [Górski 1998]. Value of specific cutting resistance k [MPa] for each performed cutting was determined with the equation:

$$k = \frac{1000\,P\,V\,t}{H\,L\,b} \qquad (1)$$

where:

- P [N] - mean cutting force
- V [m/s] - mean cutting speed
- t [s] - duration of cutting
- H [mm] - height of kerf
- L [mm] - height of sample
- b [mm] - width of kerf.

Results and discussion

The results of experimental research are shown in Fig 1. Values of specific cutting resistance were averaged for 8 samples types. For pine and beech samples the investigated relationship is as follows: with an increase in kerf height an increase in the specific cutting

resistance was observed. It is evident from data presented in the Fig. 1, that (when it is possible) operator of chain saw should avoid increasing in kerf height.

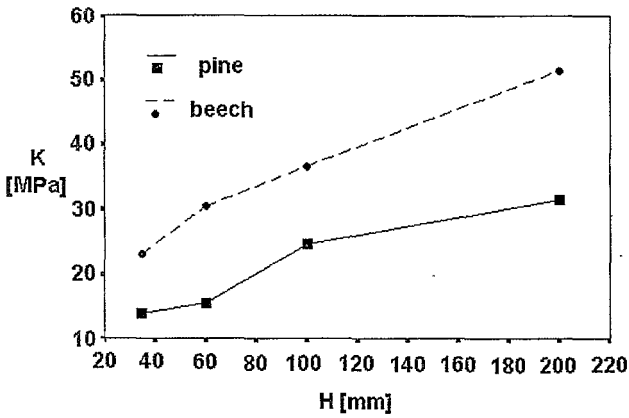


Fig. 1. The relationship between height of kerf (H) and specific cutting resistance (k).

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Streszczenie: *Zależność między wysokością rzazu a jednostkowym oporem skrawania dla piłowania drewna pilarką łańcuchową.* Artykuł prezentuje wyniki badań eksperymentalnych dotyczących powyższego zagadnienia. W trakcie badań piłowano próbki sosnowe i bukowe. Zaobserwowano, że wraz ze zwiększaniem się wysokości rzazu następował wzrost jednostkowego oporu skrawania.

Mechanical properties of window frame a new construction

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Abstract: Set of a new construction window frame was made. The idea of new construction was assembly of window frame using screws, dowels, tubes and finished single rails and using rail window frame type WS-6000 (this type of window is made in window and door factory in Włoszczowa). To choose the best window frame construction the test of load capacity was made and stiffness of corner joints was determined. As a result of research two types of corner joint were chosen. They had better stiffness characteristic than traditional glued corner joint type WS-6000 however characteristic load capacity according PN Standard was lower.

Key words: mechanical properties, window frame, stiffness of corner joint, characteristic load capacity of corner joint, new window construction

Material

Corner joints were made of pine wood traditional tenon mortise glued joint and new construction with screws or glued dowels or steel tube. The rails had profile like window frame type WS-6000 (Fig. 1). This window type is made in factory of windows and doors in Włoszczowa. Then types of corner joints were tested. Two types with the highest stiffness were chosen - type 9 and 10 (Fig. 2, 3).

Methods

Characteristic load capacity was determined according PN-88/B-10085/A2 using testing machine TIRA TEST 2300 (Fig. 4).

Characteristic load capacity was calculated according formula

$$F_{vk} = F_{vm} - t_{\alpha} \cdot s \qquad [1]$$

where: F_{vm} - average load capacity, t_{α} – coefficient for normal distribution for coefficient level 0,05; t_{α} =2,12, set quantity n = 16 (traditional), t_{α} =2,15, n = 14 (type 9), t_{α} =2,31 n = 8 (type 10), S – standard deviation.

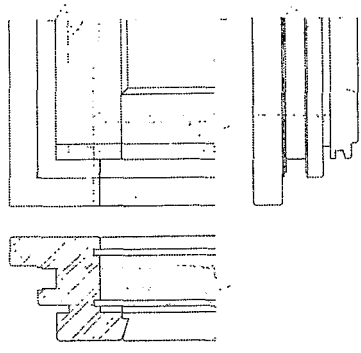


Fig. 1
Corner of window frame type WS-6000 without tenon and mortise used for joint by screws and dowels (4).

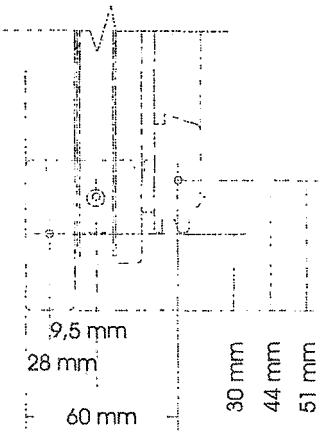


Fig. 2.

One of chosen types of corner joint - type 9.
Screw core 3,8 mm, length 110 mm in tube,
2 dowels Ø8x40mm.
Screw in tube in central position, dowels from left and right side (4).

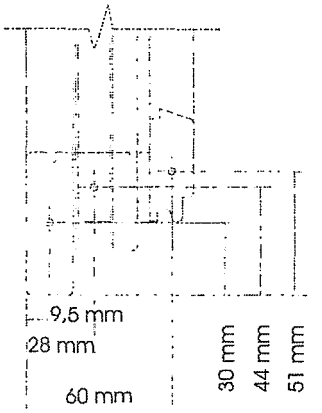


Fig. 3.

Second of chosen types of corner joint - type 10.
Screw core 5,5 mm, length 125 mm,
2 dowels Ø8x60mm.
Screw in central position, dowels from left and right side (4).

Stiffness of corner joints was determined according author's procedure (Fig. 5). Stiffness coefficient was calculated according formula:

$$K = \frac{\Delta M}{\Delta A} \qquad [2]$$

where: K – stiffness coefficient [N], $\Delta M = r \cdot (F2 - F1)$ moment change [N],
$\Delta A = A2 - A1$ deformation change [m].

New construction of window frames corners type 9 has characteristic load capacity on the level 40% of characteristic load capacity of traditional glued joint type WS-6000 and type 10 on the level 54% (Fig.6). Characteristic load capacity of new construction window is below requirements of PN (700N for single frame window construction). Stiffness of new window construction corner joint type 9 is on the level 157% of traditional glued construction and 161% for type 10 (Fig. 7).

Conclusions

1. New construction window frame with screw and dowels has a higher stiffness corner joint than traditional tenon mortise glued construction.

2. Characteristic load capacity of new window construction is lower than traditional tenon mortise glued construction and below Polish Standard requirements.

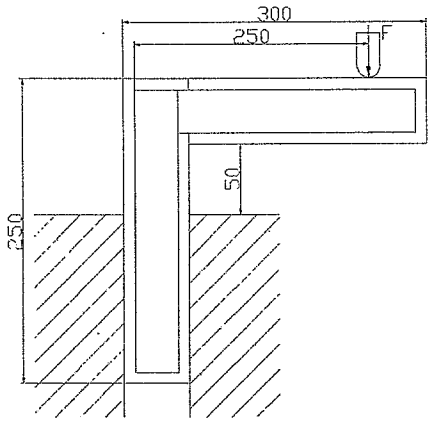


Fig. 4. Scheme of loading (4).

Results and analysis

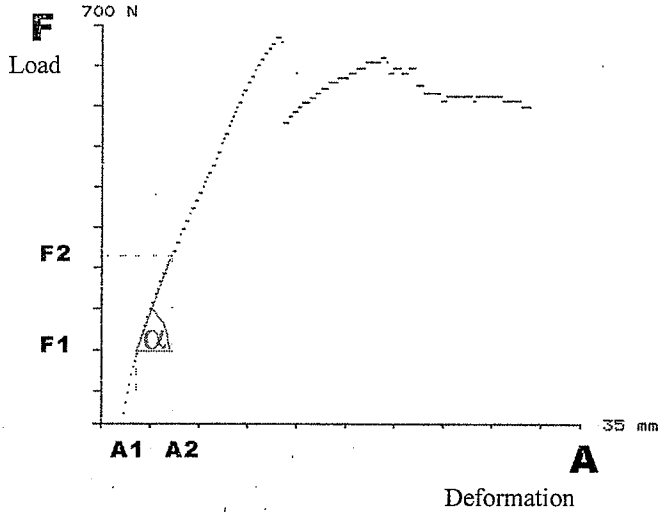


Fig. 5. Load F - deformation A. F1=100N, F2=400N (4)

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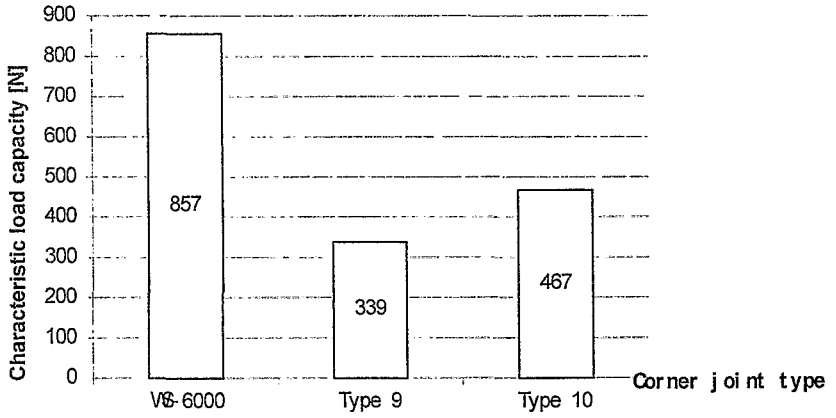


Fig. 6. Characteristic load capacity of different types corner joints.

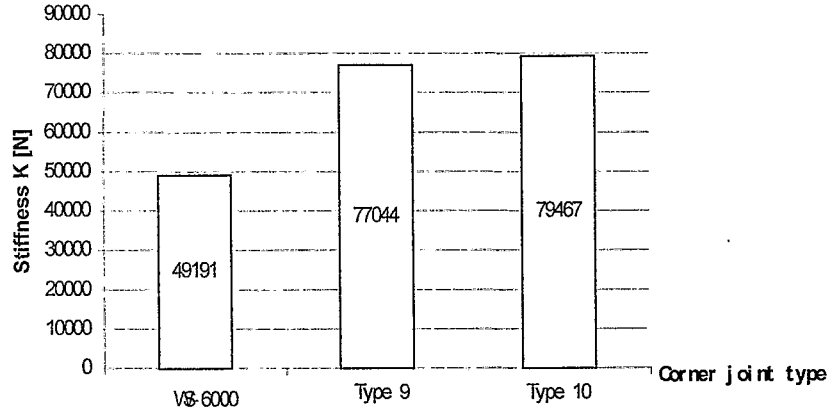


Fig. 7. Stiffness of different types corner joints.

Streszczenie: *Mechaniczne właściwości skrzydeł okiennych nowej konstrukcji.* Wykonano zbiór dziesięciu połączeń narożnikowych ramiaków skrzydła okiennego nowej konstrukcji. Nowość konstrukcji polegała na tym, że do połączenia wykończonych ramiaków o przekrojach zbliżonych do tych w konstrukcji okna WS-6000 (produkowanych w Zakładzie Stolarki Budowlanej S.A. we Włoszczowie) wykorzystano śruby, kołki i metalowe tulejki. Przeprowadzono określenie nośności i sztywności wykonanych połączeń narożnikowych. Dla wybranych dwóch połączeń nowej konstrukcji, o najwyższej sztywności i dla połączenia jak w oknie typu WS-6000, wykonano określenie nośności charakterystycznej zgodnie z PN-EN i sztywności według własnej procedury na zbiorach kilkunastoelementowych. Narożniki konstrukcji skręconej charakteryzowały się wyższą sztywnością niż narożniki konstrukcji tradycyjnej, klejonej typu WS-6000, jednakże ich nośność charakterystyczna określona zgodnie z PN była niższa.

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Chemische Untersuchung der Holzarten

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Abstraakt: *Chemische Untersuchung der Holzarten.* In dem nachfolgenden Beitrag wird ein kurzer Abriß der Wissenschaft über die Chemie des Holzes zitiert, der in der Mitte des 18. Jahrhunderts entstanden ist und aus einem Lexikon vom Ende des 18. Jahrhundert stammt.

Die Fundamente für die Wissenschaft von den Gesteinen, die Mineralogie, und von den Erzen, die Metallurgie, wurden durch Georg Agricola (1494-1555), der Rektor, Arzt, später Stadtphysikus und Bürgermeister von Chemnitz war und der 1530 die erste systematische Mineralogie, ein Buch mit dem Titel „De re metallica" geschrieben hat, gelegt.
Eine ähnlich grundlegende Behandlung von Vorkommen, Eigenschaften, Bearbeitung und Veredelung des Holzes gab es nicht. Hier gab es nur einzelne Untersuchungen über den Holzschutz und die Holzverkohlung, die eine sehr lange Vergangenheit hinter sich hatten [Kollmann 1985] .
Obwohl Holz einer der wichtigsten Naturstoffe ist, sind Untersuchungen über die Chemie des Holzes sehr schwierig, weil das Holz einen überaus verwickelten biochemischen Komplex darstellt, in dem die schon an sich sehr komplizierten Fragen des chemischen Baus der hochmolekularen kolloiden organischen Hauptbestandteile nicht für sich gesondert untersucht werden können, sondern stets im Zusammenhang mit den letzten Endes physikalisch-chemischen Kräften studiert werden müssen, die sich aus dem Zusammenwirken botanischer, anatomischer, physiologischer und biologischer Einflüsse auf das heterogene System Holz ergeben [Kürschner 1962].
Es ist deshalb kein Wunder, daß die Chemie der drei Hauptbestandteile der Holzes erst vor ungefähr 150 Jahren ihren Anfang genommen hat.
In dem nachfolgenden Beitrag möchten wir einen kurzen Abriß der Wissenschaft über die Chemie des Holzes zitieren, der in der Mitte des 18. Jahrhunderts entstanden ist *) und aus einem Lexikon vom Ende des 18. Jahrhundert stammt.
„Die Grundstoffe der Holzarten sind, wie bey allen Gewächsen: Wasser, Oel, Salz, Erde. Das Wasser ist nach seiner Absonderung von den übrigen Bestandteilen ohne Geschmack und Geruch und kommt mit den reinen gemeinen Wasser völlig überein. Die Erde zeigt alle Eigenschaften der Kalkerde. Die salzigen Stoffe sind theils flüchtig, theils fix. Die flüchtigen salze trenn man von dem übrigen Grundstoff durch die Destilation: um aber die fixen zu erhalten, verbrennt man das Holz und lauget die Asche aus. So erhält man das fixe Alcali. Flüchtige Säure findet man in allen Gewächsen überhaupt, nur in verschiedener menge. Mit hülfe des Feuers erhält man auch ein wesentliches Oel, d.i. ein sehr flüchtiges Oel, welches einen starcken Geruch völlig so wie die Holzart hat, woraus man es erhält, und welches vom Weingeiust ganz aufgelöset wird. Es heißt auch ätherisches Oel. Einige wesentliche Oele sind leichter, andre schwerer als Wasser. Die dicken oder fetten Oele sind viel weniger flüchtig, haben nur einen schwachen Geruch und werden vom Weingeist nicht aufgelöset. Sie sind beym gewöhnlichen Grade der Luftwärme in den Zwischenräumen der Gewächsstoffe flüssig erhalten wie in den Bucheckern , Haselnüssen und andern ölreichen Saamen. Einige dicken Oele erhält man daher leicht durch uspressen mittels erwärmter Pressen, andre hingegen sind mit dem übrigen Gewächsstoffe vester verbunden, mindder flüchtig als die wesentlichen Oele und erfordert starke Hitze. Um in Dämpfe aufgelöset zu werden. Die meisten Oele ober sind leichter als Wasser, und bey allen ist wohl eine Säure mit dem brennbaren verbunden. Ein

vierter einfacher Stoff ist der luftartige Stoff.. Er erzeugt sich, wenn man Holzarten mit Hülfe des Feuers zerlegt. Der auszugartige, zusammenziehende Stoff wird aus der Eiche , der Weide und andern Holzarten erhalten.

Vor der chemischen Zerlegung ist die Säure in den Holzarten mit dem alkalischen erdigen Stoffe und dem Brennbaren verbunden. Mit letztern scheint sie die Oele zu bilden, mit dem alkalischen Stoffe den auszugartigen Stoff. Aus ihrer Verbindung mit dem wesentlichen Oele entsteht das Harz, und aus der Verbindung der Säue mit dem fetten Oele das Gummi. Da nun die Säure und das Oel, wie bereits erinnert wurde, in verschiednen Holzarten von verschiedner Beschaffenheit sind: so ist auch das Gummi und das Harz nicht in allen Holzarten einerley. Beyde Gewächssäfte sind schon mehr zusammengesetzte Stoffe.
Einige Arten derselben, sind schwerer als Wasser mit wenigen Ausnahmen, und die Harze sind insbesondere durch eine Säure erhärtete wesentliche Oele. Wahrscheinlich aber rührt die grüne Farbe der Blätter vornemlich von dem harzartigen Stoffe der Gewächse her: denn wenn man Blätter in Wasser kocht, verlieren sie nur wenig von ihrer grünen Farbe und auch dies geschieht nur langsam. Man muß viel Wasser nehmen und das Kochen oft wiederholen, um die Farbe merklich zu schwächen. Läßt man sie hingegen in Weingeist kochen; so verlieren sie ihre grüne Farbe sehr bald: denn der Weingeist löset die Harze auf. Weil sie viel Oel und wenig Säure enthalten: so sind sie entzündbar und lösen sich in Wasser nicht auf. Als welches Oel nicht anders, als vermittelst eines dazwischen trettenden salzigen Soffes auflösenn kann. Der Weingeist aber löset die wesentlichen Oele auf und verbindet sich auch mit Säuren, und hieraus ergiebt sich der Grund, warum er auch die Harze auflöset. Eine solche Harzauflösung in Weingeist giebt den Lackfirniß.

Die Gummen enthalten viel mehr Säure, als die Harze, und wenigsten aber fettes Oel. Sie sind also natürliche Seifen. Der Weingeist, dessen Verwandtschaft mit der Säure des Gummi schwächer, als mit andern Säuren ist, löset sie nicht auf. Aber dagegen lösen sich die Gummen im Wasser auf. Indessen kennt man die Art., wie die Säure und das Oel im Gummi vereinigt ist, noch nicht eigentlich. Es giebt aber auch Gewächsäfte, welche Gummi und Harz zugleich un ihrer Grundmischung enthalten, und daher zum Theil vom Wasser, zu Theil vom Weingeist aufgelöset werden. . Von diesen drey Gewächssäften sind endlich noch die natürlichen Balsame zu unterscheiden, worunter man ölichte aromatische Säfte versteht, die in Harzgestelt aus manchen Bäumen hervortreten (Terpentin), aber wegen einer gewissen Menge eines damit noch verbundenen wesentlichen Oeles weicher und flüssiger, als Harz sind."

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4. Kürschner Karl, 1962: Chemie des Holzes. VEB Deutscher Verlag der Wissenschaften Berlin.

*)Der Verfasser des Abrisses, Müller Gerhard Andreas, wurde geboren zu Ulm am 23. Februar 1718, studierte in Tübingen und später in Straßburg Naturwissenschaften und Medicin. Nachdem er 1740 promovirt , wurde er Stadtphysicus in Worms, 1743. wurde er als

Garnisonarzt nach Weimar berufen und erhielt kurze Zeit darauf die Aufsicht über die fürstliche Bibliothek, Hierdurch wurde er veranlaßt seine Studien hauptsächlich den Naturwissenschaften zu widmen und er veröffentlichte verschiedene Aussehen erregende Werke. Nachdem Müller 1750 einem Rufe als Leibarzt des Grafen von Sedlnicki gefolgt war, wurde er 1751 zum Professor der Anatomie, Chirurgie und Botanik nach Gießen berufen. In dieser Stellung scheint er sich ganz den medicinischen Wissenschaften gewidmet zu haben, wenigstens hat er nur derartige Schriften veröffentlicht. Müller starb am 26. Februar 1762.[ADB 1886]

Die in der Arbeit zitierten Abhandlungen befinden sich in der Universitätsbibliothek in Warschau, Abteilung Alte Drucke.

Streszczenie:*Chemiczne badania drewna.* W artykule opisano stan wiedzy na temat chemicznej budowy drewna na podstawie osiemnastowiecznej literatury leksykograficznej.

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Holzcabinette des 18. Jahrhunderts.

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Abstrakt: *Holzcabinette des 18. Jahrhunderts:* In dem Artikel wurden einige aus der damaligen Literatur bekannte und teilweise bis heute erhaltene „Holzcabinette" beschrieben.

Der zeitgenossischen Fachliteratur sind nachfolgende Zitate entnommen.
Holzcabinette nennt man eine Sammlung von Holzarten. Ehermals war in Amsterdam das Cabinett des Albertus Seba[1)] bekannt, ferner das Hizellische in Coblenz, das Linkische [2)] in Leipzig. das Clodiusische in Zwickau, und die Holzsammlung im Dresdner Naturaliencabinett. [Deutsche Encyklopedie 1790]

Allein alle diese Holzsammlungen übertrifft die Schildbachische in Cassel [3)], von welcher das Journal von und für Deutschland 1789 eine weitleufige Beschreibung geliefert hat. Sie enthält mehr als achtzig Geschlechter, und 340 Abarten im Bücherformat, wobei die Größe und Tiefe des Buchs nach den Blättern, Blumen und Früchten der gewählten Holzart gemäß, eingerichtet ist. Der Rücken an jedem dieser Bücher zeigt a) die Schaale oder Rinde der Holzgattung, woraus das ganze Buch bestehet. b) Ein rother Titel, welcher mit goldnen Lettern nach Linneischer Ordnung, Classe, Geschlecht und speziellen Namen in lateinischer und deutscher Sprache nicht nur angiebt, sondern auch die vorzüglichsten Authoren bemerckt. Bey den harzführenden Bäumen c) ihre Harze auf eine die Natur nachahmende Art angesetzt. Endlich d) die Moose, welche aus der Schale oder Rinde entstehen. Der obere Schnitt des Buches zeiget das queer durchschnittene junge und Mittelholz mit seinen mark= und ringförmigen Ansätzen, an welchen man mittels eines Vergröserungsglases, die verschiedenen Gefäße der Pflanzen erkennen kann. Der untere Schnitt des Buches bestehet aus ganz altem Stammholz, queer durchschnitten; der aufmerksame Beobachter siehet hieran ohne viele Mühe, wie das Mark und die Gefäße mehr zusammengedrückt sind, wodurch das Holz seine Härte erlanget hat. Die obere breite Seite des Buches läßt sich durch einen Schieber öffnen, und diese obere Seite ist das unreife oder Splintholz. Die untere breite Seite des Buches zeigt das mittelmäßige Span= oder Spiegelholz, und läßt die Beobachter von dessen Güte und Schönheit urtheilen. Der vordere Schnitt giebt das ganz alte abständige Holz an. Man findet ferner auf diesem vordern Schnitt a) ein Stück poliertes Masernholz, unter diesem b) die Schwammart, die sich bei der Fäulniß des Holzes ansetzt. c) einen Cubiczoll des besten Holzes, welches die drey specifischen Schweren 1) beim flüchtigen Saft im Frühjahr, 2) beym reifen Saft im Herbst, und 3) wenn das Holz durch die Länge der Zeit ganz trocken geworden ist, nach medizinischen Gewichte bestimmt. d) ist der Grad der Hitze darauf bemercket, welches die Flamme eines Cubiczolles in dem Raume eines Cubicfußes eines Eisenblechofens bey temperierter Witterung nach Fahrenheit und Reaumúr verursachet. e) die Verminderung der Größe und des Gewichts von einem Cubiczoll glühender Kohle in dem oben bemerckten Raum genau angiebt. g) Hierunter endlich findet man den bekannten Nutzen der Pflanze, wie auch den Grund und Boden, welche die Holzart vorzüglich liebt, beschrieben. Die ganze Naturgeschichte der Pflanze, besonders der feineren Theile, oder der Ernährungs= und Befruchtungswerkzeuge, ist in dem innerern Raume des Buchs enthalten. Man siehet auf dem Boden den Saamen und dessen Gehäuse, nach Tournefort. Zur Rechten stehet der Keim mit der Wurzel, den Fettblättern, der Samenkapsel, und den beyden ersten Blättchen. In der Mitte selbst siehet man einen Ast von der Pflanze an welchem man von unten die Trag= und Wasserreißknospen bemerckt, wie sie nach verdünnten Saften treiben,

und getrieben haben; dann die verschiedenen stufenweise größer gewordnen grünen Blätter; jede Art in ihrer natürlichen Farbe. Zur Seite gegen den Ast findet man den Monat der Blütezeit, die kleinen Blüthenknospen, stufenweise bis zur Schließung des Fruchtknotens mit Griffel und Staubfäden nach Linneischer Ordnung; dann die abgeblüheten, welk und trocken gewordenen Blumen; die angesetzte kleine Frucht ebenfalls stufenweise von der ersten Entstehung bis zur Vollkommenheit und endlichem Absterben, wie auch den Monat bemerckt, worinnen die Frucht zur vollkommenen Reife gelanget. Auf der linken Seite zeiget sich endlich ein Skelet von einem Blatte.

Eben so merkwürdig ist das Holzcabinet des um die Forstwissenschaft so verdienten Herrn von Burgsdorf [4]. Es enthält dasselbe: 1) Die aus dem Saamen keimenden Holzpflänzchen, nach ihren Entwickelungen, Verstärkungen, inner und äussern Zufällen an Wurzel, Stamm und übrigen Theilen, bis nach gleichsam überstandenen Kinderkrankheiten, oder bis die Pflanzen, ihrer zunehmenden Größe wegen, aufgetrocknet, in einer todten Sammlung nicht füglich mehr Platz haben würden. 2) Die Hölzer selbst, als das vornehmste Product der Förste, in geviertheilten, oder nach Beschaffenheit der Stärke noch mehr gespaltenen kurzen Klötzchen, woran die äussere Rinde, die Safthaut, der Splint, das reife Holz und der Kern zu sehen sind, und zwar auf der einen Seite gehobelt und poliert, auf der andern aber, um die Fibern besser betrachten zu können, ohne alle Bearbeitung. Die andere horizontale Fläche des Holzchens ist polirt, um die Structur des Holzes in den Jahrringen zu erkennen, welches zugleich das Mittel der deutlichen Wahrnehmung der Röhren, und zugleich, der mehrern und mindern Vestigkeit des Holzes, abgiebt. Die andere horizontale Fläche des Klötzchens, oder das sogenannte Herrenholz bleibt rauch, wie es die Säge gewöhnlich lässet. 3) Die Blätter als wesentliche Sommerkennzeichen der Geschlächter und Arten, gepreßt aufgetrocknet, und sowohl nach der untern als obern Fläche nebst den Stielen, auf weißem Papiere bevestigt. 4) Die Blüthen ganz und stückweise nach ihren einzelnen Theilen. 5) Die Früchte oder Saamenbehältnisse getrocknet, und auf Tafeln aufgesetzt. 6) Die einzelnen reinen Saamen, in Schachteln oder Gläsern. 7) Die im Winter gesammelten Zweige ohne Laub, oder mit den Knospen und Augen, deren Sitz und Gestalt wesentliche Geschlechtsunterscheidungszeichen abgeben. 8) Einzelne, theils inn=, oder äussere Zufälle und Naturbegebenheiten an den Bäumen und Sträuchen, um den Ursachen und wirkenden Kräften nachspüren, und von Zeit zu Zeit immer gründlicher von Dingen urtheilen zu können, die, ob sie uns gleich oft vor Augen liegen, dennoch aus Mangel hinlänglicher Beobachtung noch nicht so klar und deutlich erwiesen sind, als es wohl seyn sollte.

Herr Bellermann [5] [Bellermann 1788] bietet den Liebhabern eine Sammlung von Holzarten für einen sehr mäßigen Preis an. Die Stücke sind in Form der Taschenkalender geschnitten; an jedem ist Kern, Jahrwuchs, Splint und Rinde. Letztere macht den Rücken aus, worauf der Linneische Name wie ein Buchtitel gedruckt ist. Holzarten, die nicht solche Stärke erreichen, sind zusammengesetzt. Sechs Holztafeln nebst aufgeklebten Titeln, sechs iluminierte Kupfertafeln, und sechs Blätter Text, kosten einen halben Ducaten.

Im Forst=Archiv [1792] schreibt Kandidus Huber, Pfarrvikar daselbst, Ebersberg in Baiern den 20sten des Christm. 1791 unter dem Titel „Ankündigung einer natürlichen Holz=Bibliothek": ...Ich habe zwar bisher verschiedene Holzsammlungen gesehen, z.B. eine Art von Schubläden, worinn Laub und Saamen enthalten waren: schön gehobelte Holzplatten mit dem Namen der Holzart u.s.w. Aber in Form natürlicher Bücher, die man eben so, wie andere Bücher eröfnen und schließen kann, und die gleich einer Bibliothek in einem Naturalienkabinete, oder sonst in einem Schranke aufgestellt werden können, habe ich nie weder gesehen, noch davon gehört, oder gelesen (Bellermanns Holz=Kabinet scheinet dem K.H. nicht bekannt zu seyn A.d.H.).Um nun Liebhabern der Forstbotanik, und den Vorstehern der Naturaliencabinette etwas nützliches und erwünschtes in die Hände zu liefern, und hauptsächlich auch, um in unserm Vaterlande zur Verbreitung der so nöthigen, und doch fast

durchgehends mangelnden wissenschaftlichen Kenntniß unserer einheimischen Holzarten etwas beyzutragen, kündige ich eine ganz neue, natürliche Holz=Bibliothek auf Subscription an.

Die Bibliothek besteht aus 100 Bänden meistens von einheimischen wilden Holzarten, in welchen Holz, Blüthe, Laub, Winterzweige, und Saamen jedesmal nach seiner Art enthalten sind. Alle Bände sind nach Beschaffenheit des Wuchses in 7 Höheklassen eingetheilt. Der Band der Bauholze ist 10 Zoll: vom Baumholze der ersten Größe 9 Zoll: der zweyten Größe 8 Zoll: der dritten Größe 7 Zoll: vom ganzen Strauche 6 Zoll: vom halben 5 Zoll: von rankenden Strauche und Erdhölze 4 Zoll hoch. Bey jedem Bande sieht man von außen rückwärts die natürliche Rinde eines jeden Baumes oder Strauches, worauf oben mit ausgezeichneten Goldbuchstaben der beste, deutlichste, und nach Maßgebung des Herrn von Burgsdorf billig in Deutschland überall anzunehmende Name steht, seitwärts von außen sieht man, wie sich das Holz durch den Hobel bearbeiten läßt: auf der obern Fläche sind der feine Schnitt und die Jahresauswüchse angebracht; auf der untern zeigt sich die Sägearbeit...

Auch im 19 Jh. gab es solche Holzsammlungen, die sogar durch den Buchhandel zu beziehen waren, so die vorzüglichen 'Querschnitte von Nördlinger [6] (11 Bde, jeder mit 100 aufgeklebten Querschnitten der Holzarten, Stuttgart 1852-1888) und von Burckhardt [7] „Fünfzig Querschnitte der in Deutschland wachsenden Bau=, Werk= und Brennhölzer, Stuttgart 1858).

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   Frankfurt am Mayn bey Varrentrapp und Wenner.

3 Bellermann Joh. Bartholomäus.1788: Abbildungen zum Cabinet der vorzüglichsten Holzarten , nebst deren Beschreibung. Erfurt

4 Forst=Archiv zur Erweiterung der Forst= und Jagd=Wissenschaft und der Forst= und Jagd= Literatur herausgegeben von Wilhelm Gottfried von Moser. Zwölfter Band Ulm 1792. Bd. 12 1792

5 Journal von und für Deutschland , hrsg Sigmund von Bibra. Frankfurt am Main 1789

[1] Seba Albertus, holländischer Naturforscher und Sammler, geb. 1663 zu Etzeln in Ostfriesland, gest. 1736 als Apotheker zu Amsterdam. Er schrieb „Locupletissimi rerum naturalium thesauri accurata descriptos (4 Bde mit 450 Kupfertafeln in Folio, Amsterdam 1734-1765) [Brockhaus' Lexikon 1898].

[2] Link Heinrich Friedrich, Botaniker geb. 2 Febr. 1767 zu Hildesheim, studierte zu Göttingen Medizin und Naturwissenschaften, wurde 1792 ordentlicher Professor der Naturgeschichte, Chemie und Botanik zu Rostock. 1811 wurde er Professor der Chemie und Botanik zu Breslau, 1815 zu Berlin, wo er als geh. Medizinalrat, Professor und Direktor des Botanischen Gartens starb. Autor vieler wiss. Bücher. [Brockhaus' Lexikon 1898].

[3] Es handelt sich um die Holzbibliothek des Tierpräparators und Naturforschers Schildbach, der vor über 200 Jahren in Kassel ein Nachschlagewerk zu sämtlichen der Region vertretenen

Baumarten anfertigte, indem er in Buchform aus dem Holz und der Rinde des Baumes einen Kasten baute, in den er Blätter, Blüten, Früchte und Samen des Baumes sowie Blütennachbildungen und genaue Beschreibungen legte. Sie ist heute eine der Attraktionen des Naturkundemuseums Kassel.

[4] Burgsdorf Friedrich August Ludwig von. Forstmann , geb. 23. März 1747 zu Leipzig, trat jung in französische Kriegsdienste, mußte aber, als er den Neffen des Generals Valières beim Spiel tödlich verwundet hatte, flüchten, kam 1762 nach Georgenthal in Thüringen, um sich für den Forstdienst auszubilden, wurde 1764 Jagdpage am gothaischen Hofe und bereiste von 1767 an Deutschland, England, Holland und Frankreich. Nach seiner Rückkehr hörte er forstbotanische Vorlesungen bei Gleiditsch in Berlin, kaufte 1777 eine Forstsekretarstelle, mit der die Verwaltung des Tegeler Forstreviers bei Berlin verbunden war, legte ausgedehnte Pflanzungen an, richtete einen Samenhandel ein und betrieb namentlich die Einführung fremder Holzarten. 1787 wurde er von Friedrich Wilhelm II. mit dem Unterricht der Jagdpagen und der Herausgabe eines Forsthandbuchs beauftragt. Als Direktor der Forstakademie in Berlin und Geh. Forstrat hielt er nun stark besuchte öffentliche Vorlesungen. Er starb 18. Juni 1802 in Berlin. Verfasser etlicher Lehrbucher, wie „Beiträge zur Erweiterung der Forstwissenschaft" (Berlin 1780), „Versuch einer vollständigen Geschichte vorzüglicher Holzarten in systematischen Abhandlungen", ein epochemachendes Werk - es erschienen nur zwei Teile „Die Buche" (Berlin 1783) und „Die einheimischen und fremden Eichenarten" (Berlin 1787, 1800) [Brockhaus 1898].

[5] Bellermann Johann Bartholomäus. Geb. 1756, Geschäftsmann. [Hamberger/ Meusel 77.393].

[6] Nördlinger Hermann von. Forstmann, geb. 13. Aug. 1818 in Stuttgart, studierte in Tübingen und Hohenheim, wurde 1842 Professor an der franz. landwirtschaftlichen Schule zu Grand-Jouan in der Bretagne, 1845 an der Akademie Hohenheim, 185o trat er in den ausübenden Staatsdienst, übernahm jedoch 1855 die erste forstliche Professur sowie die Leitung der Oberförsterei in Hohenheim. Als 1881 die forstliche Abteilung der Akademie Hohenheim an die Universität Tübingen verlegt wurde, wirkte er dort bis 1887, trat dann als Oberforstrat in den Ruhestand und starb 19. Jan. 1897 in Ludwigsburg. Autor sehr vieler Bücher über die Forstwissenschaft, u.a. Die technischen Eigenschaften der Hölzer für Forst- und Baubeamte, Technologen und Gewerbetreibenden, Stuttgart 1860 [Brockhaus 1898].

[7] Burckhardt Heinr. Christian. Forstmann, geb. 26. Febr. 1811 zu Adelsleben bei Göttingen, trat 1828 in des hannov. Feldjägerkorps, studierte 1833-34 in Göttingen und wurde dann im königl. Wald= und Inspektionsdienste beschäftigt; 1835 nahm er Privatdienste, später trat er in den königlichen Dienst zurück. Von 1844 bis Mitte 1849 war er Lehrer und Revierverwalter an der Forstschule zu Münden. Nach deren Aufhebung wurde er als Forstrat später Oberforstrat in die hannov. Domänenkammer berufen. 1858 als Forstdirektor und Generalsekretär in Forstsachen in das Finanzministerium berufen. Er war auch Mitglied des Staatsrats. Als Hannover 1866 an Preußen überging, verblieb er in seiner Stellung mit der Funktion eines preuß. Oberforstmeisters. 1883 wurde ihm bei Hannover ein Denkmal errichtet. Sein Hauptwerk „Säen und Pflanzen nach forstlicher Praxis" Hannover 1855.

Die in der Arbeit zitierten Abhandlungen befinden sich in der Universitätsbibliothek in Warschau, Abteilung Alte Drucke.

Streszczenie:*Osiemnastowieczne gabinety drzewne.* W artykule opisano zbiory osiemnastowiecznych ksylotek z Drezna, Kassel, Koblencji, Lipska i Zwickau. Ksyloteki te zwane wówczas gabinetami drzewnymi posiadały bardzo bogate zbiory obejmujące różne gatunki drewna pozyskane z pni i gałęzi drzew, a także próbki drewna pokazujące wady i ślady obróbki po różnych narzędziach stolarskich. Część z gabinetów prowadziła działalność handlową wykonując na zamówienie i sprzedając zestawy drewnianych próbek. Niektóre z tych zbiorów (np. z Kassel) istnieją i są podziwiane do dnia dzisiejszego.

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Ausgewählte Untersuchungen zur Veränderung von Holz nach 160jähriger Unterwasserlagerung

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Schlüsselwörter: Eichenholz, Tannenholz, Unterwasserlagerung, chemische Eigenschaften.

Abstrakt: In der Arbeit sind die Ergebnisse einer Untersuchung von 160-Jährigem Eichen- und Tannenholz von der Münsterbrücke in Zürich zusammengafasst. Das Holz hatte in den Randzonen eine weiche etwa 1-2 cm dicke Schicht. Der Zelluloseanteil ging in den Randzonenbei beiden Holzarten zurück. In den Aussenzonen waren Bakterien erkennbar. Im Inneren des Holzes war die Struktur noch sehr gut erhalten.

Einleitung

Die Münsterbrücke im Zentrum Zürichs wurde in den Jahren 1836-1838 (Anonym 1995) errichtet. Die Brücke hat eine Gesamtlänge von 72 m und besteht aus vier gleichmässigen Bögen mit 3 steinernen Brückenpfeilern.

Im Rahmen einer geplanten Instandsetzung der Brücke sollte der Zustand des zur Gründung der Pfeiler verwendeten Holzes geprüft werden. Dieses befand sich 2 m unter der Wasseroberfläche. Für die Errichtung der beiden Brückenpfeiler wurden zunächst vertikal Holzpfähle (Eiche, Fichte und Tanne) in den Fluss gerammt.
Die Pfahlköpfe befinden sich heute ca. 2m unter dem Wasserspiegel, ein Luftzutritt liegt nicht vor. Über diese vertikalen Pfähle wurde ein Rost aus horizontalen Balken aufgebaut. Der Zwischenraum wurde mit Sand, Bauschutt und z.T. mit Lehm (bei den Widerlagern) verfüllt. Um die tragende Konstruktion des Pfeilers wurde zum Schutz zusätzliche eine Umbauung aus Holzpfählen und o. g. Material verwendet.

Allgemein gilt Holz bei völliger Unterwasserlagerung in Süsswasser als sehr beständig (s. Holzlexikon, DRW- Verlag Stuttgart, 1988), da es infolge der Wassersättigung nicht durch Pilze zerstört wird.
Unter besonderen Bedingungen (z.B. sehr sauerstoffreiches Wasser) kann es allerdings zu Moderfäule kommen. Eine Beeinflussung der Holzqualität durch Bakterien tritt bei extrem langem Wasserangriff auf. Bei Bakterienbefall erhöht sich die Durchlässigkeit des Holzes durch Zerstörung der Tüpfelmembranen. Schweingruber (1978) verweist auf diese weichen Zonen an Holz, das zwischen einigen hundert und mehrere tausend Jahre (bis zu 6000 Jahre) unter Wasser gelagert wurde. Er wies nach, dass sich die Holzeigenschaften - je nach Lagerungsbedingungen -langfristig etwas ändern.

Die tangentiale Schwindung stark modifizierter Hölzer -durch welche die Risse in Radialrichtung entstehen - steigt deutlich an (auf bis zu 50-75%), die Längsschwindung dagegen nur wenig (2-3% nach Schweingruber (1978)).
Bisherige Veröffentlichungen über langzeitig wassergelagertes Holz zeigen, dass offensichtlich grosse Schwankungen im Erhaltungszustand vorhanden sind, was auf verschiedene Lagerbedingungen sowie verschiedene Ausgangszustände des Holzes zurückzuführen sein könnte.

Material und Methodik

Aufbauend auf den o.g. Untersuchungen (Niemz, Zürcher, Kucera, Bernatowicz (1999) wurden an Holz aus der Münsterbrücke in Zürich an der Landwirtschaftlichen Hochschule in

Warschau die chemische Zusammensetzung des Holzes analysiert und an der ETH ausgewählte Rasterelektronenmikroskop-Aufnahmen der Randzonen und des Pfahlinneren und mechanische Prüfungen angefertigt. Als Versuchsmaterial dienten Tanne und Eiche. Dadurch sollten ergänzende Aussagen zum Material gewonnen werden. Es wurde ca. 10g Material aus den Aussen- und Innenzonen entnommen. Bild 1 zeigt die Scheiben und das Entnahmeschema.

Extraktstoffe

Es wurden lösliche Bestandteile in einer Alkohol- Benzen- Mischung (1:1) ermittelt. Dazu wurde das Holz zu Partikeln zerkleinert und mittels Sieben klassifiziert. Verwendet wurde der Durchgang durch ein Sieb mit 1,5 mm Maschenweite und der Rückstand auf dem Sieb mit 0,49 mm Maschenweite.

Es wurden 5 g der feuchten Partikeln in ein Soxlet- Gefäss gegeben, welches mit Methanol-Benzen- Mischung aufgefüllt wurde. Die Extraktion dauerte 6 Stunden. Danach wurde das Material bei 105°C getrocknet und der Anteil an Extraktstoffen E berechnet.

$$\mathbf{E= (M_E-M_{dtr})*100\ (\%)} \qquad \text{(Gl. 1)}$$

M_E- Masse der darrtrockenen Extraktstoffe

M_{dt}- Masse der darrtrockenes Holz

Cellulose

Der Cellulose- Anteil Z wurde nach Kürschner -Hoffer bestimmt (Alkohol- Benzen-Extraktion).

$$\mathbf{Z= M_C/M_{dtr}*100\ (\%)} \qquad \text{(Gl. 2)}$$

Lignin

Der Ligninanteil L wurde nach Jayns- Knole nach Alkohol-Benzen Extraktion bestimmt.

$$\mathbf{L= M_L/M_{dtr}*\ 100(\%)} \qquad \text{(GL. 3)}$$

Ergebnisse

Das Holz hatte bei der Entnahme aus dem Wasser in den Randzonen eine weiche (schwammige), etwa 1-2 cm dicke Schicht. Diese riss bei der Trocknung stark auf (Bild 1). Besonders ausgeprägt war dies bei Tanne und Fichte. Das Eichenholz zeigte z.T. die übliche dunklere Färbung. Sie trat in der Randzone bis zu einer Tiefe von 5 mm auf. Mit zunehmendem Abstand von der Oberfläche wurde die Farbe wieder heller.

Bei Fichte ist in den Aussenzonen (Bild 2a) ein deutlicher Abbau von Teilen der Zellwand erkennbar. Im Inneren war dagegen die Struktur noch sehr gut erhalten (Bild 2b). Der Erhaltungszustand der Eiche ist im Bild 3 ersichtlich. Auch hier trat in der Aussenzone ein deutlicher Holzabbau auf.

Tabelle 1 zeigt die chemische Analyse des Holzes. In den Randzonen ist ein deutlicher Anstieg der mineralischen Bestandteile vorhanden (vermutlich durch Einlagerung von im Wasser mitgeführten Sand).

Der Celluloseanteil ging in den Randzonen bei beiden Holzarten zurück. Es wurde also primär Cellulose abgebaut.

Das Holz war im Inneren noch sehr gut erhalten und zeigte keine Beeinträchtigung der Druckfestigkeit. Ebenso ist die Holzstruktur im Stamminneren weitgehend unverändert. In den Aussenzonen waren Bakterien erkennbar (teilweise Abbau der Tüpfelmembran).

Tabelle 1: Chemische Zusammensetzung des Holzes

Holzart/Zone	Anteil in Bezug auf darrtrockene Holzmasse (%)			
	Extraktstoffe	mineralische Bestandteile	Cellulose	Lignin
Tanne				
-aussen	0,8	3,0	54,9	34,7
-innnen	1,1	1,6	62,7	29,1
Eiche				
-aussen	2,3	2,9	44,5	22,6
-innen	3,5	1,2	45,8	22,1

Tabelle 2: Mechanische Eigenschaften des Tannen- und Eichenholzes.

Eigenschaft	Holzart			
	Stat.	Tanne	Eiche I hell	Eiche II verfärbt
Rohdichte [kg/m^3]	x	478	728	744
	s	74	46	74
Druckfestigkeit [N/mm^2]	x	36.7	48.2	37.9
	s	7.7	8.1	6.1
Holzfeuchte [%]	x	12.4	15.0	14.7
	s	0.5	0.6	0.4

x - Mittelwert
s - Standardabweichung
Probenanzahl: Eiche I: 37; Eiche II: 20; Tanne: 32

Tabelle 3: Richtwerte für die Rohdichte und die Druckfestigkeit nach Wagenführ (1996)

Kenngrösse	Eiche	Tanne
Rohdichte: kg/m^3	430...690..960	350..450..710
Druckfestigkeit in N/mm^2	54..61...67	31...47...59

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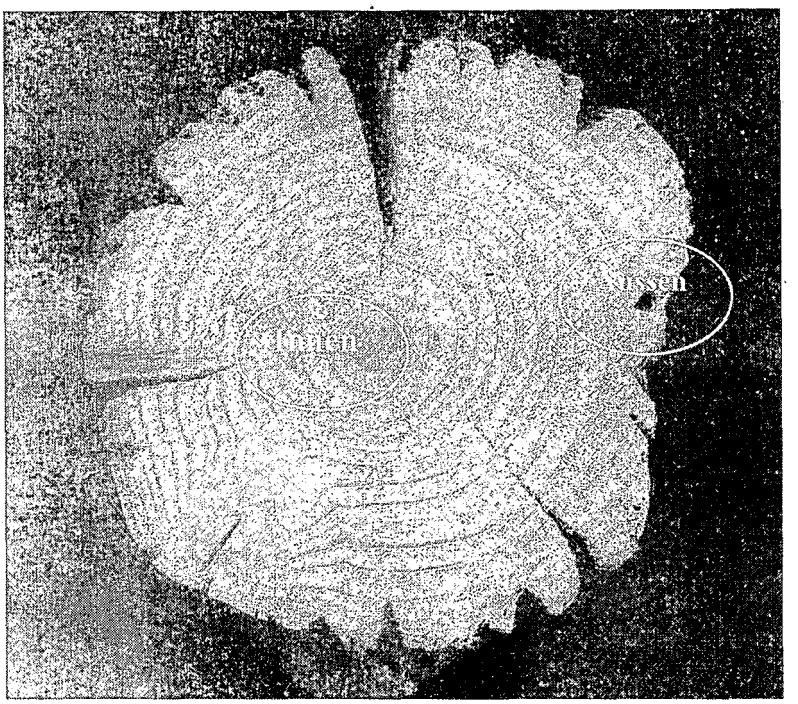
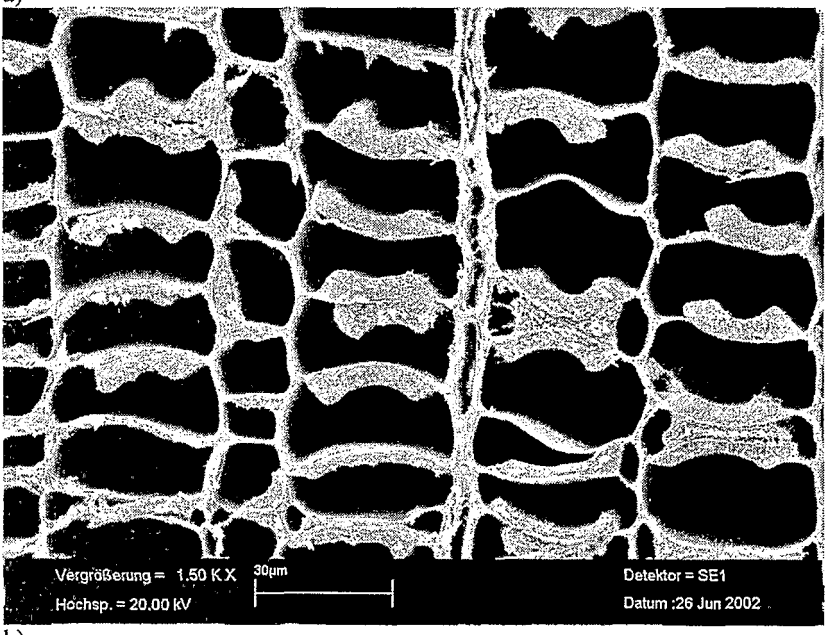


Bild 1: Foto des verwendetes Versuchsmaterials
und des Entnahmeschemas für die chemische Analyse (am Beispiel Tanne)
Foto: G. Gantenbein, ETH Zürich

a)



b)

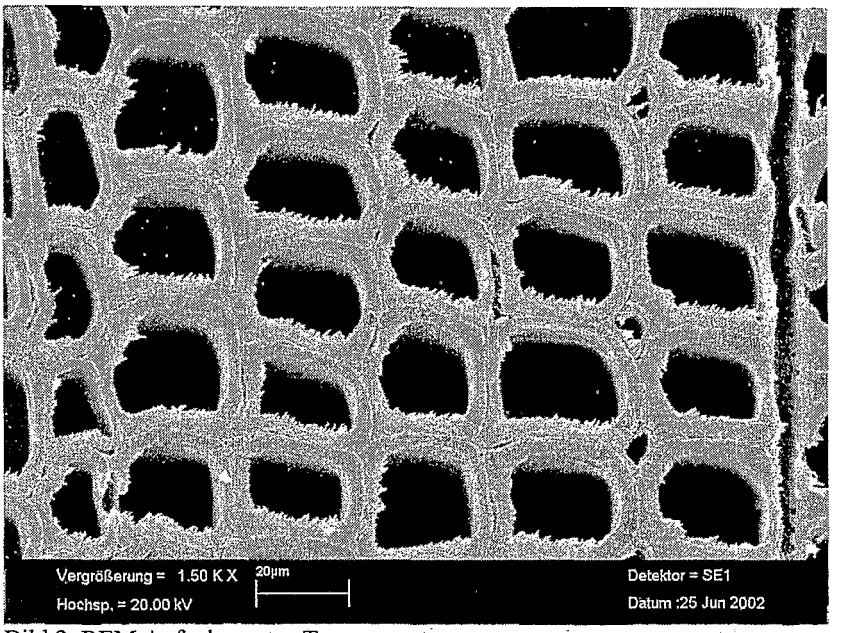
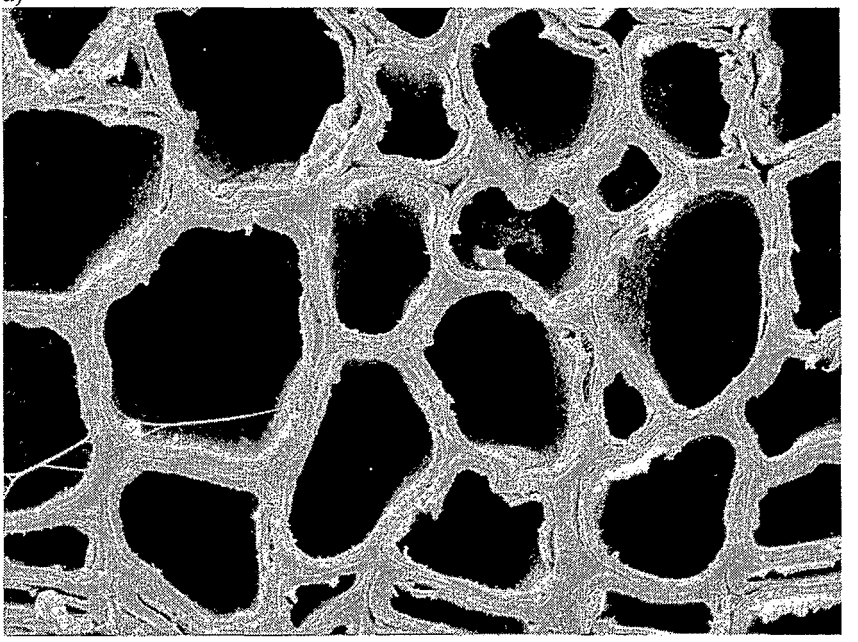


Bild 2: REM Aufnahme von Tanne
a) Aussenzone
b) Innenzone
Foto: G. Gantenbein, ETH Zürich

a)



b)

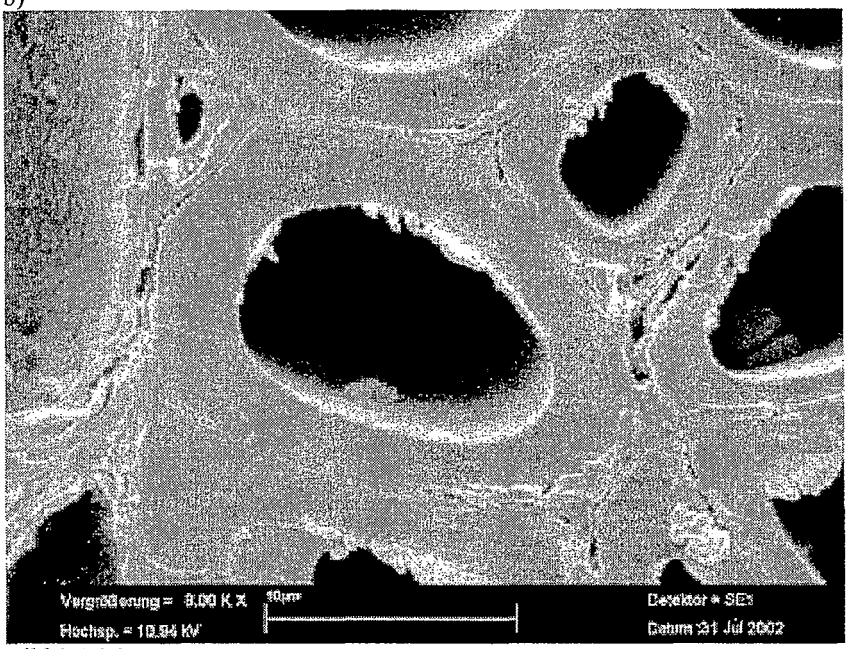


Bild 3: Eiche
a) Aussenzone
b) Innenzone
Foto: G. Gantenbein, ETH Zürich

Streszczenie
Badania nad zmianami drewna po 160 letnim składowaniu w wodzie. Badaniom poddano drewno jodły i dębu pochodzące z mostu zbudowanego w Zurichu w latach 1836-1838. Stwierdzono, że drewno warstw środkowych było dobrze zachowane i miało nie zmienioną wytrzymałość na ściskanie. Drewno warstw zewnętrznych wykazywało rozkład powodowany przez bakterie. W warstwach zewnętrznych stwierdzono znaczny wzrost udziału składników mineralnych, co prawdopodobnie spowodowane zostało naniesieniem piasku przez wodę.

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Modern designes of encampments

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Abstract: *Modern designes of encampments* The article discusses important construction characteristics of modern encampements. The author stressed equal importance of their strength and durability as well as the need of their adjustment to human requirements from the point of view of physiology and orthopaedics. The discussed encampement characteristics play an important role to make them comfortable for users. Attention was drawn to the importance of elasticity of the applied upholstery materials for the comfort of encampement users.

Key words: encampments, design, ergonomy

Encampements constitute a part of furniture intended for resting in lying position. They can be characterised by a wide range of constructional and material complexity depending on the assumed utilisation and functional requirements. In addition, the most important constructional principle of each and every encampement is, besides a specified strength and utilisation durability, to fulfil human requirements determined by physiology and orthopaedics. Therefore, from the point of view of ergonomics, it is essential to ensure a proper support of the body in reclining position as well as encampement rigidity and degree of encampement deformation.

Orthopaedic and physiological requirements make it necessary for the upholstered construction of the encampement to act as a support for the spinal column and, at the same time, to distribute reaction forces derived from the weight of the user's body over the largest possible area and, possibly, most uniformly. In addition, these functions should be maintained in the case of changing body position on the encampement. Proper support of the user's body on the encampement depends on its rigidity and degree of deformation.

From the point of view of orthopaedics, the best encampement is one that supports the spinal column along its entire length (Fig.1). This, in turn, depends primarily on the construction and material composition of the upholstery of the encampement and the construction of the

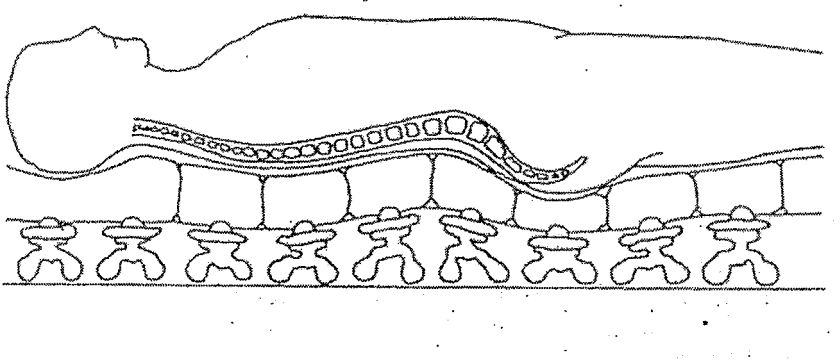


Figure 1. Proper support of the spinal column in an encampement

substratum. This means that the entire upholstery system of the encampement should undergo deformations over small radii of the curvature and, simultaneously, support the user's body in each of its points irrespective of the adopted position (Fig.2). This depends, to a considerable extent, on the substratum construction of the encampement upholstery system. Substrata characterised by a so called continuous construction made of a number of elements mutually interlinked along and across the encampement, e.g.: undulated springs or spirally flattened springs as well as upholster belts tend to deform under operational loads only on one radius of the curvature across and along the encampement. This kind of deformation is exceptionally unfavourable for the user's spinal column, especially in the longitudinal direction. That explains why these types of substrata are becoming increasingly unpopular in modern encampement constructions. This does not happen when substrata are manufactured from elements, which can undergo deformations, that are independent from one another (Fig.3). This type of base construction successfully substituted substrata applied until recently. New substrata, often referred to as ergonomic, are made from slats placed across the longitudinal axis of the base. The most important constructional feature of this type of bases is the kind of applied slats and the method of their attachment in the base frame. In order for the construction to fulfil the condition of a permanent support of the user's body and, simultaneously, to adjust to curvatures along its entire length, slat grips must ensure free movement in the direction perpendicular to the base plane and a certain amount of rotation in the plane perpendicular to the longitudinal axis of the slat (Fig.4).

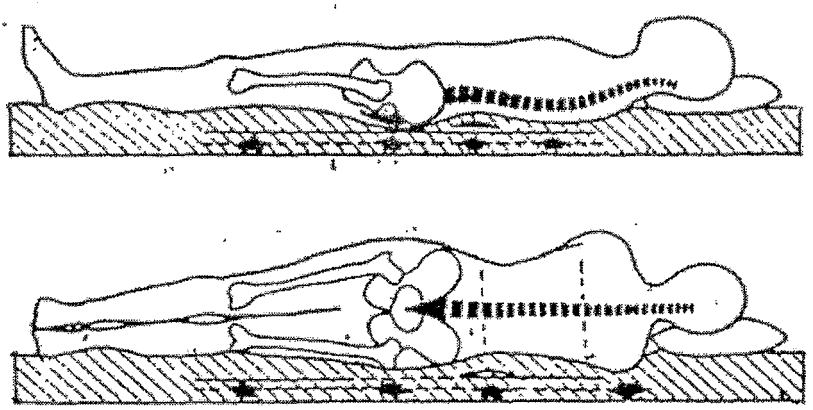


Figure 2. Proper encampement deformation under operational load

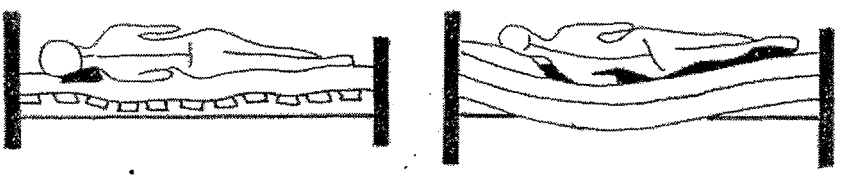


Figure 3. Encampement deformation made on a base of continuous and non-continuous construction

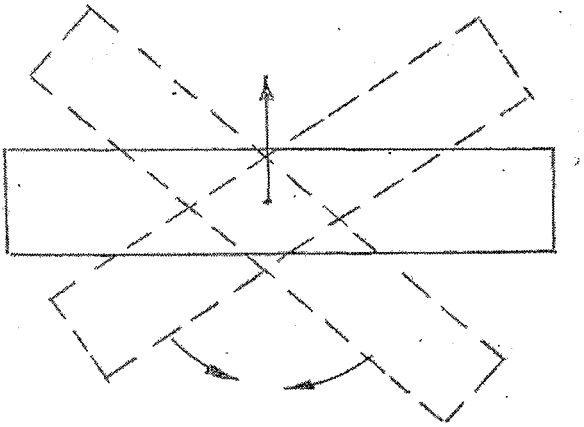


Figure 4. Desirable degrees of freedom of the base slat grip

With regard to the materials applied in the construction of the encampement upholstered system, their most important characteristics include: their elastic traits, which determine the way and extent of the encampement deformation as well as the value and distribution of loads on the surface of the user (Fig, 5). The above characteristics are essential in determining utilisation usefulness of encampements and have a significant impact on the degree to which man's physiological and orthopaedic requirements are to be met.

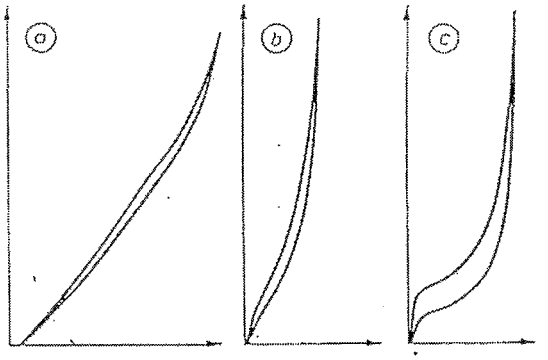


Figure 5. Deformation characteristics at loading and unloading of different upholstery materials: A/ springs, B/ latex foam, C/ polyurethane foam

That is why encampements which guarantee the fulfilment of such requirements incorporate in the construction of their upholster system spring units (panels) which play a decisive role in ensuring comfort of resting places. In order to meet this level of requirements, upholstered encampement systems employ most commonly pouch-like spring units which, due to their construction, guarantee independent deformation of individual springs under the influence of operational loads (Fig.6). In addition, the construction of pouch-like spring units makes it possible for the upholstered system of the encampement to be made in such a way as to allow it to be characterised by a sectional rigidity along its length.



Figure 6. Deformation of a pouch-like unit

Medical and biomechanical investigations showed that optimal resting position of the human body occurs when the position of the spinal column and muscles is similar to that found in vertical position. Hence the desire of encampement designers to create an upholstered system which would adjust to the shape of human body and exert a minimal and identical pressure along its entire surface. This would take all loads off the spinal column and reduce pressure on muscles and prevent circulatory disturbances, especially in the surface venous system.

An encampement which adjusts to the shape of the human body completely and, at the same time, fulfils all other conditions is a water mattress. Areas adjacent to shoulders and pelvis, which constitute the heaviest parts of the body plunge into the mattress more deeply and, consequently, the pelvis deflects towards the back and, therefore, the pressure that vertebras in the lumbar area exert on intervertebral disks is four times smaller in comparison with traditional mattresses. Unit pressures exerted on the surface of the user's body resting on a water mattress do not exceed 28 mm Hg Fig.7). This level is considered by physiologists as the limiting level to guarantee appropriate functioning of the surface venous system contributing to healthy rest and sleep.

Problems of construction of modern encampements discussed in this article emphasise that, apart from definite strength and durability, they should also guarantee the fulfilment of human requirements with regard to physiology and orthopaedics and this is strictly correlated with the application of appropriate construction and material solutions.

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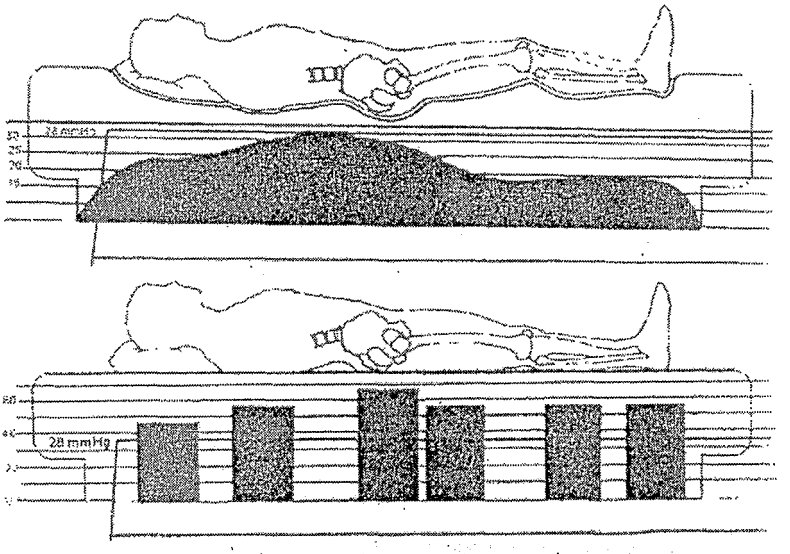


Figure 7. Distribution of pressures on a water and traditional mattress

Streszczenie: *Współczesne konstrukcje leżysk.* W artykule omówiono istotne cechy konstrukcji współczesnych leżysk. Podkreślono równorzędne znaczenie ich wytrzymałości i trwałości oraz dostosowanie konstrukcji do wymagań człowieka z punktu widzenia fizjologii i ortopedii. Wyszczególniono cechy leżysk decydujące o wygodzie ich użytkowania. Zwrócono uwagę na znaczenie sprężystości materiałów tapicerskich w kształtowaniu stopnia wygody użytkowania leżysk.

Stiffness and bending strength of loose tongue joint in case construction

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Key words: corner joint, loose tongue joint, particleboard, stiffness, bending strength

Abstract: The influence of joint dimensions on the bending strength and stiffness of loose tongue joint in case construction was investigated. Factors such as thickness of panel, width and height of loose tongue were considered. The regression functions for the bending strength and rigidity coefficient of the joint were calculated. The mechanical properties of the joint considerably depend on the dimensions of the loose tongue, and slightly on the thickness of joined panels.

Introduction

Despite the significant supremacy of dowel joints, the loose tongue joint still occupies an important place in furniture industry. Yet, it was rarely an object of investigation. The bending strength and stiffness of this joint were analysed in relation to a mitre (Kjučukov and Josifov 1968, Dzięgielewski and Leśniewska 1983, Albin et al. 1987), without taking its changing geometrical dimensions into account. Therefore, it was decided to make investigation in order to determine the stiffness and bending strength of a corner joint in case construction, as dependent on the thickness of joined plates and geometrical dimensions of the joint.

Materials and methods

Investigation were carried out using specimens of the corner joint, being an element of typical case furniture (fig. 1).

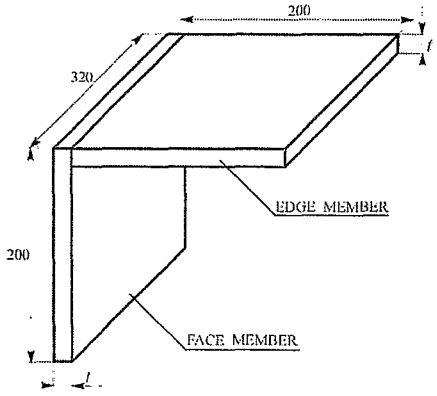


Fig. 1. Construction of corner joint

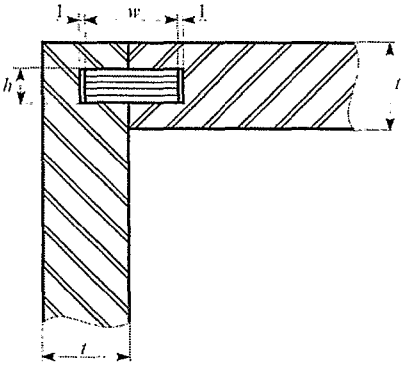


Fig. 2. Dimensions of loose tongue joint

The two most popular thicknesses of panels: 16 and 18 mm were taken into consideration. Changing dimensions of the transverse section of the loose tongue were assumed (fig. 2). Three widths w (12, 18 and 24 mm) and heights h (3, 6 and 9 mm) were accepted. A complete plan of test was assumed, including all combinations of joint

dimensions and thicknesses of panel. 15 specimens of joints were made for every investigative combinations. Total number of specimens was equal to 270.

Material of test specimens was three-layer raw particleboard of general usage, whose properties are given in Table 1. Loose tongues were made of beech wood (*Fagus sylvatica* L.). Racoll Express 25 was used for connecting joint elements.

Table 1. Properties of panels used in the investigation

Property of board	Panel with tickness of 16 mm		Panel with tickness of 18 mm	
	mean value	standard deviation	mean value	standard deviation
Density [kg/m^3]	641	11,7	690	6,7
Moisture [%]	7,8	0,63	8,1	0,72
Bending strength [MPa]	14,7	1,45	13,2	1,20
Modulus of elasticity [MPa]	2920	158,3	2770	116,1
Tensile strength perpendicular to the plane of the board [MPa]	0,36	0,041	0,32	0,038

The specimens were loaded, which resulted in closing the arms of the joint. The examination of the stiffness of the joint was conducted through determing the relative rotation angle of the joint arms γ, being the result of the action of the bending moment M in the corner of the joint. In the examination, the loads were used that ensured linear dependence of joint deformation on bending moment. For particular investigative combination, the increment of force ΔP ranged from P_d=30 N to P_d=240 N. The specimens were loaded four times with the forces of values from P_d to P_g, measuring the increment Δf in relative move of the edge member. The average value of this increment from the last three measurements was obtained. Based on it, the increment $\Delta\gamma$ [rad] of relative rotation of the joint arms was calculated.

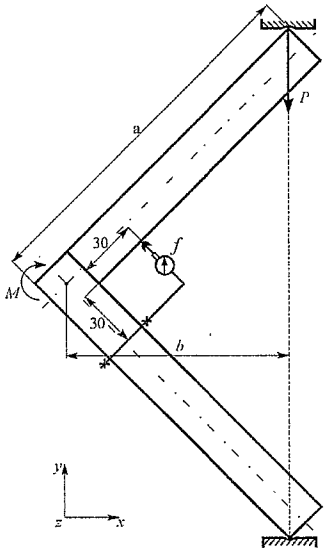


Fig. 3. Diagram of measuring of the angle of relative rotation of specimen

Rigidity coefficient k, being a measure of joint stiffness, was calculated from the formula (1):

$$k = \frac{\Delta M}{\Delta\gamma} = \frac{\sqrt{2}}{2} \cdot \frac{\Delta P}{\Delta\gamma}(a - t) \qquad (1)$$

where: k – rigidity coefficient of the joint [Nm/rad],
ΔP – loading increment [N],
$\Delta\gamma$ – rotation angle increment [rad],
a – length of arm joint [m],
t – thickness of panel [m].

The determing of the bending strength was made using the same specimens, measuring the value of the P_{max} force, for which the destruction of the joint took place. This force causes the appearance of the maximal bending moment M_{max} in the corner of the joint, which was recognised as the measure of the bending strength of the joint.

$$M_{max} = P_{max} b \tag{2}$$

Results and discussion

Based on the test results obtained in this study, approximate functions for the rigidity coefficient k (3) and bending strength M (4) of the loose tongue joint were calculated, that took the thickness of panel and dimensions of the loose tongue into account. Slight average approximation errors (4.4 % and 3.9 % respectively) and very high multidimensional correlation coefficients equal to 0.969 and 0.990 respectively, testify that approximate functions are very well fitted to the results of the investigation.

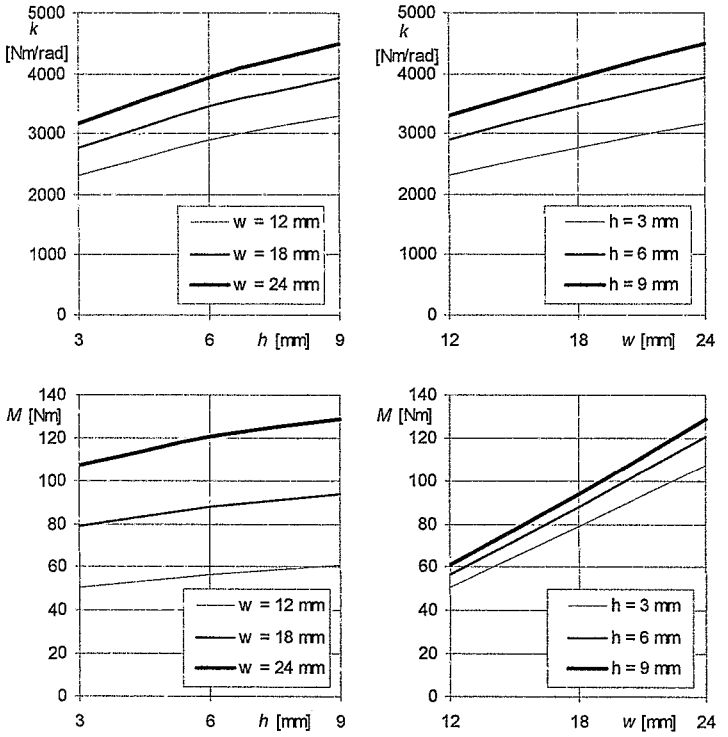


Fig. 3. Relationships of the rigidity coefficient k and bending strength of the joint to height and width of loose tongue.

$$k = 2.62\, t^{1.270} h^{0.321} w^{0.445} \tag{3}$$

$$M = 0.933\, t^{0.691} h^{0.162} w^{1.081} \tag{4}$$

where: k – rigidity coefficient of loose tongue joint [Nm/rad],
M – bending strength of loose tongue joint [Nm],
t – thickness of panel [mm],
h – height of loose tongue [mm],
w – width of loose tongue [mm].

Based on the formulas, diagrams were drawn to present the relationship of the bending strength and rigidity coefficient of tested joint to joint dimensions: the width and height of the loose tongue.

The relationship of rigidity coefficient of the joint both to the height and to the width of the loose tongue is nonlinear. The pace of increasing of rigidity coefficient diminishes with the increase in loose tongue dimensions. The threefold increase in the height of the loose tongue (from 3 to 9 mm) causes an increase in rigidity coefficient by 42.3 %. A similar effect is caused by the change of the width of the loose tongue. The twofold increase in this dimension (from 12 to 24 mm) makes rigidity coefficient increase by 36.1 %.

The effect of the dimensions of the loose tongue on bending strength is varied. The increase in the height of the loose tongue causes the increase in bending strength, the change of the height from 3 to 6 mm corresponding to a higher increase in the bending strength than that from 6 to 9 mm. The threefold increase of the loose tongue (from 3 to 9 mm) causes a relatively slight increase in bending strength (by 19.5%). A considerably greater effect on bending strength of the joint has the width of the loose tongue, the increase in this dimension approximately determines a proportional increase in bending strength. The twofold increase in the width of the loose tongue makes bending strength increase over two times (by 111.6%).

A slight effect on the mechanical properties of the loose tongue joint has the width of joined panels. The joint of 16 mm boards is characterised by stiffness 14% and bending strength 8 % smaller than that made of 18 mm panel.

Conclusions

Based on the above analysis, the following conclusions can be made:

1. Mechanical properties of the loose tongue joint considerably depend on the width and height of the loose tongue.
2. The increase in the height and width of the loose tongue influences an increase in stiffness and bending strength of a joint.
3. The joint panels with the thickness of 16 mm are characterised by stiffness and bending strength smaller about 14 and 8 % respectively than those with the thickness of 18 mm.
4. A characteristic image of destruction in bending of loose tongue joint is delamination of face member.

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Streszczenie:*Sztywność i wytrzymałość połączenia kątowego ściennegoo złączu wpustkowym.* W pracy przedstawiono badania dotyczące wpływu wymiarów złącza wpustkowego na sztywność i wytrzymałość ściennego połączenia kątowego. Czynnikami zmiennymi były: grubość płyt oraz wysokość i szerokość wpustki. Wyprowadzono funkcje regresji w postaci iloczuny funkcji potęgowych dla wytrzymałości i współczynnika sztywności połączenia. Stwierdzono, że właściwości mechaniczne połączenia zależą istotnie od wymiarów wpustkich a w niewielkim stopniu od grubości łączonych płyt.

Hölzerne gebäude

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Abstrakt: In der Arbeit wird ein Text aus dem 18. Jh. zitiert, in dem die Voraussetzungen beschrieben werden, die ein Gebäude hinsichtlich der Brandfestigkeit, des Schutzes vor holzzerstörenden Pilzen, Feuchtigkeit und Wasser, der sparsamen Verwendung von Holz und seiner Wahl sowie der Anordnung der Heizkörper und des Brandschutzes erfüllen muß.

Schlüsselwörter: Holz, Gebäude

In einer Enzyklopädie aus dem 18. Jahrhundert, die nicht zu Ende gedruckt wurde, befinden sich einige interessante Beiträge, deren Autor der Hohenloher Baurat, Salinendirektor, Kammerdirektor und Bergrat Johann Georg Glenk, geb. 1751, gest. 1806 war. Die in dem Beitrag enthaltenen Informationen zeigen nach über 210 Jahren eine erstaunliche Aktualität, was die Autoren veranlaßt hat, ihn als ganzes zu drucken.

„Den ersten Begriff zu unsern von Holz gebauten Gebäuden gaben ohne Zweifel die Hütten der ersten Bewohner dieser Erde, welche sie bauten, um sich von den Anfällen, der Witterung, der Thiere und ihrer Gesellschafter zu schützen, und wurden nach der Absicht und dem Gebrauche derselben bald mit Baumstöcken, worauf Decken und Dächer ruheten , gebaut, bald aber mit liegenden Hölzern aufgeführt. Erstere waren der Ursprung der sogenannten Hütten= und Säulengebäude, letzere aber der Blockhausgebäude. Weil nun aber letztere viel Holz kosten, so hat man in denjenigen Ländern, in welchen man gegenwärtig mehr auf die Sparsamkeit des Holzes zu sehen genötigt worden, und dabey doch nach der Landesart dem Landmann seine Blockhäuser nicht ganz verwerfen konnte, auf eine andere Bauart derselben gedacht, und an die Stelle der dicken und ganzen und ganzen liegenden Bäume, Bretter, Dielen oder Bohlen genommen, daß dergleichen Gebäude der Planken um Güter ziemlich ähnlich sehen; daher sie auch Plankengebäude genennent werden (s. diesen Artikel). Von der Bauart der Säulengebäude sind andere hölzerne entstanden, welche man Riegelgebäude nennen kann, weil ihre äussere und innere Wände aus Riegelwänden (s. Riegelwände) bestehen.

Daß die hölzerne Gebäude ihre gute und böse Seite haben, ist bekannter, als es nöthig wäre, hier viel davon zu reden. Die allgemeinen Eigenschaften derselben sind: Feuerfestigkeit, Verwahrung vor der Fäulniß, Beschützung vor Wasser, Winter und der Kälte, nebst einer wohlangebrachten Holzersparung. Hölzerne Gebäude sind dem Feuer sehr gefährlich, und sind sie einmal recht im Brand, so sind gemeiniglich alle Rettungsmittel fruchtlos. Es ist daher bey solchen vorzüglich alles zu vermeiden, was Gelegenheit zum Feuerfangen geben kann, und zugleich darauf bedacht zu seyn, daß das einmal nöthige Holz, nicht so schnell Feuer fange. Von dem ersten wird der Artikel Feuerordnung, von dem letztern aber der Artikel Feuerfestigkeit mehreres sagen.

Über die Feuerfestigkeit schreibt man 1784 folgendes:

Die Wände betreffend, so wird gut gewirtschaftet wenn man bey dem ohnehin theuren und vergänglichen Holze, die äussern Wände der Gebäude gerne von Stein baut, wenigstens die Scheidewandungen an benachbarten Gebäuden, und das ganze untere Geschoss.

Man suchte durch Lehm und andere feuerveste Dache zu helfen, und proportionierte feuerveste Ueberzüge vor das Holz. Die Feuerstellen und Feuerwerke betreffend, so sollen alle Wände woran Küchenheerd, Stubenofen, Waschkessel und Backofen zu stehen kommen, ganz von Steinen ohne alles Holzwerk aufgemauert werden. Die Küchenböden sind mit Steinen zu belegen, die Backöfen im zweyten Stockwerk zu vermeiden, die Schornsteine durch die Firste zu führen, auf den Geschossen nicht mit dem Gebalke verbinden u.dgl. mehr. [Deutsche Enzyklopedie 1784].

Die Verwahrung vor der Fäulniß erfordert 1) eine geschickte Anwendung der verschiedenen Holzarten, jedes nach ihrer Natur und Beschaffenheit, nach welcher solche am wenigsten von der Fäulnis angegriffen wird, z.B. Eichenholz an das Wetter und Tannenholz in die Trockne; 2) daß man das Holz zur gehörigen Zeit, d.i. im Winter fällt; denn im Winter ist der Saft des Baums, nicht nur in dem Stamm zurückgetreten, und hat desselben Röhren erfüllt, sondern er wird auch durch die Kälte in solchem verdicket, daß also einestheils die wässerichten Theile der Luft oder des Lehmes, welche die Fäulniß befördern, nicht so leicht eindringen können, anderntheils auch die kalte Luft die Gährung des Saftes hindert, als wodurch der Holzwurm abgehalten wird. Bedencket man noch diesen Vortheil, den man durch die Fällung des Holzes im Winter erhält, daß nemlich das Reissen und Spalten desselben dadurch gehindert wird, weil das Holz austrocknen kann, ehe die große Hitze kommt; so hat man Ursache genug, solche besonders bey den lehmernen Gebäuden auf das nachdrücklichste zu empfehlen. So muß auch das Holz, ehe es in das Gebäude gelegt wird, vorhero sattsam trocknen; hierdurch wird sowohl das Vermodern des Holzes von innen, als das Reissen und Spalten desselbigen verhindert. Diese Trocknung des Holzes muß weder in der Sonne, noch von den Winden geschehen, weil sie sonst so schnell erfolget, und dasselbe dadurch reisset, sondern im Schatten. [Alberti 1485]

Es kann aber das Trocknen des Holzes theils geschehen, theils befördert werden, wenn es, wie schon erwähnt, a) im Winter gefällt, b) mit Ochsenkoth nach Art der Alten beschmieret, oder in Schleim eingesenkt wird: c) durch Legen in Sand; d) durch Trocknen im Rauch; e) durch Anzündung des Stamms in dem Gipfel, denn da ziehet sich die Feuchtigkeit heraus. Die Feuchtigkeit muß man von den lehmernen Wängen so viel möglich abzuhalten suchen; und dieses geschiehet, a) wenn man das Holz nicht eher einlegt, als nachdem solches vorhero wohl getrocknet ; b) wenn man da, wo das Holz an die lehmerne Wand so liegen kömmt, oder bey verschlierten Decken, neben den Balken Letten gebraucht, womit es überdeckt wird; dieser hält besser, als Theer und alles andere, die Feuchtigkeit von dem Holze ab, und verwahrt es sehr lange vor der Vermoderung, auch im Boden. Die Alten mauerten die Mauern am Meere damit, und zu Plinii Zeiten baute man Thürme und Wachhäuser auf den Bergen, von solchem bis zu Hannibals Zeiten. Inzwischen ist solcher nicht überall zu haben: und wird dahero in dessen Ermangelung das Holz gegen den Lehm mit Theer, Vogelleim, Wiener Zinnoberfirniß, Kienöl, auch wohl gar mit Kohlen und zerstoßenen Kieselsteinen bestreut.

Die Beschützung gegen Wasser und Erdfeuchtigkeit erfordert eine Entfernung alles Bauholzes von der Nähe derselben.

Dieses ist die Ursache, warum man alle Schwellen und Fußböden wohl von der Erde erhaben, zu untermauern hat: weil sie ohne dieses Mittel bald verfaulen, und das Senken der Gebäude verursachen. Gegen Wind und Stürme müssen die Gebäude gesichert seyn: denn wenn sie nur im guten und stillen Wetter bestehen könnten, so wären die Gebäude weder vest noch dauerhaft. Die Wände müssen auch den Wind aufhalten und das Eindringen in die innern Theile des Gebäudes verhindern. Das letztere wird durch das verblenden oder bewerfen der Gebäude von aussen und innen erreicht.

Beyde sind auch das Mittel vor der Kälte. Die Holzersparniß ist bey dem in den meisten Ländern sich einfindenden Holzmangel eine Tugend der hölzernen Gebäude, wovon in diesem Artikel mehr nachgelesen werden kann. In den kältesten Himmelsgegenden hat man Häuser von Holz. Sollte das Holz wohl eine bessere Schutzwehr gegen die Kälte seyn, als eine Mauer?

Die stärksten, saftigsten und reifsten Bäume schicken sich zu den Wänden solcher Häuser am besten. Zuförderst probiert man die Stämme, wenn sie noch stehen, vermittelst einiger Schläge mit der Axt, alsdann kratzt man das Moos herunter, behauet sie, und setzt sie zusammen, wie sie künftig zu stehen kommen sollen. Alsdann schaft man sie an den Ort des künftigen Hauses, und richtet es auf.

Bey dieser zweyten Aufrichtung zeigt es sich, wie viel darauf ankommt, die Fugen gleich anfänglich genau gemacht zu haben. Wenn nicht alles richtig zugehauen und zusammengepaßt ist, so krümmen oder werfen sich die Wände; die Luft dringt hinein, und die Mäuse bauen sich Nester in die mit Moos angefüllten Oefnungen.

Der schwache Theil des Holzes wird abgehauen, aber nie der starke; die Einschnitte kommen in den Kern des Holzes in gleicher Entfernung von jeder Seite; sie dürfen auch nicht stärker seyn , als die halbe Dicke des Holzes. Alles muß wohl ineinander gefügt und genagelt werden.

In den Grund dieser Häuser wirft man Schichtkiesel und eiserne Schlacken, aber keine Feilspäne, welche sich bald in Staub und Erde verwandeln. Diese Schicht, welche bis an das Täfelwerk geht, wird mit Kalk bedeckt. Auf diese Weise haben die Bewohner weder von Mäusen noch von der Feuchtigkeit beschwerden auszustehen. Man kann auch einen doppelten Boden von Brettern machen, und den Zwischenraum zwischen beyden von einem Fuß mit gemeinen Kalk und Kies ausfüllen. Oben auf streuet man trockenen Sand oder Sägespäne, um ihn reinlich zu halten.

In Ermangelung starker Balken macht man dergleichen Häuser auch von dicken Pfosten, und sägt einen Stamm der Länge nach mitten durch. Diese halbe Stämme werden nicht weiter behauen noch abgerichtet, sondern mit der glatten Seite auswärts miteinander verbunden. Wenn sie ein Jahr lang recht ausgetrocknet sind, richtet man das Haus auf, und giebt ihm von aussen einen Anstrich , daß es wie steinern aussiehet. Innwendig werden in den Fugen fichtene Pfähle gesetzt, und die Wand wird mit einem Mörtel beworfen, der aus Kalk, Sand und Thon besteht, der gut durchgearbeitet, und mit Roggenspreu oder Sägespänen vermengt wird, damit es desto besser am Holze hafte.

Um dergleichen Wände auszubessern, wenn sie den Einsturz drohen, oder um sie ganz aufzurichten, ohne sie auseinander zu nehmen, setzt man an den Ecken starke Streben, die sich an ein mit Gewalt in die Erde getriebenes Stück Holz stützen. Auf der Seite, wo sich die wand schief gesenkt hat, treibt man lange spitzige und mit Oel beschmierte Keile von hartem Holz ein. Nach Proportionen des Widerstandes, der überwunden werden soll, werden mehrere oder wenigere Steifen oder Streben erfordert.

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Streszczenie: *Budynki drewniane.* W artykule zacytowano osiemnastowieczny tekst w którym omówiono warunki jakie muszą spełniać drewniane budynki pod względem ognioodporności, ochrony przed grzybami rozkładającymi drewno, wilgocią i wodą pod względem oszczędności i doboru surowca drzewnego oraz rozmieszczenia urządzeń grzewczych i ochrony przed pożarami.

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Die in der Arbeit zitierten Positionen befinden sich in der Universitatsbibliothek Warschau, Abteilung Alte Drucke.

Химический состав древесины берёзы, поражённой трутовиком настоящим (*Fomes fomentarius* L. ex Fr.)

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Содержание: В работе описаны исследования химического состава древесины берёзы (*Betula pendula Roth.*), поражённой трутовиком настоящим (*Fomes fomentarius L. ex Fr.*). Исследования проводились на пробах, отобранных на трёх разных высотах ствола, на которых находились плодовые тела гриба, а также на поперечном разрезе в древесине из периферической зоны, находящейся по стороне трутовика, из сердцевинной зоны и из периферической зоны, находящейся по другой стороне трутовика. На основании полученных результатов было установлено, что самым большим содержанием экстактивных веществ обладают плодовые тела трутовика, а в следующей очереди древесина периферической зоны со стороны трутовика по сравнению с древесиной сердцевинной зоны. Поражение древесины трутовиком настоящим вызвало незначительное гидролитическое разложение целлюлозы в древесине периферической зоны, особенно со стороны трутовика, а также убыток лигнина, самый большой в периферической зоне ствола. В поражённой берёзовой древесине установлено увеличенное содержание гемицеллюлоз, особенно в древесине периферической зоны.

Введение и цель работы.

Среди отечественных видов деревьев берёза проявляет наименьшие требования по отношению к почве и климату (Puczyłowska 1992, Gieting 1982). Берёза является нетеневыносливым видом, при прорастании в густых насаждениях деревья слабнут в результате чего подвергаются поражению грибковыми заболеваниями (Krutul, Kozakiewicz 1998). Трутовик настоящий развивается обычно на ослабленных деревьях бука и берёзы, а также на валеже и сухостое оставленном в лесу. Гниение древесины в месте внедрения трутовика настоящего очень быстро распространяется от поверхности к сердцевине ствола (Krzysik 1978, Kundzewicz 1986). Гниль обладает признаками трухлой гнили. В поражённой древесине вначале появляются неоднородные светлые и тёмные пятна – по этой причине гниль называют мраморной. Чёрные линии отделяют поражённую древесину от здоровой. В трещинах древесины и под корой выступают белые доли грибницы. Гниль, вызванная трутовиком настоящим имеет деструктивный характер, в последней фазе разложения древесина делается ломкой, распадающейся по годичным кольцам на пластинки – по этой причине гниль называют трухлявой. Трутовик настоящий (*Fomex fomentarius L.*) является одним из самых главных патогеннов берёзы. В связи с этим необходимо провести подробные исследования процессов разложения берёзовой древесины, вызванных этим грибом (Krutul, Kozakiewicz 1998)

В работе ставилось за цель провести исследования изменения химического состава древесины в зависимости от положения проб древесины в стволе берёзы бородавчатой (*Betula pendula Roth.*), поражённой трутовиком настоящим (*Fomes fomentarius L. ex Fr.*)

Экспериментальная часть.

Исследовавшийся материал был отобран из части берёзового ствола, поражённого *Fomes fomentarius L. ex Fr.* После срубки дерева из ствола (около 45-летнего) были вырезаны три диска толщиной около 80 мм, с плодовыми телами трутовика настоящего. Дерево прорастало на подзолистой почве из песка и суспеси в насаждении бор свежий, в лесничестве Подозожаны во П Природно-лесной области Мазурско – Подляской.

Для химических анализов из каждого диска отобрано по три пробы древесины и по одной пробе из приросших плодовых тел трутовика настоящего. Пробы древесины были отобраны из следующих зон: заболонной, лежащей по стороне трутовика, сердцевинной и заболонной, лежащей по противоположной по отношению к трутовику стороне ствола. В исследованиях использовано раздробленную фракцию проб 0,49 мм в диаметре.

Были проведены следующие испытания:

- Определение содержания экстрактивных веществ при помощи аппарата Соклета при использовании смеси этанола с бензолом (1:1)
- Определение содержания целлюлозы по методу Кушнера – Хоффера
- Определение содержания лигнина в соответствии с Польской Нормой PN-74/P 50092
- Определение содержания гемицеллюлоз при использовании 1 % раствора NaOH

Результаты исследований были вычислены по отношению к абсолютно сухой массе пробы.

Результаты исследований и их анализ.

На рис. 1 представлены данные относительно содержания веществ, растворимых в смеси этанола с бензолом (1:1) (экстрактивных веществ) в древесине и плодовых телах трутовика настоящего в отдельных поперечных разрезах. Из представленных данных (рис 1) следует, что больше всего экстрактивных веществ содержат плодовые тела трутовика настоящего. Плодовые тела, отобранные из разреза А содержат трехкратно больше экстрактивных веществ, по сравнению с древесиной переферической зоны, находящейся по противоположной стороне трутовика. Плодовые тела трутовика, отобранные в месте разреза Б и В содержат почти двухкратно больше экстактивных веществ по отношению к древесине переферической зоны, находящейся по противоположной стороне трутовика. Древесина переферической зоны по стороне трутовика также содержит большее количество экстрактивных веществ по отношению к древесине переферической зоны, находящейся по противоположной стороне трутовика. Наличие трутовика настоящего повлияло на увеличение содержания экстрактивных веществ в древесине переферичекой зоны, лежащей в близи трутовика.

На рис. 2 представлены данные относительно содержания целлюлозы в древесине переферической зоны, находящейся по стороне трутовика, в древесине сердцевинной зоны и в древесине переферической зоны, находящейся по противоположной стороне трутовика. Из представленных данных следует, что древесина переферической зоны содержит на около 1,8 % больше целлюлозы по сравнению с древесиной переферической зоны, находящейся в близи трутовика. Древесина переферической зоны ствола, находящаяся по противоположной стороне трутовика также содержит больше целлюлозы (около 1,0 %) по сравнению с

древесиной переферической зоны, находящейся по противоположной стороне трутовика. Из полученных результатов следует, что трутовик не осуществлил разложения целлюлозы сердцевинной зоны ствола. Причиной этого является образование фальшивой ядровой древесины, что замедляет развитие грибницы. Клеточные стенки с закупоренными порами являются механическим барьером и значительно препятствуют развитию грибницы и ее проникновения в соседние клетки. Древесина переферической зоны, находящейся по стороне трутовика, обладает самой большой влажностью, что способствует воздействию ферментов, выделяемых мицелами гриба. В результате чего в этой сфере древесина обладает наименьшим содержанием целлюлозы. В выводах следует указать, что наличие трутовика настоящего не привело к большим убыткам целлюлозы в древесине, оно повлияло на уменьшение содержания целлюлозы в древесине переферической зоны по сравнению с древесиной сердцевинной зоны.

На рис. 3 представлены результаты определения лигнина на поперечном разрезе ствола березы, пораженной трутовиком настоящим. Из полученных результатов следует, что самое большое содержание лигнина в древесине из трех исследовавшихся поперечных разрезов ствола было в сердцевинной зоне (ок. 23,5 %).

Ложная ядровая древесина частично замедляет развитие мицелл трутовика, однако одновременно приводит к недостаточности функционирования проводящей системы и тем самым к ослаблению дерева. Паразит использует такое положение и внедряется в ослабленную заболонную древесину. Поэтому в древесине заболонной зоны, находящейся по стороне трутовика, содержиться меньше лигнина по сравнению с древесиной отобранной из сердцевинной зоны и из заболонной зоны, находящейся по противоположной стороне трутовика, на поперечных сечениях Б и В.

Среди лиственных пород древесина березы обладает относительно высоким содержанием лигнина (ок. 25 %). Из полученных данных следует, что наличие трутовика настоящего привело к значительному убытку лигнина, особенно в древесине переферической зоны.

На рис. 4 представлены результаты определения содержания гемицеллюлоз на поперечном разрезе березового ствола, пораженного трутовиком обыкновенным. Из проведнных исследований следует, что меньше всего гемицеллюлоз находится в древесине сердцевинной зоны.

В исследовавшейвся древесине из трех поперечных разрезов находилось такое же количество гемицеллюлоз (23,3 %).

Содержание гемицеллюлоз в древесине периферической зоны, так со стороны трутовика, как и с другой стороны больше по сравнению с древесиной сердцевинной зоны. Причиной такого состояния является то, что одновременно при разложении лигнина увеличивается относительное содержание веществ, растворимый в 1 % NaOH (гемицеллюлоз) в древесине периферической зоны. Меньшее содержание целлюлозы в древесине этойзоны указывает на гидролитическое разложение высших полисахаридов.

Выводы.

На основании проведённых исследований установлено, что:

1. Больше всего экстрактивных вещест находится в плодовых телах трутовика, а затем в древесине периферической зоны, находящейся по стороне трутовика по сравнению с древесиной сердцевинной зоны.

2. Поражение древесины трутовиком настоящим вызвало незначительное гидролитическое разложение целлюлозы в древесине периферической зоны и разложение лигнина на поперечном разрезе ствола, особенно в древесине периферической зоны.
3. В поражённой трутовиком настоящим (*Fomes fomentarius L. ex Fr.)* берёзовой древесине (*Betula pendula Roth.)* периферической зоны находится увеличенное количество гемицеллюлоз.

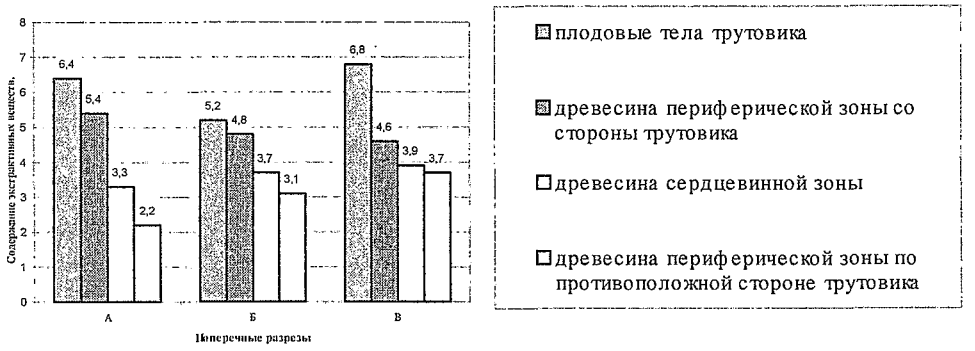


Рис. 1 Содержание экстрактивных веществ в плодовых телах трутовика настоящего и в древесине поперечных разрезов ствола А, Б и В .

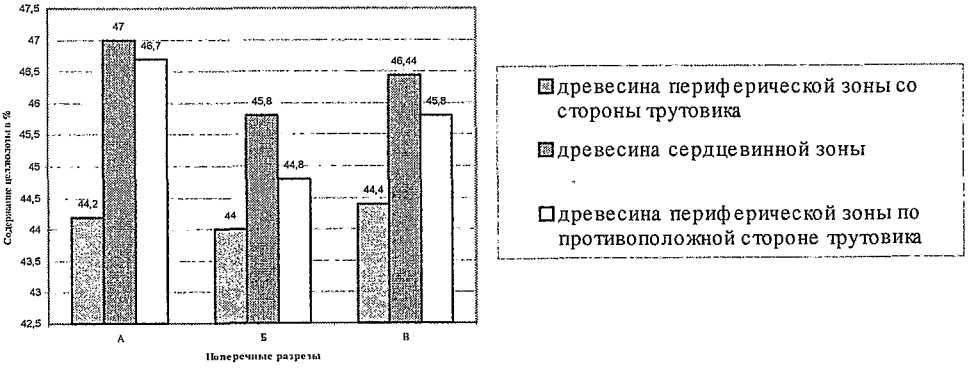


Рис. 2 Содержание целлюлозы в древесине поперечных разрезов ствола А, Б и В.

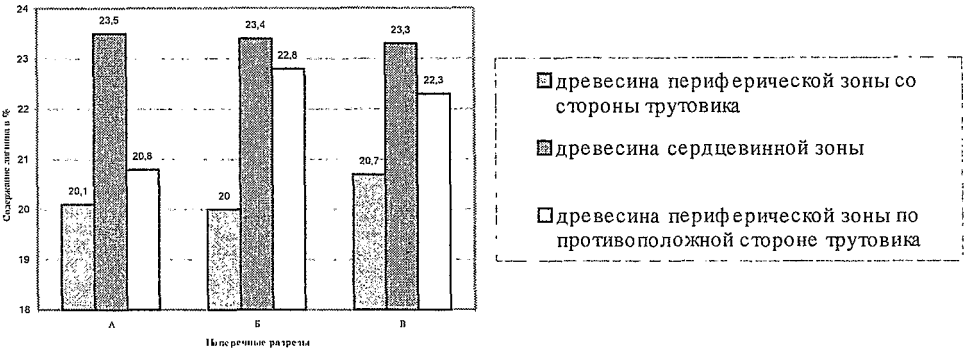


Рис. 3 Содержание лигнина в древесине поперечных разрезов ствола А, Б и В.

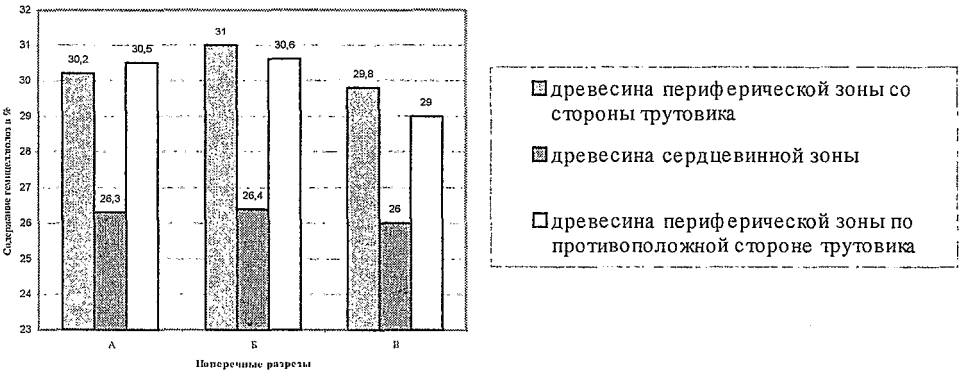


Рис. 4 Содержание гемицеллюлоз в древесине поперечных разрезов ствола А, Б и В

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Streszczenie: *Skład chemiczny drewna. brzozy brodawkowatej (Betula pendula Roth.) porażonego hubą pospolitą (Fomes fomentarius L. ex. Fr.).* Przeprowadzono badanie składu chemicznego drewna brzozy *(Betula pendula Roth.)* porażonego przez hubę pospolitą (*Fomes fomentarius L .ex Fr.*). Badanie przeprowadzono na próbkach pozyskanych z trzech wysokości pnia, na których znajdowały się owocniki grzyba, a także na przekroju poprzecznym w drewnie strefy przyobwodowej od strony huby, strefy przyrdzeniowej i strefy przyobwodowej po przeciwnej stronie huby. Na podstawie uzyskanych wyników stwierdzono, że najwiekszą zawartością substancji ekstrakcyjnych charakteryzują się owocniki huby, a następnie drewno strefy przyobwodowej od strony huby w odniesieniu do drewna strefy przyrdzeniowej. Porażenie drewna przez hubę pospolitą spowodowało nieznaczny rozkład hydrolityczny celulozy w drewnie strefy przyobwodowej, szczególnie od strony huby i ubytek ligniny najwiekszy w strefie przyobwodowej pnia. Porażone drewno brzozowe charakteryzowało się zwiększoną zawartością hemiceluloz, szczególnie w strefie przyobwodowej.

Biological corrosion and timber constructions

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Abstract: Wood is a lignocellulose material characterized by its natural variability, which, to a certain degree, finds its reflection in quality classes of this material and its susceptibility to undergo biodegradation. Presence of biocorrosion agents and, frequently, excessive amount of defects occurring in structural timber eliminates this kind of material from application in housing industry. Occurrence of biodegradation agents in structural timber with time reduces its strength, frequently resulting in a considerable decline of safety of utilization of the entire object. That is why the objective of this study is a comprehensive analysis of factors causing wood biocorrosion and reasons for their development. The performed investigations were carried out on wood constructions of an old tram depot and wooden summerhouses.

Key words: biological corrosion, wood

Introduction and objective of research project

Timber, because of its appropriate physico-mechanical properties as well as wide availability, has always been an important material used in a wide range of utility constructions. In recent years, we have witnessed a real renaissance of timber application, among others, in housing construction, as evidenced by a steadily increasing popularity of skeleton housing constructions modelled on the so called Canadian technology.

Wood is a lignocellulose material characterized by its natural variability, which, to a certain degree, finds its reflection in quality classes of this material and its susceptibility to undergo biodegradation. Timber biodegradation can be defined as a more or less selective breakdown of its elementary constituents such as: cellulose, hemicellulose, lignin etc. by living organisms. The principal transmitters of biocorrosion include fungi and insects, in other words technical timber pests. Apart from the above-mentioned factors of timber biodegradation, there are other pests such as: bacteria, algae, nematodes and, in warm marine waters, also crayfish and bivalves.

The presence of biocorrosion agents and, frequently, excessive amount of defects occurring in structural timber eliminates this kind of material from application in housing industry. With time, the occurrence of biodegradation agents in structural timber reduces its strength frequently resulting in a considerable decline of safety of utilization of the entire object.

Therefore, the objective of this study is a comprehensive analysis of factors causing wood biocorrosion and reasons for their development. The obtained results will allow better understanding of the process of timber destruction and aging.

Research methodology and result analysis

In order to better recognize some factors of timber biocorrosion, investigations were carried out on conditions of timber constructions of an old tram depot as well as the construction and timber parts of wooden summerhouses. The following methods were employed to perform these investigations:

- Mechanical, surface and, in places, deep penetration of material involving pricking with a metal tool of the infested material with the aim to determine the extent of losses and weakening of the examined elements (Ważny, 2000),

- Visual inspection based on qualitative and quantitative estimation of external symptoms of timber biocorrosion such as, for example: losses, discolouring or escape holes left by technical timber pests,
- Acoustic assessment using a wooden hammer with the aim to determine the extent of presence of technical timber pests inside the examined constructions.

The estimation of the current condition of examined objects was characterized by a comprehensive analysis aiming at preparing an accurate inventory of damages and identification of factors of biocorrosion. Results of the performed analysis of the examined objects were presented in the form of a description, tables, photographic documentation as well as inventory drawings.

The performed investigations allowed determining damages of timber elements of constructions ranging from several percent to complete destruction of timber tissue (Photo 1). The most serious damages of timber constructions of the examined objects were brought about by the presence of domestic fungi causing brown rot as well as technical timber pests. In the case of timber summerhouses, active presence of insects from the formic family *Fomicidae* was observed. The insect was identified on the basis of the key for determining imagoes from formic family developing in wood as technical timber pests – the ant from the species of *Camponotus herculeanus ligniperda* Latr. (Photo 2) (Dominik 1989).

The ant belongs to the 4th classification group of technical timber pests based on the type of infected wood and the extent of damage caused in buildings. Group four is characterized by the fact that insects drill timber exclusively with the aim to use it as hiding places. Ants infest timer in buildings very rarely and, usually, when houses are built close to tree stands where these insects occur in their natural habitat. Nevertheless, in favourable conditions, incurred damages can be considerable, as was the case with of the examined objects. Quantitative and qualitative characteristics of damages caused by technical timber pests are presented in some selected inventory drawings, photographs and in the enclosed Table (Krajewski).

In the case of timber beams forming part of old brick walls found in the old tram depot, characteristic escape holes observed there, as well as environmental features, allowed identification of the presence of insects from the families of *Anobiidae* and *Cerambycidae* – *Hylotrupes bajulus* L. (Photo 3). These insects belong to the 1st and 2nd classification group of technical timber pests based on the type of damaged wood and extent of damages Groups I and II comprise the most dangerous species which can go on destroying wood for several generations until complete destruction of sapwood and which cannot be eliminated by maintaining engineering construction prophylaxis.

The most serious damage of timber construction elements and woodwork observed in the examined houses was caused by the presence of domestic fungi. Domestic fungi belonging to basidium fungi (*Basidiomycetes*) cause the most extensive structural damages in wood in the result of brown decomposition (mainly destruction of cellulose) and light decomposition (mainly degradation of lignin). In favourable conditions, biological decomposition of wood caused by a very dangerous group of domestic fungi can result in a rapid infestation of very extensive parts of timber constructions, even in a matter of several months. In the case of the examined constructions, locally, up to 90% losses of timber volume in the result of brown and grey decomposition were recorded. Detailed qualitative and quantitative characterisation of construction timber damages in the examined objects caused by domestic fungi is presented in Table 1 and in enclosed photograph inventory.

Table 1. List of timber construction elements affected by biocorrosion

Type of examined object	Area infected by fungi causing brown or grey decomposition	Characterisation of infestation	Infestation by technical timber pests	Remarks
Rafter framing in hall of old buildings	Locally from about 0.2 cm^2 to about 5 cm^2. Generally, from 10% to 30%	Timber discolouration: blue, grey, white, black; presence of mycelium; brown and grey decomposition	Not observed	Leakage area – about 30% in summer and 50% in winter; corrosion of bitumen roof cover over infested areas; error in roof design and construction (Photo 4)
Timber beams forming part of old brick walls	Local timber losses from 20% to over 90%	Discolouration: blue, grey, white, black, brown; prismatic cracks in wood; brown and grey decomposition	- locally escape holes Ø 2 mm (*Anobiidae*) amounting to about 160 per m^2; in fungi infested parts – local timber losses from 20 - 90%, - locally elliptical escape holes (*Cerambycidae*) amounting from 100 – 190 per m^2,	The most serious tissue losses found in the ground beam and bottom parts of the construction.
Construction of a wooden summerhouse	Surface. Local brown and grey decomposition. The most serious tissue losses found in the ground beam	Timber discolouration: blue, grey, white, black.	Advanced decomposition of wood tissue from about 20 to over 90% of wood volume; destruction caused by technical timber pests from the formic family (*Fomicidae*)	Decomposition in the neighbourhood of leaking water-drainage pipes. The wooden construction is used as a hiding place for insects. A nest was found about 2.5 m above ground. Many of these insects were found in the neighbouring tree stands (about 30% of trees were infested) (Photo 2)

It is evident from the above presented research results, that quantitative infestations of the examined objects were similar. The main difference concerned the agents of the observed biocorrosion resulting from their utilisation and location: town – an old tram depot and neighbourhood of forest – summerhouses. However, in both cases, an important task of administrative authorities is to control regularly the state of these objects because of favourable internal and external conditions for the development of biodegradation agents.

The observed damages in summerhouses resulting from the presence of the technical timber pest from the *Formicidae* family could be attributed primarily to the direct vicinity of a forest.

Another cause of the observed infestation with timber insects was favourable conditions for their development inside the examined buildings consisting in insufficient moisture insulation in bathrooms and kitchens, inadequate protection treatment against insects of internal construction elements: wood, fibreboard etc.

The identified damages by the technical timber pest found in constructions of the tram depot occurred in the result of favourable external conditions (insolated wall – *Cerambicydae* – *Hylotrupes bajulus* L.; fungi infested construction timber – *Anobiidae*) (Krzysik 1974).

The observed biodegradation caused by brown and grey rot fungi developed primarily in the result of inadequate ventilation (or its total lack) of the above-mentioned rooms and, in the case of bottom parts (floor, ground beam), because of insufficient drainage of the foundation. The highest level of wood degradation by domestic fungi was found to occur mainly in elements of increased humidity resulting from leaking water-drainage systems or in places exposed to increased humidity caused by atmospheric precipitation. It should also be

emphasised that the extent and level of the observed biodegradation of the examined buildings could also be attributed, to a considerable degree, to the lack of proper inspection and inadequate treatment of timber constructions with preservatives.

Summing up

The performed investigations allowed to identify:

- Localised biocorrosion of rafter framing of buildings of the old tram depot developed in the result of infestation by brown and grey rot fungi. In some places, the infestation exceeded 50% of the rafter area and could be attributed to leakages of the roof,
- Local damages of bottom parts of walls with wood beams – up to 90% of volume losses resulting from brown and grey rot fungi,
- Dispersed damages reaching up to 50% of wood volume caused by insects from the group of technical timber pests from *Anobidae* and *Cerambycidae* families,
- Advanced biocorrosion – locally up to 90% - of volume loss of construction elements and woodwork of summerhouses caused by the presence of a technical timber pest, a timber-eating ant – *Camponotus heculeanus ligniperda* Latr.

The performed investigations allowed determining that the main cause of damages and losses of wood of constructional elements was lack of appropriate conservation and inspections.

Majority of biodegradation in building industry can be attributed to errors perpetrated at the stage of designing and construction as well as during the utilisation of buildings. At the moment, there are two standards in operation concerning the design of timber constructions: PN-81/B-03150 (11) and PN-B-03150:2000 (2). Both of these standards refer to appropriate legal regulations or standards from the area of protection of timber constructions against biocorrosion where appropriate requirements in this area are specified.

It appears important to carry out investigations associated with timber biocorrosion and its consequences in view of the fact of inadequate attention paid to the above-mentioned standards by designers as shown by the absence of appropriate annotations in technical documentations of buildings with timber elements and of poor knowledge of users about threats posed to timber constructions by biological agents. This is very important when we remember that biodegradation agents can cause serious material losses resulting from shortening the service life of wooden elements by six times (Hardt 1998). That is why the objective of this study was to identify factors of biocorrosion, which are most dangerous for wooden constructions, causes of their appearance and to estimate possible extent of damages.

It should be remembered that the effect of biodegradation factors on timber varies depending on: timber species and conditions of its harvesting and storage, character of loads timber is subjected to in a given construction. That is why it is essential for its condition to guarantee: appropriate choice of protection methods and chemicals, correctness of the technical design and realisation, appropriate utilisation, inspection and current conservation of buildings. A comprehensive protection of timber against agents of biological destruction should comprise a wide range of treatments, which should form a coherent conservation system. Hence, timber protection in building industry should not be associated exclusively with the application of wood protection chemicals toxic for environment. Apart from actions connected with chemical impregnation, there are a number of activities which, when applied consistently and with appropriate skill and knowledge, will improve stability of constructions with wooden elements.

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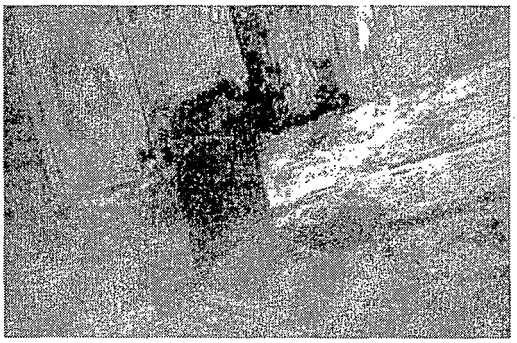


Photo 1. Advanced decomposition of timber (brown and grey) at the mounting of gutter.



Photo 2. A section of the main wall beam in a workshop of an old tram depot; visible are traces of

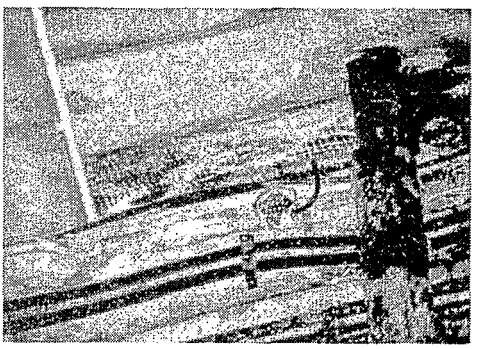


Photo 3. Section of a rafter framing in a workshop of an old tram depot; visible is brown and grey

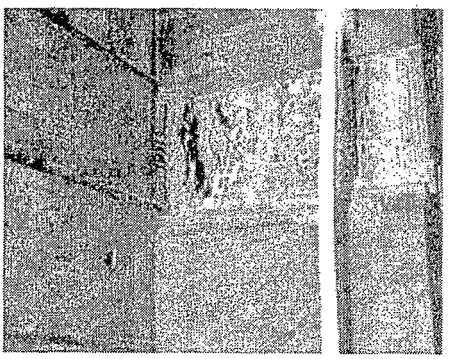


Photo 4. Section of internal wooden panelling and construction of a summerhouse: visible are distinct

Streszczenie: *Biologiczna korozja konstrukcji drewnianych.* Drewno jest materiałem lignocelulozowym, i ma swoją naturalną zmienność, co w pewnym zakresie znajduje odzwierciedlenie w klasach jakości tego materiału oraz skłonności do ulegania jego biodegradacji. Obecność czynników biokorozji oraz nadmierna ilość wad występujących w tarcicy konstrukcyjnej eliminuje taki materiał z zastosowań w budownictwie. Pojawienie się czynników biodegradacji w drewnie konstrukcyjnym, z biegiem czasu obniża jego wytrzymałość, co w rezultacie ma poważny wpływ na bezpieczeństwo użytkowania obiektu. Dlatego też celem niniejszego opracowania jest zagłębiona analiza czynników biokorozji drewna oraz przyczyn ich rozwoju. Materiałem realizacji tematu były drewniane konstrukcje: obiektów zabytkowej zajezdni i domków wypoczynkowych.

Effect of salt preservative agents upon wettability of solidified PVAC adhesives applied in woodworking industry

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Abstract: *Effect of salt preservative agents upon wettability of solidified PVAC adhesives applied in woodworking industry.* The influence of salt preservatives agents added to PVAC adhesive on wetting properties of solidified layers formed on pine wood surface was determined. For experiments 3% Boramon, and 30% Ogniochron as a model preservatives, and two component PVAC adhesive were used. Preservatives were added in amount 2.5 and 5.0%. These mixtures were then put with the applicator on pine wood surface as layers of thickness of 210 μm, which then were hardened. Contact angle for redistilled water on the surface of solidified adhesives was measured in the function of conditioning time, after 24, 72, 168 and 336h. Surface free energy (γ_S), work of adhesion (Wa) and surface tension on the interface (γ_{SL}) together with its dispersion and polar shares were calculated. It was stated among other, that glue layers characterized high Wa values over 100 mJ/m^2. System with Boramon showed highest values of Wa, following also the criteria of minimizing of energy on the interface

Key words: pine wood, salt preservative agent, PVAC adhesive, contact angle, adhesion

Introduction

The possibilities of use of wood, especially in buildings, depends on the way of its connecting as well as protecting against environmental conditions, biotic agents and fire [Popowska and Bernatowicz 1998]. Many solution base first of all on glued wood, where the growing attention is paid to gluing of impregnated wood. Literature data state that individual preservatives can distinctly influence the state of surface of glued wood, disadvantaging for example: wetting process, flow properties, and adhesive penetration. As a result of dissolving or diffusion, these agents can infiltrate adhesives, catalyzing or inhibiting the processes of their hardening or adhesion [Lutomski and Paprzycki 1988, Proszyk et al. 2002].

There are past papers that concerned investigation of surface free energy of polycondensation and polymerization adhesives on pine wood impregnated with salt preservatives [Lis and Proszyk 2001b, Lis and Krystofiak 2001a, b]. As a conclusion of these research it was proved, among other things, that impregnated pine wood could be successfully subjected to gluing [Lis and Proszyk 2001a].

To continue above problem, a research project of model character was undertaken, with the objective to determine the influence of salt preservatives added to PVAC adhesive on wetting properties of solidified layers on pine wood surface.

Experiments

For experiments, it was used:

- model preservatives agents prepared in laboratory conditions basing on producers' directions:

  4% Boramon 170 it is bioprotective and biocide preparation (on the base of quaternary ammonia salts, boron compounds, and aid agents)

  30% Ogniochron preparation with anti-fire action, protects also wood against fungi and insects (on the ammonium salts of phosphate and sulphuric acids, urea, and boron compounds)

- two component PVAC adhesive catalyzed with hardener (20 % aluminium chloride).

Glue mixtures, that were prepared following producers directions, then were added preservatives of amount 2.5 and 5.0% dry mass respectively, relatively to dry adhesive substance. These mixtures were then put with the applicator on pine wood surface (density 420±20 km/m3, MC 12±1%) as layers of thickness of 210 μm, which then were hardened in air-conditioned room (20±2°C, RH=65±5%).

Contact angle for redistilled water on the surface of solidified adhesives was measured according to literature data, carrying out measurements in the function of their air conditioning time, after 24, 72, 168 and 336h. Basing on the obtained values of contact angle and theoretical assumption, surface free energy (γ_S), work of adhesion (Wa) and surface tension on the interface (γ_{SL}) together with its dispersion and polar shares were calculated [Liptáková and Paprzycki 1983, 1984].

Results

Fig. 1 presents results of investigation of γ_S, Wa, γ_{SL}, as arithmetic mean value for considered systems. Basing on thermodynamic consideration of adsorption theory of adhesion, particularly focusing on ratio of γ_S values of interacting materials, the adhesion of glue to substrate can be evaluated. Generally, it is assumed, that resistant bonds are developed, when γ_S of solidified adhesives is lower than γ_S of surface of glued materials. Considering, basing on literature data [Liptáková and Paprzycki 1983, 1984] γ_S=64.0 mJ/m^2 (γ_S^d=26.0; γ_S^p=38.9 mJ/m^2) for pine wood and comparing it with results of calculation performed for PVAC adhesive, it can be stated, that only Boramon slightly tampered beneficial relations that took place in adhesive-wood system.

Adhesive layers characterized with high Wa values over 100 mJ/m^2. A correlation was observed between Wa and surface tension on the interface. When the Wa value is the higher, than the lower γ_{SL} is. However, it should be pointed out, that γ_{SL} values for PVAC adhesive supplemented with Boramon followed the criteria of minimization of energy on the interfaces, which assumes that major condition of high adhesion is γ_{SL} value within the range of 1-3 mJ/m^2. It is worth to point out here, that in case of Ogniochron, as the passage of layers' air conditioning time, only slight exceptions from the above presented criteria were observed, which did not extended the value of 3.5 mJ/m^2.

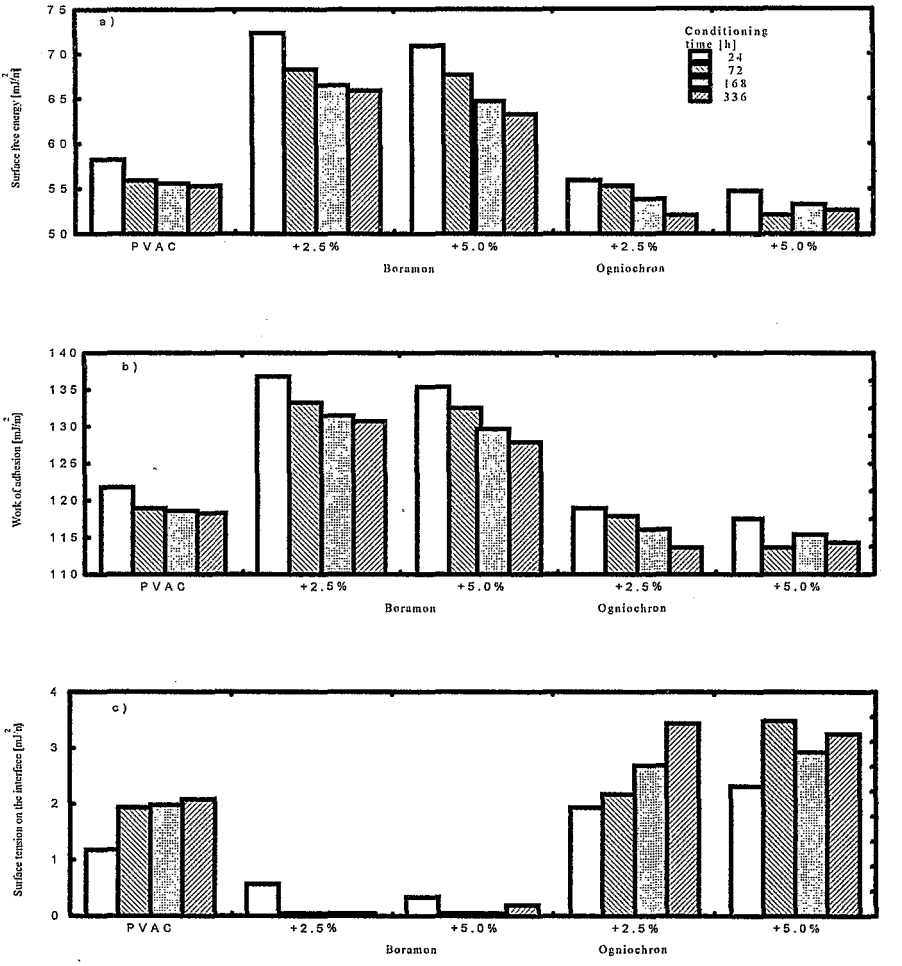


Fig. 1. Effect of salt preservative agents (Boramon and Ogniochron) added to PVAC adhesive upon the course of surface properties of solidified layers and wood-adhesive system in function of conditioning time: a) surface free energy, b) work of adhesion, c) surface tension on the interface

Conclusions

1. PVAC adhesive layers catalyzed with hardener in form of solution of aluminium chloride with addition of salt preservative agents (Boramon and Ogniochron) characterized with more favorable relations of γ_S and Wa in wood-adhesive system.
2. The share of Boramon in adhesive resulted in increasing of γ_S value about 10%, while Ogniochron share slightly decreased it.

3. Glue layers characterized high Wa values over 100 mJ/m^2. Systems supplemented with Boramon showed highest values of Wa, following also the criteria of minimizing of energy on the interface.

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Streszczenie: *Wpływ solnych środków impregnacyjnych na zwilżalność zestalonych klejów PVAC stosowanych w drzewnictwie* Celem pracy było określenie wpływu solnych środków impregnacyjnych dodawanych do kleju PVAC na zwilżalność zestalonych warstw na powierzchni drewna sosny. Do doświadczeń użyto Boramon i Ogniochron jako modelowe impregnaty oraz dwuskładnikowy klej PVAC katalizowany chlorkiem glinu. Do mas klejowych dodawano impregnaty w ilościach odpowiednio 2,5 i 5,0% i nanoszono na powierzchnię drewna w postaci warstw o grubości 210 μm, które utwardzono w klimatyzowanym pomieszczeniu (20±2°C, RH = 65±5%). Kąt zwilżania dla wody redestylowanej na powierzchni zestalonych klejów mierzono zgodnie z danymi literaturowymi, prowadząc pomiary w funkcji czasu ich klimatyzowania po upływie odpowiednio 24, 72, 168 i 336h. Z uzyskanych wartości kąta zwilżania obliczono γ_S, Wa oraz γ_{SL} wraz ze składowymi dyspersyjną i polarną. Na podstawie wyników przeprowadzonych badań m. in. stwierdzono, że warstwy klejowe charakteryzowały się wysokimi wartościami Wa wynoszącymi ponad 100 mJ/m^2. Układy z dodatkiem Boramonu wykazywały najwyższe wartości W_a spełniając jednocześnie kryterium minimalizacji energii na granicy faz.

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Adhesion of UF glues prepared on the basis of reactive solvents to wood as a result of interaction surface forces

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Abstract: *Adhesion of UF glues prepared on the basis of reactive solvents to wood as a result of interaction surface forces.* In paper adhesion properties of adhesive obtained with the use of reactive solvents of urea (RS) with changeable molar ratio are presented. RS are synthesized at molar ratio F: U of 5.1:1.0. Adhesive resins obtained through dissolving of the urea in the RS at molar ratio F:U in the range (1.8-1.0):1.0. For obtained adhesive layers on the surface of beech wood contact angle for redestilled water was measured. Then surface free energy, work of adhesion, and surface tension on the interface were calculated. It was stated among other, that UF resins prepared basing on RS show great similarity of surface forces with standard adhesives used in woodworking industry
Key words: wood, reactive solvent, UF resin, hardening, contact angle, surface free energy, work of adhesion

Introduction

Elaborated in last time by the scientific team of Prof. Z. Wirpsza [Wirpsza, Kowalski and Stawarz 2001], anhydrous reactive solvents (RS) of urea are creating possibilities of obtaining UF adhesive resins with considerable limited content of water. The reactive solvents are the products of reaction of the formaldehyde with chemicals containing active hydrogen ions of groups C-H, N-H, and O-H. In practice they are commonly waterless substances, liquid in room temperature, which could be modified and hardened.

In our initial trials of experimental plywood and particleboard with the use of UF adhesives on the base of RS were obtained with fulfilling physical and mechanical requirements of the proper quality standards [Jóźwiak et al.2002 a, b]. It was stated among others, that plywood made with the use of UF adhesives on the base of RS at F:U molar ratio in the range 1.2:1.0 - 1.8:1.0 is fulfilling requirements for the class 1 of gluing quality for indoor plywood acc. to the EN-314-2 standard.

Evaluation of adhesion that bases on adsorption theory assumes investigation of surface forces of contacting materials. That approach makes possible theoretical determination of maximal adhesion, assuming that all surface force actions are used. As a primary criteria of adhesion evaluation, work of adhesion (Wa) is considered. According to Dupre's equation, Wa is the difference between sum of surface free energy of solidified adhesion and substrate and surface tension on their interface.

In this paper are presented results of the studies on adhesion of the UF glues obtained on the basis of RS with changeable molar ratio F:U to wood at comparable hardening conditions.

Materials and methods

In experiments was applied RS synthesized at molar ratio F: U of 5.1:1.0, with water content 4.74 %, dynamic viscosity 1200 mPa·s and pH 6.1. Adhesive resins were obtained through dissolving urea in RS in quantities corresponding with the molar ratios F: U in the range (1.8-1.0):1.0 in the step every 0.2 mole. Process was carried out on water bath in temperature 80°C, till to the moment of total dissolving of the urea. After obtaining of

uniform solution, UF resins were cooled down to temperature 20°C. Time of preparation of the resins and their fundamentals properties in Table 1 are presented.
Glue mixtures were made with addition of hardener NH_4Cl in quantity 0.5 p.w. /100 p.w. of resin and spread in amount 165±5 g/m². Adhesive layers on the surface of beech wood (*Fagus sylvatica* L.) were hardened at the following constant parameters (open assembly time 10 min, pressing pressure 0.1 MPa, temp. 100°C, time 6 min).
Then samples were conditioned (temp.20±2°C, and RH 65±5%), and after lapse time 24, 48, 72 and 168 h contact angle for redestilled water of the surface of adhesive layers was measured with microscopic methods.

Results

Properties of UF resins obtained with the application of RS solvent are presented in Table 1. On the base of analysis of obtained results, it can be stated, that together with increase molar ratio F:U, the time of dissolving of urea in temp. 80°C is lowering from 8 to 4.5 min, while the gelation time in 100°C from 48 to 27 s. The most stable resins were obtained for molar ratio F:U in the range of 1.1:1.0-1.2:1.0.

TABLE 1. Properties of UF adhesive resins obtained through dissolving of urea in reactive solvents with their adopted marking

Marking of glue mixtures	Molar ratio F:U	Time of dissolving of urea	Viscosity	Gelation time in 100°C	pH	Stability
		min	mPa·s	s	(-)	h
M-1	1.0:1.0	8.0	1800	48	5.7	2
M-2	1.1:1.0	6.5	1800	42	5.5	96
M-3	1.2:1.0	6.0	1400	35	5.5	120
M-4	1.3:1.0	5.0	1500	32	5.5	72
M-5	1.4:1.0	5.0	1700	29	5.6	48
M-6	1.6:1.0	4.5	1700	27	5.5	48
M-7	1.8:1.0	5.0	2300	27	5.5	48

Surface free energy (γ_S) of hardened UF resins was calculated according to Neuman et al. 1974 and Liptáková 1980 and its dispersion and polar shares acc. to Kloubek 1974. Values of (γ_S) for beech wood were adopted following Liptáková 1987 (γ_S=67.6 mJ/m²; γ_S^d=24.7 and γ_S^p=42.9 mJ/m²). It is worth to state here that these values slightly differ from previous data included among others in papers of Nguyen and Johnson 1978 and Wehle 1979. However they more precisely describe surface free energy of wood since Liptaková and Kudela 1994 managed to limit the influence of porous wood structure and its surface unevenness on wetting hysteresis. Work of adhesion of wood-resin system and surface tension on the interface were calculated using formulas from literature [Liptáková and Paprzycki 1983].

TABLE 2. Contact angle of glue layers in function of conditioning time

Marking of glue mixtures (acc. to Table 1)	Conditioning time [h]	Statistical data			
		x_{max}	X	x_{min}	v
		[deg]			[%]
M-1	24	60.95	55.06	49.20	6.76
	72	68.78	63.46	57.85	5.43
	168	70.05	63.88	60.97	4.49
M-2	24	58.42	56.56	55.15	1.90
	72	66.87	64.42	60.70	3.24
	168	67.72	65.18	62.25	3.28
M-3	24	68.50	63.76	58.18	4.29
	72	72.85	68.83	62.53	4.61
	168	72.50	69.22	66.40	3.85
M-4	24	68.88	66.07	62.95	3.19
	72	70.68	69.26	66.62	1.91
	168	71.70	69.94	68.00	1.53
M-5	24	68.85	67.00	66.00	1.26
	72	73.28	71.87	68.70	2.31
	168	73.40	71.99	70.77	1.36
M-6	24	71.90	67.92	65.77	3.79
	72	72.22	70.88	69.13	1.55
	168	85.55	72.73	67.47	9.14
M-7	24	73.38	71.46	69.32	2.12
	72	75.35	73.45	71.30	1.97
	168	81.82	75.39	69.42	6.10

The results of measurements of contact angle of glue layers together with elementary statistic estimation are presented in Table 2. The analysis of these data proves that values of contact angle is higher as the molar ratio of F:U raises. For example at molar ratio of F:U=1.0:1.0 (glue mixture M-1), contact angle of layers determined after 24h of air conditionig was 60.95 deg, while for F:U-1.8:1.0 (glue mixture M-7) this value was 73.38 deg. The stated relation shows that as the molar ratio of F:U raises, obtained layer characterize with higher hydrophobicity.

As a result of analysis of data from Table 2 it can be predicted that during air conditioning of layers an increment of contact angle took place, what can be explained with the additional crosslinking of resin.

TABLE 3 Surface free energy (γ_S) with their dispersion (γ_S^d) and polar (γ_S^p) shares of glue layers in function of conditioning time

Marking of glue mixtures (acc. to Table 1)	Conditioning time [h]	γ_S	γ_S^d	γ_S^p
		mJ/m^2		
M-1	24	50.34	32.54	17.80
	72	45.40	32.79	12.61
	168	45.15	32.78	12.37
M-2	24	49.46	32.64	16.82
	72	44.83	32.77	12.07
	168	44.39	32.74	11.65
M-3	24	45.22	32.78	12.44
	72	42.28	32.54	9.74
	168	42.05	32.50	9.55
M-4	24	43.88	32.71	11.17
	72	42.03	32.50	9.53
	168	41.64	32.44	9.20
M-5	24	43.34	32.66	10.68
	72	40.54	32.25	8.29
	168	40.48	32.24	8.24
M-6	24	42.80	32.60	10.20
	72	41.10	32.35	8.75
	168	40.06	32.15	7.91
M-7	24	40.77	32.29	8.48
	72	39.65	32.06	7.59
	168	38.56	31.79	6.77

In Table 3 results of calculation of γ_S for glue layers were presented. Depending on molar ratio F:U in glue mixtures, after 24h of air conditioning these values varied 40.77-50.34 mJ/m^2. These values together with dispersion and polar share comply literature data for hardened UF adhesives used in standard version [Paprzycki and Pajdosz 1992, Proszyk and Krystofiak 2001]. For example Paprzycki and Pajdosz in research on the influence of hardening parameters of UF adhesives on γ_S value, stated that γ_S varied within a range 37.12-43.42 mJ/m^2. During air conditioning of layers a lowering of γ_S value took place, because of decreasing of polar share. Considering γ_S=67.6 mJ/m^2 for beech wood and comparing it with data from Table 3 for tested glue mixtures, occurred relation can be considered beneficial in the light of adsorption theory of adhesion.

Glue layers characterized with high Wa values within a range of 94.64-111.97 mJ/m^2 after 24h of air conditioning. Work of adhesion value complied with literature data for wood-UF adhesive system. It show the possibility of strong bonding between wood and UF resin.

Conclusions

1. The wettability of hardened layers from UF resins that bases on reactive solvent (RS) depends on molar ratio of F:U in adhesive. As the ratio increases the value of contact angle gets higher. During air conditioning of layers the increase of contact angle value took place.
2. The values of both surface free energy of hardened UF resins based on RS, and work of adhesion in beech wood-resin system follow the criteria of adsorption theory of adhesion, showing the possibility of strong bondings.
3. UF resins prepared basing on RS show great similarity of surface forces with standard adhesives used in woodworking industry.

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Streszczenie: *Adhezja klejów UF sporządzonych na bazie reaktywnych rozpuszczalników do drewna wywołana oddziaływaniem sił powierzchniowych.* Określano adhezję do drewna klejów UF uzyskanych na bazie reaktywnego rozpuszczalnika mocznika (RS) syntetyzowanego przy stosunku molowym F:U jak 5,1:1,0. Klejowe żywice otrzymywano poprzez rozpuszczenie mocznika w RS przy stosunku molowym F:U (1,8-1,0):1,0. Dla uzyskanych warstw klejowych na powierzchni drewna bukowego dokonywano pomiarów kąta zwilżania dla wody redestylowanej. Następnie obliczono swobodną energię powierzchniową, pracę adhezji oraz napięcie powierzchniowe na granicy faz. Stwierdzono m.in., że kleje UF sporządzone na bazie reaktywnego rozpuszczalnika wykazują bardzo zbliżone relacje w zakresie sił powierzchniowych do produktów standardowych stosowanych w przemyśle drzewnym.

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Studies of suitability of epoxy and polyester adhesives for gluing wood with steel

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Abstract: *Studies of suitability of epoxy and polyester adhesives for gluing wood with steel.* The possibilities of use of bonding agents for connecting wood with steel were investigated threw determining strength, water- and thermal resistance of glue lines. For experiment 2 adhesive resins were selected of trade name EPIDIAN 57 and POLIMAL VE-2MM, which were used for gluing general purpose St3SX steel with pine and beech wood. Before gluing the steel surface was prepared by sanding or pickling. For investigation of glue line shearing strength ITL samples were used, while splitting test samples were prepared acc. to BN-77/7103-13 standard. Strength, water- and thermal resistance of glue lines were determined following the procedures included in PN EN 204 and WATT'91 directions. Considerably better results were obtained for epoxy glue lines, that followed only requirements defined for interior conditions of use.

Key words: wood, steel, epoxy adhesive, polyester adhesive, glue line, strength, durability

Introduction

The pieces of some exploited construction solutions, for example of wooden beams in ceiling or roof sheathings, undergo total damage particularly because of moisture and biotic factors. There are several methods of increasing strength or repairing of such beams, for example: the replacement of damaged part, increasing strength with steel framework, gluing on compression side: polyester rods reinforced with glass fiber, steel sheets, steel rods, steel straps, straps reinforced with carbonic fiber [Penczek 1986, Mielczarek 1994, Jasieńko and Rapp 2001]. In order to keep required rigidity and stability of whole system, it is popular to strengthen the construction with metal elements using adhesives that ensure proper strength of various joins. Results of published research on gluability of wood with steel sheet dates quite early years [Zenkteler and Tyszka 1968, Kocoń 1974]. Thus a scientific project was undertaken with the objective to determine, in laboratory conditions, the usefulness of contemporarily offered epoxy and polyester adhesives for joining wood with metals, with particular consideration of way of preparation of steel surface for gluing.

Experiments

For experiments the following adhesive resins were used:

- EPIDIAN 57 epoxy resin with Z-1 hardener (triethylenetetraamine) and MARTINAL ON-310 filler (aluminium hydroxide)
- POLIMAL VE-2MM polyester resin with hardener (hydrogen peroxide of methyl ethyl ketone), accelerator (10% cobalt naphthenate) and AEROSIL (silicon dioxide)-thixotropic agent.

Definite weight (±0,01g) of EPIDIAN 57 adhesive was prepared using the following proportions: 100 mass parts of resin, 10 mass parts of Z-1 hardener and 100 mass parts of MARTINAL-ON 310 filler. POLIMAL VE-2MM adhesive was prepared following the proportions: 100% of resin, 2% of hardener, 1.5% of accelerator and 0.5% of AEROSIL.

For gluing pine wood (*Pinus sylvestris* L.) of density of 450±50 kg/m^3 and beech wood (*Fagus sylvatica* L.) of density of 650±50 kg/m^3 were used at MC 8±1%. For joining

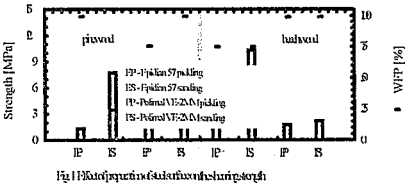
with wood, general purpose steel St3SX was used, which surfaces were preliminarily degreased with acetone. Then some of the samples were subjected to sanding operation in special chamber with stream of quartz sand of granularity of 65μm at pressure of 0.6-0.7 MPa, while the surfaces of the rest of samples were pickled with liquid prepared at the ratio of 1:1 (v/v) from hydrochloric acid of 36% concentration and distillated water [Brojer, Hertz and Penczek 1982]. Pickling time was 8 – 10 min at temperature 20±2°C. After taking out of the solution, samples were washed again with acetone in order to rinse and accelerate surface's drying. Gluing process was carried out according to adhesive producer's directions. For investigation of glue lines shearing strength three-layer ITL samples were used, while for splitting test samples acc. to BN-77/7103-13. Strength, water- and thermal resistance of glue lines were determined following procedures included in PN EN 204 (tests no. 1-3) and WATT'91 directions (Anonymous 1991).

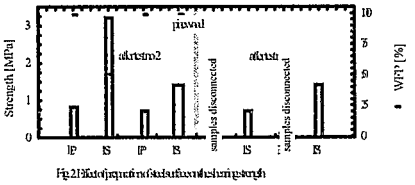
Results

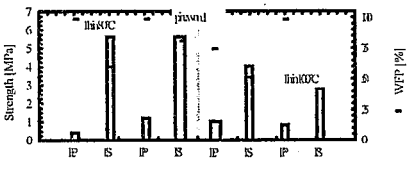
Fig 1-3 presents results of investigation of shearing strength of glue lines, respectively after tests number 1, 2, and 3 acc. to PN-EN 204 and after 1h of sample's heating in temperature 80 and 100°C acc. to WATT' 91 procedure. Obtained results in most cases express real glue lines shearing strength in wood-steel system, not glued wood. Evaluating the influence of tested bonding agents for gluability of wood with steel, it was stated that, considerably better results were obtained for surfaces subjected to sanding. It means that steel surface after this process has more expanded structure, which benefits it's gluability.

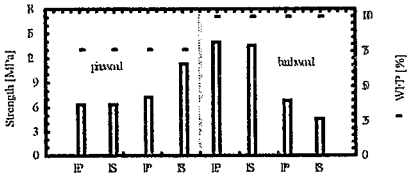
On the base on carried out studies it was stated that glue lines from both adhesives did not meet requirements of water resistance tests acc. to PN-EN 204, which was also proved by analysis of the disconnection of glue lines at destructive loading. In almost case, destruction was in 100% in cohesion layer of glue lines.

Relatively good strength (5.6 MPa) of glue lines subjected to thermal resistance test (80°C) was obtained both for EPIDIAN 57 and POLIMAL VE-2MM for sanded surfaces of the steel. The lowest strength of glue lines subjected to splitting for samples prepared from pinewood and steel of pickled surface was obtained for polyester adhesive. Fig. 4 presents relative results of glue line's strength for splitting of samples prepared form beech wood. The highest values of glue lines strength, that in this case reached the level of 6.2 daN/cm, were obtained for EPIDIAN 57 adhesive.









Conclusions

1. For considered EPIDIAN 57 and POLIMAL VE-2MM adhesives used for gluing pine and beech wood with general purpose steel, it was stated that depending on wood species and particularly on the way of steel surface preparation, there was considerable variance of glue lines shearing strength within a range 0.34 – 10.47 MPa.
2. The highest shearing strength of glue lines after test number 1 acc. to PN EN 204 was showed by samples form beech wood. These values for EPIDIAN 57, depending on the way of surface preparation (pickling-sanding), were: 2.18 and 10.47 MPa. Considerably lower glue lines strength was obtained for samples glued with POLIMAL VE-2MM, which was respectively 1.63 and 2.12 MPa.
3. In water resistance tests significant lowering of glue lines strength were observed. The biggest changes took place after test 3 acc. PN EN 204, in which only glue lines prepared on steel after sanding showed slight strength. Evaluated adhesives are unsuitable for preparation of glue lines capable of contacting with water.
4. The highest values of glue lines splitting strength were obtained for samples prepared from beech wood. Using EPIDIAN 57 for variously prepared steel surface, obtained results laid within a range 13.7-13.0 daN/cm, while use of POLIMAL VE-2MM resulted in 4.7-6.6 daN/cm.

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Streszczenie: *Badania przydatności klejów epoksydowych i poliestrowych do łączenia drewna ze stalą.* Określano możliwości stosowania środków wiążących do łączenia drewna ze stalą poprzez określenie wytrzymałości, wodo- i termoodporności spoin klejowych. Do doświadczeń wytypowano 2 żywice o nazwach handlowych EPIDIAN 57 oraz POLIMAL VE-2MM, którymi sklejano stal ogólnego przeznaczenia St3SX z drewnem buka i sosny. Przed klejeniem powierzchnię stali przygotowywano poprzez piaskowanie lub trawienie. Do badania wytrzymałości spoin na ścinanie użyto próbek ITL a na rozszczepianie wg BN-77/7103-13. Wytrzymałość, wodo- i termoodporność spoin określono zgodnie z procedurami zawartymi w PN EN 204 oraz wytycznymi WATT'91. Zdecydowanie lepsze rezultaty uzyskano dla spoin z kleju epoksydowego, spełniających jedynie wymagania określone dla suchotrwałych warunków użytkowania.

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Effect of kind of hardener in epoxy resins applied for gluing wood on the strength and durability of glue lines

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Abstract: *Effect of kind of hardener in epoxy resins applied for gluing wood on the strength and durability of glue lines.* Studies on the effect of kind of hardener in epoksy resin on the strength and durability of glue lines. For experiments EPIDIAN 57 resin, and Z-1, TFF and PAC hardeners were used. Shearing strength at tension (acc. to PN EN 205) and compression loading (acc. PN-B-03156) were determined. Strength and durability of glue lines after selected tests were determined acc. to PN EN 204 standard and technical approval ITB. On the basis of carried out experiments it was stated among others, that no matter which hardener applied in the resin, obtained glue lines followed only requirements in D1 – D2 durability classes acc. to PN EN 204 and test number 1 of ITB technical approval.

Key words: wood, epoxy resin, hardener, glue line, strength, durability

Introduction

In some special processes of wood gluing, like bonding wood with other materials, epoxy adhesive resins (E) are used. Epoxy adhesives are in continuously wider use during renovation of wooden monuments [Ciabach 1992].

For hardening of E resins in not raised temperature first of all (aliphatic polyamine, products of amine and polyamineamide) are used. The amount of hardener should be accurately calculated depending on concentration of epoxy groups in the resin, because the excess of non-reacted (amine) results in lowering of glue lines strength [Brojer, Hertz i Penczek 1982].

Past investigations of possibilities of E adhesives' usage in wood industry [Olson and Blomquist 1962, Zenkteler and Tyszka 1968, Zenkteler and Sobczak 1975, Vick 1997, Vick and Okkonen 1997] showed their considerable usefulness, especially for gluing of wood with metals and some plastics.

The analysis of literature data proves that until now E adhesives and particularly the problem of their hardening were not paid much attention. In order to enriching current knowledge a research project was undertaken, with the objective to determine, in laboratory conditions, strength and durability of glue lines from E adhesives using various hardeners.

Experiments

For experiments EPIDIAN 57 adhesive resin was used, for which curing the following hardeners were used:

- Z-1 – on the base on triethylenetetraamine
- TFF – product of reaction of phenol, formaldehyde and secondary polyamine
- PAC – product of condensation of unsaturated fatty acids with polyamide.

As a filler aluminum hydroxide was used as trade product named MARTINAL ON-310. Table 1 shows components of prepared adhesive mixtures together with their adopted marking.

TABLE 1. Composition of glue mixtures and their adopted marking

Amount of components [p.b.w.]				Filler [%] (in relation to dry mass of resin)	Marking
EPIDIAN 57 resin	Hardeners				
	Z - 1	TFF	PAC		
100	10	-	-	-	M-1
		-	-	5	M-2
		-	-	10	M-3
	-	22	-	-	M-4
	-	-	50	-	M-5
	-	-	65	-	M-6
	-	-	80	-	M-7

For gluing beech wood (*Fagus sylvatica* L.) with density 650±30 kg/m^3, and pine wood (Pinus sylvestris L.) 520±30 kg/m^3, at MC 10±1% were used. Samples for determination of shearing strength at tension (acc. to PN EN 205 standard) and compression loading (acc. PN-B-03156) were prepared. Glue mixtures which prepared acc. to Table 1, spread in amount 110±5g/m^2 (one side), close assembly time was 10 min, pressing carried out in screw clamp in time 24 h (T=20±2°C, RH=65±5%). Strength and durability of glue lines after selected tests were determined acc. to PN EN 204 standard and technical approval ITB [Anonymous 1998].

Results

Figures 1-3 show the comparison of example results of shearing strength of glue lines at various loading, after selected durability tests. It was stated, that no matter which hardener was added to EPIDIAN 57, glue lines followed only requirements of D1-D2 durability classes acc. to PN EN 204 and test no 1 acc. ITB technical approval. The highest durability was showed by glue lines from glue mixtures with PAC hardener, in which failure at destructive loading took place in 100% in cohesion layer.

The highest thermal resistance was showed by glue lines from EPIDIAN 57 with TFF hardener, and slightly lower with Z-1 and PAC. All of them followed strength requirements of chosen experimental procedures, which guarantees the achievement of high temperature resistance.

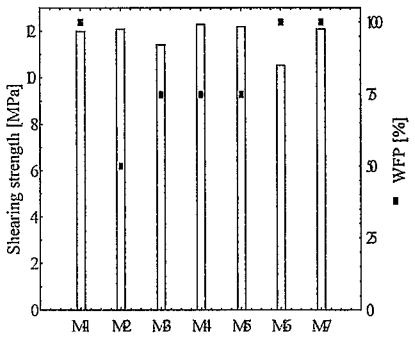


Fig. 1. Strength of glue lines after test 1 acc. to PN EN 204

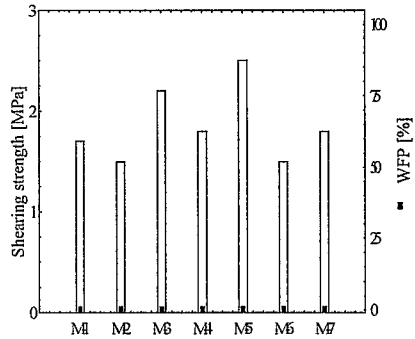


Fig. 2. Strength of glue lines after test 3 acc. to PN EN 204

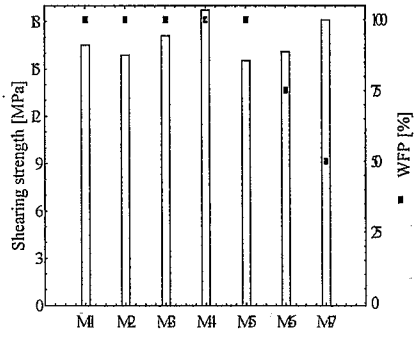


Fig. 3. Strength of glue lines after test 1 acc. to technical aproval ITB

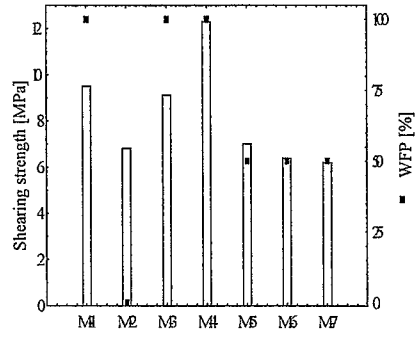


Fig. 4. Strength of glue lines after 1h in 80°C acc. to WATT 91

Conclusions

1. Glue lines from EPIDIAN 57 resin with Z-1, TFF and PAC hardeners, and MARTINAL ON-310 filler showed the shearing strength in interior condition of 10.5-18.7 MPa, depending on the way of loading acting (tension, compression). The most preferable properties of glue lines from EPIDIAN 57 resin were obtained using TFF hardener.
2. No matter which hardener obtained glue lines followed only requirements in D1 – D2 durability classes acc. to PN EN 204 and test number 1 of ITB technical approval.
3. Glue lines from E resin with various hardeners and filler showed very high thermal resistance, that considerably exceeded requirements of stated procedures.

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Streszczenie: *Wpływ rodzaju utwardzacza w żywicach epoksydowych przeznaczonych do klejenia drewna na wytrzymałość i odporność spoin klejowych.* Badano wpływ rodzaju utwardzacza w żywicy epoksydowej na wytrzymałość i odporność spoin klejowych. Do doświadczeń użyto żywicę EPIDIAN 57 oraz utwardzaczy Z-1, TFF i PAC. Określano wytrzymałość spoin na ścinanie metodą rozciągania wg PN EN 205 i ściskania wg PN-B-03156. Badano odporność po wybranych testach wg PN EN 204 oraz aprobaty technicznej ITB. Na podstawie wyników przeprowadzonych badań m.in. stwierdzono, że spoiny z kleju EPIDIAN 57 bez względu na rodzaj i ilość użytego utwardzacza spełniały jedynie wymagania odporności w klasach D1 – D2 wg PN EN 204 oraz testu nr 1 aprobaty technicznej ITB.

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Investigations of thermal resistance of glue lines from hot melt adhesives for upholstery furniture production

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Abstract: *Investigations of thermal resistance of glue lines from hot melt adhesives for upholstery furniture production.* The objective of the paper was the examination of thermal resistance of glue lines from selected upholstery HM adhesives, considering the influence of adhesive type and elastic properties of used PUR foams. For the experiments 3 adhesives of Jowatherm (240 00, 242 00 and 267 00) group and 5 types of PUR foams were used. Basing on the results of the experiment it was found that tested Jowatherm adhesives showed varied thermal resistance of glue lines and considering that feature, they can be arranged (in descending order) as follows: 242 00 > 240 00 > 267 00. It was proved that there was a correlation between thermal resistance of glue lines and elastic properties of PUR foams.

Key words: upholstery furniture, HM adhesive, PUR foam, elasticity, glue line, thermal resistance

Introduction

For gluing of various materials used in upholstery furniture production solvent-born adhesives are widely used [Bernaczyk and Proszyk 1995, Sedliačik 2002]. Recently an introduction of hot-melt and dispersion adhesives to industrial practice began as proecological solution [Hilbrath 2000a, b, c, Pivoluska 2002]. However, the achievement of acceptably high thermal resistance of glue lines especially from HM adhesives, keeping relatively high mechanical strength and elasticity of glue lines causes some difficulties. It is because these adhesives base on APAO and EVA thermoplastic polymers or EPR, EPDM, SBS and SIS rubbers.

As it was stated during until now performed investigation, the elastic properties of polyurethane foams influence on the thermal resistance of glue lines. The estimation of glue lines resistance basing on softening point is misleading, since this resistance depends on properties of glued materials, particularly on thermal expansion, relation of adhesion and cohesion forces and values of stresses.

The analysis of literature proves that besides few research papers and general data placed in various catalogues and instruction of application of individual adhesives for upholstery furniture production, there is a lack of published information that spotlight the problem of thermal resistance of glue lines form HM adhesives. Thus a experimental scientific project was undertaken with the objective to determine the thermal resistance of glue lines from HM adhesives, that base on various polymers, together with elastic properties of PUR foams.

Experiments

For the experiments 3 Jowatherm adhesives on the APAO, and rubbers basis were used. Their properties are shown in Table 1, which bases on producer's catalogue data.

TABLE 1. Properties of Jowatherm adhesives

Properties	Kind of Jowatherm adhesive		
	267 00	240 00	242 00
	APAO	Thermoplastic rubbers	
Density [g/cm^3]	0.95±0.02		
Apparent viscosity [mPa·s] in temp.[°C]:			
140	-	5000	-
160	-	-	2300
180	6250	-	-
Softening temp. acc. to Kofler's heating metal [°C]	65-75	50-60	70-80
Application temperature [°C]	180-190	140-160	

Five standard PUR foams were selected labeled as: VP18, VP2015, VP2540, VP3050, VP35). Some chosen properties of these foams, basis on cataloque data of producer are presented in Table 2.

TABLE 2. Properties of PUR foams

Properties	Kind of foams				
	VP18	VP2015	VP2540	VP3050	VP35
Apparent density [kg/m^3]	18	20	25	30	35
Hardness CLD[kPa 40%], at least	250	210	425	500	450
Stability deformation [%], no more than	7	7	7	7	6
Tensile strength [%], at least	200	200	150	100	150

To examine thermal resistance of glue lines, an experimental procedure was chosen, which had been developed in JOWAT firm laboratories in Detmold. This method basis on evaluating the degree of failure in glued PUR foam samples in relation to the temperature of heating chamber and the time of exposition. The principle of this procedure was described by Proszyk, Bródka and Krystofiak 2001.

Results

Table 3 presents the comparison of values of thermal resistance of glue lines from investigated adhesives considering the type of glued foams. As the result of general analysis of data, the highest values of thermal resistance were shown by Jowatherm 242 00 adhesive glue lines. Depending on foam type, glue lines underwent total disconnection after 20 min in temperature 60°C (except samples from VP3050 foam). Disconnection degree of glue lines after 30 min in temperature 50°C did not exceed 25%, which means, that this warm did not considerably affect on the thermal resistance of glue lines. This set of results clearly presents the dependence of thermal resistance of glue lines on elastic properties of used foams.

TABLE 3. Results of the investigations of thermal resistance of glue lines from HM Jowatherm adhesives

Kind of Jowatherm adhesive [acc. to Table 1]	Parameter's of experiments		Kind of foam [acc. to Table 2]				
	Temp. [°C]	Time [min]	VP18	VP2015	VP2540	VP3050	VP35
			Average degree of disconnection of glue line [%]				
240 00	50	10	5	5	10	15	5
		20	15	20	20	25	20
		30	30	45	60	35	40
	60	10	100	100	100	100	100
242 00	50	10	0	0	0	5	5
		20	5	10	10	25	10
		30	20	20	25	35	20
	60	10	70	65	60	100	75
		20	100	100	100	-	100
267 00	50	10	5	0	5	20	0
		20	20	15	35	45	5
		30	40	30	75	100	20
	60	10	60	55	100	-	100
		20	100	75	-	-	-
		30	-	100	-	-	-

Conclusions

1. The thermal resistance of examined glue lines strictly depends on adhesive type that is used for foam gluing. The experiment results show that considering the thermal resistance of glue lines, the examined HM Jowatherm adhesives can be arranged (in descending order) as follows: 242 00 > 240 00 = 267 00.
2. Significant connection was observed between thermal resistance of glue lines and elastic properties of used PUR foam types. The lowest hardness and higher value of permanent deformation of foams result in higher thermal resistance of examined glue lines. Results of comparison of samples bonded with the same glue allow ordering foams (in the descending order of thermal resistance of glue lines) as follows: VP2015 > VP18 ≥ VP2540 ≥ VP35 > VP3050.

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Streszczenie: *Badania termoodporności spoin z klejów topliwych przeznaczonych do produkcji mebli tapicerowanych.* Badano termoodporność spoin z wybranych klejów tapicerskich z grupy topliwych z uwzględnieniem wpływu rodzaju kleju i właściwości sprężystych stosowanych pianek PUR. Do doświadczeń użyto 3 kleje Jowatherm bazujące na APAO i kauczukach termoplastycznych oraz 5 rodzajów pianek PUR. Termoodporność spoin określono zgodnie z procedurą badawczą opracowaną w laboratorium firmy JOWAT. Na podstawie rezultatów przeprowadzonych badań wykazano, że termoodporność spoin jest ściśle związana zarówno z rodzajem kleju jak i właściwościami sprężystymi pianek. Im mniejsza gęstość pozorna i twardość pianek, tym wyższa termoodporność testowanych spoin dla danego kleju.

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Применене ультразвуков и гамма излучения для контролья степени сохранения древесных конструкционных элементов

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Содержание: Исследованию подвержено 70-летнюю стропильную ногу из костела. Измеренено скорость ультразвуков и плотности древесины. На основе полученных результатов плотности древесины и скорости ультразвуков вычислено модуль упругости древесины.

Предложенные методы исследования с успехом могут быть использованы для неразрушающего испытания сохранения древесных конструкции. Примененная методика измерения позволяет контролировать степень сохранения элементов постройки.

Введение

Несомненно положителной стороной неразрушающих методов исследованя материалов была замечена в применении к исследованям метали или керамических изделий, там получен опыт облегчил их применение для древесины.

Для измерения местной плотности древесины с успехом была.применена техника измерении абсорбции и рассеяния гамма излучения древесиной.

Использование техник измерения скорости ультразвуков для контроля местных свойств древесины представлялось неопоринмым.

В наших раньших исследованях применяя новой метод приложения зондов к поверхности материала мы показали возможность измерения скорости на коротком участке материала. Такой подход дал возможность сканировать весь материал. Тем самым в нашей методе для проведения измерении не нужна вырезка образцов.

Использование радиационой и ультразвуковой техник в том же самом месте позваляет на неразрушающие и местное определение модуля упругости древесины.

Одной из многих возможности такой техники измерения является контролирование степени сохранения древесных конструкценньх эльементов встроенных в постройки.

Чтобы определить степень сохранения конструкционных элементов нужен доступ по меньшей мере со стороны одной поверхности. Тагда измеряя рассеяние гамма-квантов можно определить распределение плотности.

Розумеется доступ к большему количесту поверхностей позволяет на больее полноценный контрол.

Надо подчеркнуть, что наш метод контроля является совсем неразрушающим. В этом методе измерения не нужны образцы и нет обходимости и сверления материала.

Потому такой подход может быть использован для контролирования степеня сохранения старинных предметов.

Методика исследования

А) измеренение скорости ультразвуков

К измеренению скорости ультразвуков примерено переносный аппарат „TM 543E Elpan" при его помощи проводилось измерение время прохождения ультразвуковой волны вдоль волокон древесины.

Зонды аппарата были приложены перпендикулярно к поверхности материала в расстоянии 0,2 м. Эта пара зондов перемещалась по материале с постоянным шагом 0,1м чтобы просканировать целую поверхность.

Время пролета с учетом постоянного базиса пролета (0,2 м) было пересчитано на скорость, которую с координатами положения сохранял в памяти компютер.

Измерительные головоки сцепляно с поверхностью древесины пользуюсь гелем дла ультрасонографии.

Етот гель не имеет побочных реакции с поверхностью древесных эльементов.

Исспользовано сверхзвуковую резонансную частоту 100 kHz. Колебание стимулировано импульсно.

Б) измеренение плотности древесины

Местная плотность древесины была, как уже сказано, определена с помощью радиометрического денситометра.

В качестве гамма излучения применено долгоживущий источник америция Ам-241

Денсиметрическое измеренение получали в результате считивания интенсивности обратного рассения излучения исследовавшего материала, где диаметр коллиматора определяет местность измерения.

На основе сравнения интенсивности гамма излучения рассеянного иссптанным материалом с интенсивностью рассеяннния эталоном в одинаковых условиях, можно определить плотность. Метод подробно, вместе с соотвегсвующими математическими формулами предствлено в работе [2]

В) модуль упругости древесины

Модуль упругости является функцией плотности и скорости ультразвуковой волны (по формуле 1)

$$V = \sqrt{\frac{E}{d} * \frac{1}{(1-k^2)}} \qquad (1)$$

где:

к – это коофициент Поиссона величина которого состатляет по литературным данным 0,3.

v – скорость ультразвуков

d - плотность древесины

Исследовавшийся материал

Исследованию подвержено 70-летнюю стропильную ногу из костела. Ее длина приблизительно 6 м поперечный разрез 12x15 cm. Плотность была измерена на одной поверхности в пунктах оддаленных от себя на 0,15 м при постоянном шаге установки 0,1м

Подведение итогов

Более широкие поверхности мы исследовали на двух измерительных линиях: одна при крайе заболоньи и одна измерительная линия через ядровую древесину.

На узкой поверхности измерено только на двох измерительных линиях через заболонь; полученые результаты были усреднены.

Добовачно для изменшения разброса результатов примерено взвешенное усреднение на очередных 4 пунктах в процессе хонинга

На основе полученных результатов плотности древесины и скорости ультразвуков вычислено модуль упругости древесины для всех измерительных пунктов.

На диаграмме 1 представлено изменение скорости ультразвуков на длине стропильной ноги со стороны широкой поверхности.

Причиной наблюдаеного разброса кажется неравномерность обезценивания материала.

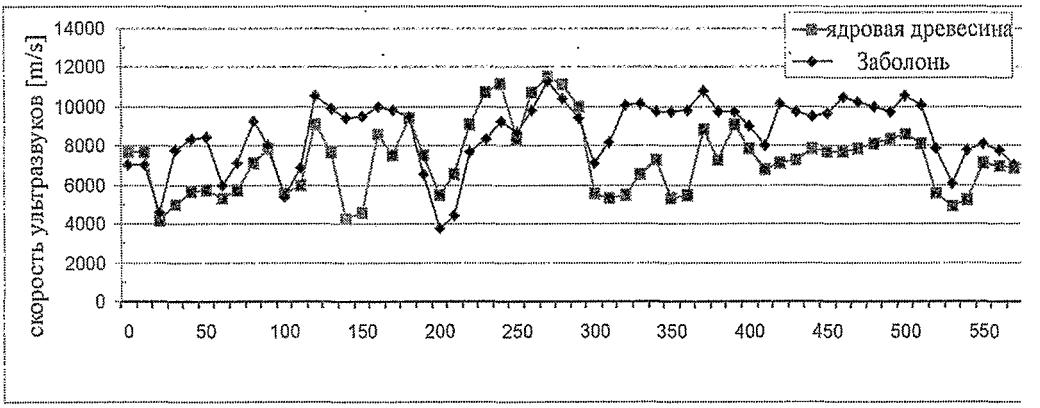


Диаграмма 1: Скорость ультразвука измерена на широкой поверхности

На диаграмме 2 составлено результаты измерения скорости ультразвуков и ее плотности. Надо обратить внимание на сильное сходство характера представленных на диаграмме кривых, а тоже на меньшую флуктуацию плотности в составлении с флуктуациями скорости ультразвуков.

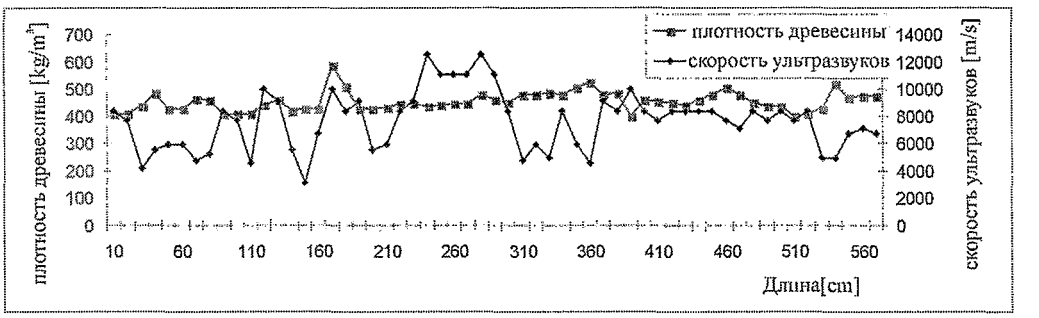


Диаграмма 2:Составление результатов измерения скорости ультразвуков в древесине и плотности, измеренных на широких поверхностях стропильной ноги

Диаграмма 3 представляет изменение местной плотности и модуля упругости а диаграмма 4 изменение скорости ультразвуков и вычисленного модуля упругости.
Сильное сходство характера представленных на диаграмме 4 кривых указывает как ценной информацией содержает скорость ультразвуков, потому что вычисленный модуль упругости во втарой степени зависит от относительно легкой в измерению скорости ультразвуков проходящих вдоль волокон древесины а тоже меньша флуктуация измерения плотности причиняется к тому, что величина модуля упругости сильно зависит от скорости ультразвуков.

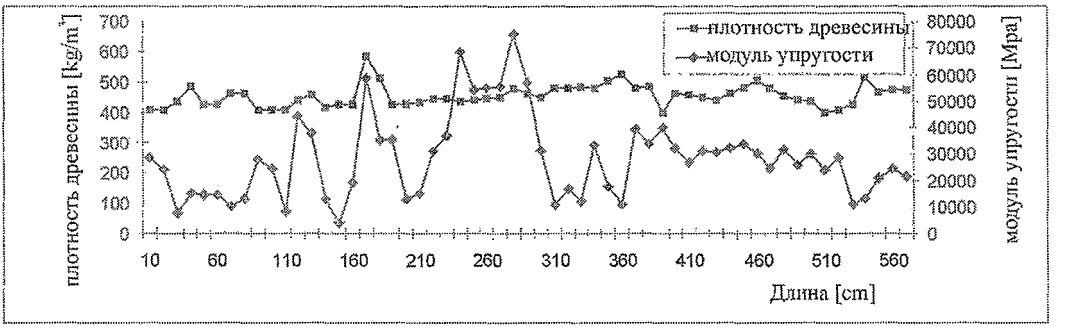


Диаграмма 3: Составление результатов измерения местной плотности и модуля упрулости древесины на длине стропильной ноги (измерение из поверхности)

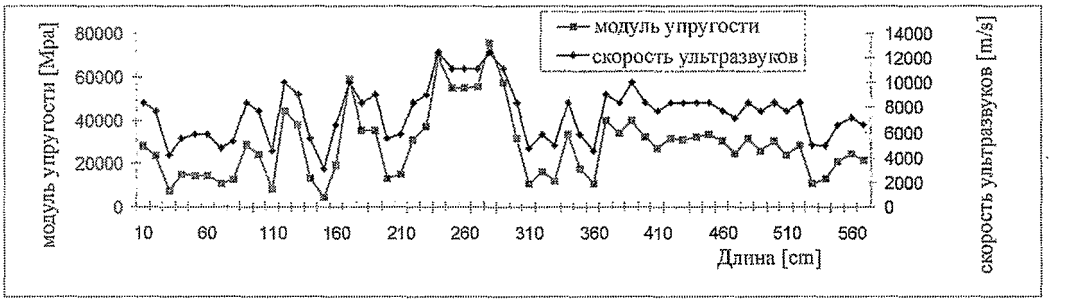


Диаграмма 4: Составление изменения скорости ультразвуков вычисленнего модуля упругости древесины на длине стропильной ноги

Предложение

1 предложенные методы исследования с успехом могут быть использованы для неразрушающего испытания сохранения древесных конструкции

2 примененная методика измерения позволяет контролировать степень сохранения элементов постройки.

3 измерение скорости ультразвуков является бодее чувствительным по сравнеиию с измерением плотности древесины.

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Streszczenie: *Zastosowanie ultradźwięków i promieniowania gamma do kontroli stanu zachowania drewnianych elementów konstrukcyjnych.* Zbadano 70-cio letnią krokiew pochodzącą z kościoła w Laskach k/Warszawy. Określono prędkość przejścia ultradźwięków wzdłuż włókien, oraz zmierzono gęstość. Wyniki badań wskazują na możliwość wykorzystania ultradźwięków i promieniowania gamma do określania stanu zachowania wbudowanych elementów konstrukcyjnych

Selected aspects of ultrasonic wave propagation in wood of *Larix decidua* Mill.

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Abstract: The radial gradient of the ultrasonic wave speed was found qualitatively similar to the gradients of the tracheid length and wood density. The speed of the ultrasonic wave propagation varied from 5140 in wood close to the core to 6230 m/s in mature wood. The dependence of the speed of the ultrasonic wave propagation on the wood density can be described by a linear equation or quadratic equation at the comparable values of the coefficient of determination (R^2=0,81). With increasing length of tracheids the speed of the ultrasonic wave propagation along the fibres increases and the dependence can be described by a linear equation at a high coefficient of determination (R^2=0,82).

Introduction

One of the most interesting problems related to ultrasonic wave propagation in wood is the effect of the length of tracheids (fibres) on the speed of ultrasonic waves propagating along the fibres. Only a few papers have been published on the intra- and inter-species relations between the speed of ultrasonic wave propagation along the fibres and the length of anatomical elements of wood. Among the most interesting papers on the intra-species relations are those by Dzbeński and Szymański (1976) and Dzbeński (1984), who reported a linear correlation between the speed of ultrasonic wave propagating along the fibres and the length of tracheids in scots pine, characterised by a high correlation coefficient (r>0,9). Polge (1984) reported an equally high correlation between the speed of ultrasonic waves and the length of tracheids in mazzard. Niemz and Aguilera (1995) studied interspecies relations between the ultrasonic wave speed and the mean length of tracheids and fibres in five coniferous and six deciduous species in Chile. They reported a linear relation between the parameters compared but characterised by a low correlation coefficient 0.6 for deciduous species and 0.39 for coniferous ones. In full recognition of the importance of the subject the Chair of Wood Science at the Agricultural University in Poznań has undertaken a study on the material aspects of ultrasonic wave propagation in wood. The aim of the study reported was to determine relations between the ultrasonic wave propagation and the length of tracheids and density of wood of *Larix decidua* Mill.

The methods

Taking into regard the variation of wood anatomical elements and its radial density and their dependence on the biosocial position of a tree in a tree stand, the study was performed for samples representing dominant, intermediate and suppressed trees. From just felled larch trees of 40 years of age at the level of breast height diameter we cut out a 3 cm thick disk and 2 cut blocks of 70cm in length. From the blocks some radial 20mm thick boards were cut out. The boards were cut into slabs of 20 mm in width. Each slab was labelled with the distance of the slab from the pith and the numbers covering these annual rings. Then the slabs were cut into samples of 30 mm in length. The samples were conditioned in desiccators over selected saturated salt solutions until the sample moisture content reached 18% and then 12%. The head surfaces of the samples were sandinged and the wood density was determined by the stereometric method.

From the disk a 20mm wide slab was cut out in the north–east direction. In this slab the length of tracheids were measured along the northern tree radius. In order to do this samples

of early and late wood were separately taken out of the annual rings number 3, 6, 9, 12, 15 and then from every fifth one. The samples were macerated in a (1:1) mixture of acetic acid and 30% hydrogen peroxide solution. The process of maceration was conducted at 60^0C for 24 hours. In the selected annual rings in the macerated samples the lengths of 30 early and late wood tracheids a computer image analyser measured. The time of ultrasonic wave propagation through the samples studied was measured to an accuracy of 0,02 μs by using a ultrasound meter type 543 with a head working at the frequency of 0,5 MHz. The head was connected with the sample through a layer of silicon lubricant. A scheme of the setup for measurement of the time of ultrasonic wave propagation through a sample studied is presented in Fig. 1.

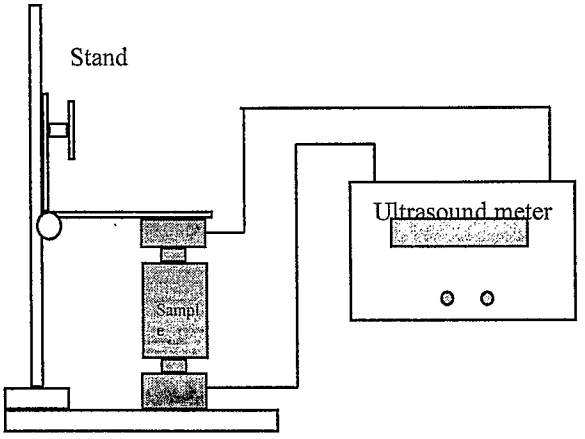


Fig. 1. A scheme of the setup for measurements of the time of ultrasonic wave propagation through the sample.

Results

The results of the measurements of the tracheid length and wood density in air-dry state as a function of the sample distance from the pith are presented in Fig. 2. For the sake of clarity the plot has been made for the mean values of the parameters analysed. The plot implies that the tracheid length and the wood density increase with the distance from the core, which has been already established. The increase both in the tracheid length and wood density is the strongest up to about 20th annual ring. In further annual rings the values of these two parameters stabilise. The minimum values of the length of early and late tracheids measured in the 3rd annual ring (in the middle of the sample in which the ultrasonic speed was measured) were 1740 and 2150μm. In the annual rings at a greatest distance from the core and also placed in the middle of the samples, the mean values of the tracheid length were 4310 and 4760μm. Thus, the difference in the tracheid length between the samples in which the ultrasonic wave propagation was measured was over twice the value. The mean wood density in air-dry state was in the range from 397 to 630 kgm^{-3}.

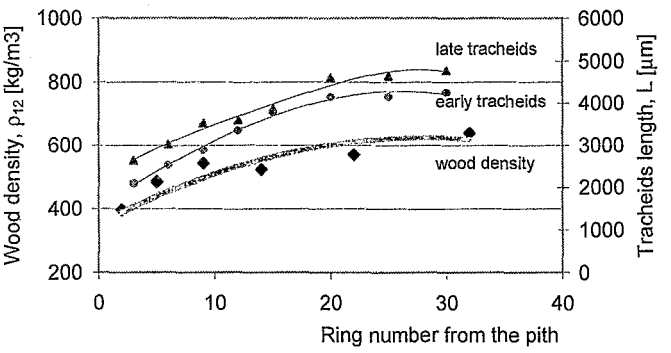


Fig. 2. The tracheid length and wood density versus the sample distance from the pith.

As follows from Fig. 3, the ultrasonic wave propagation speed in larch wood measured along the fibres varies from 5140 to 6230 m/s. It increases with increasing distance of the sample from the core up to ~ 60 mm, and then stabilises. The figure presents mean values of the ultrasonic wave propagation speed obtained from 6 times repeated measurements. The differences in this parameter in the samples at the same distance from the core did not exceed ±70 m/s and the value of the difference from the mean value was the highest for the samples core wood. The results indicate that the ultrasonic wave speed increases with the maturation of the wood tissue. In the zone of mature wood in which the tracheid length and wood density is stabilised, also the ultrasonic wave speed gets stabilised. A similar character of changes in the parameters analysed as a function of the sample distance from the core suggests a relationship between them.

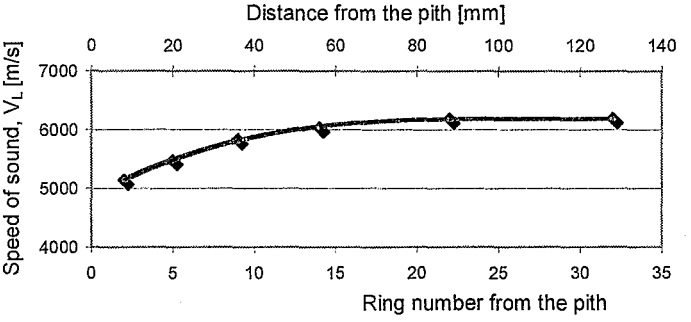


Fig. 3. The speed of ultrasonic wave propagation along the fibres versus the sample distance from the pith.

The dependencies of the ultrasonic wave propagation speed and the wood density and tracheid length are shown in Figs. 4 and 5. The two dependencies were approximated by linear functions, however, the dependence of the ultrasonic wave speed on the wood density can also be approximated by a quadratic function in the form $Y = -0{,}0145x^2 + 18{,}294x + 340$, at a comparable value of the coefficient of determination (R^2=0,8056). This function reaches a maximum at the wood density of $\rho_{12} = 640$ kgm^{-3}. Therefore, we can put a hypothesis that this

value can be treated as a limiting density of the normal wood tissue of this tree species. For higher wood density values at which the ultrasonic wave speed is observed to decrease, the cell wall structure begins to show the features typical of compression wood. It has been established that in the compression wood the ultrasonic wave speed is much lower than in the normal wood [Moliński et al. 2000]. Final verification of this hypothesis requires further study. It should be mentioned that already in 1965 Burmester reported a decrease in the speed of the ultrasonic wave propagating along the fibres with the wood density increasing over a certain value in the wood of pine, spruce and beech trees, and in the wood of limba tree the relationship was negative in the whole range of the wood densities.

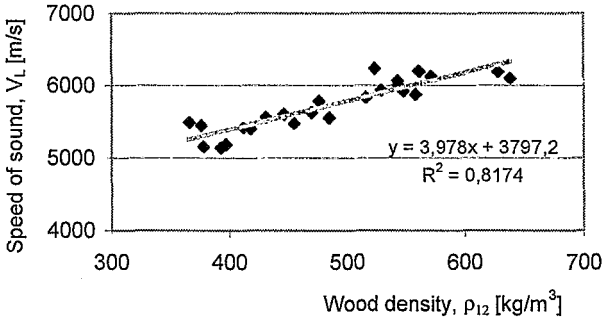


Fig. 4. The speed of ultrasonic wave propagation along the fibres versus the larch wood density.

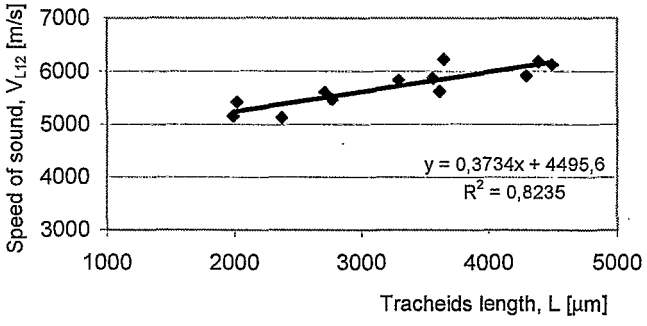


Fig. 5. The speed of ultrasonic wave propagation along the fibres versus the length of tracheids in larch wood.

A comparison of the coefficients of determination of the above discussed dependencies leads to a conclusion that the speed of ultrasonic wave propagation along the fibres depends to the same degree on the wood density and the length of tracheids. The two latter parameters are strictly correlated in a given tree species.

Conclusions

1. The radial gradient of the speed of ultrasonic wave propagation along the fibres in larch *Larix decidua* wood is qualitatively similar to the radial gradient of the tracheid length and wood density.
2. The speed of ultrasonic wave propagation along the fibres in larch tree wood varies from 5140 in wood near the core to 6230 m/s in mature wood.
3. The dependence of the ultrasonic wave propagation speed on the wood density can be approximated by a linear equation or quadratic equation of comparable values of the coefficient of determination.
4. With increasing tracheid length the speed of ultrasonic wave propagation along the fibres increases. This dependence can be described by a linear function at a high coefficient of determination (R^2=0,82)

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Streszczenie: *Wybrane, materiałowe aspekty propagacji fal ultradźwiękowych w drewnie Larix decidua Mill.* W pracy przedstawiono promieniową zmienność długości cewek, gęstości drewna w stanie powietrznosuchym i prędkości propagacji ultradźwięku wzdłuż włókien w drewnie modrzewia *Larix decidua* Mill.

Stwierdzono, że promieniowy gradient prędkości rozchodzenia się ultradźwięku jest jakościowo podobny do promieniowego gradientu długości cewek i gęstości drewna. Wartości liczbowe prędkości propagacji ultradźwięku mieszczą się w przedziale od 5140 dla drewna przyrdzeniowego do 6230 m/s w drewnie dojrzałym. Zależność prędkości propagacji ultradźwięku od gęstości drewna można opisać równaniem liniowym, lub funkcją drugiego stopnia o porównywalnych współczynnikach determinacji (R^2=0,81). Wykazano, że ze wzrostem długości cewek rośnie prędkość ultradźwięku wzdłuż włókien. Zależność tą można opisać równaniem linii prostej o wysokim współczynniku determinacji (R^2=0,82).

Stability analisys of thin-walled plywood cylindrical shape

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Abstract: The Engesser-Shanlay modified theory for thin-walled axially crushed cylindrical rods for case when rods are made of plywood (patent application P 353556) is presented in the paper. The problems of critical loads in elasto-plastic states have been considered. The squeeze ratio of critical transverse section has been defined by value α - angle, which to slenderness ratio is related. The received theoretical curves $\sigma_H(\lambda)$ and $\sigma_{kr}(\lambda)$ for thin-walled plywood cylindrical shape made of birch has been presented next to similar curves for steel R35 (standards PN-73/H-74240, PN-75/H-84019) and aluminium alloy Pa4 (standards PN-85/H-74592, PN-79/H-88026).

The wood that is probably the one renewed hard technical material should be used in balance to renew possibility. Because renew term of wood is relatively long, it should be used in clever way. The example of so use of wood could be the thin-walled plywood cylindrical shape [1], which may be used, particularly with light core, as responsibility structures like furniture legs, poles, posts, elements of wood houses, masts and etc. The advantage of so structure is awaited relatively high load capacity by low weight and possibility of production from defective material, i.e. from wood which can't be used for round or square-sawn timber but can be still used for fretted facing board or face veneer. Taking under consideration using the thin-walled plywood cylindrical shape for so structures you should firstly analyse its load capacity for axial loading, i.e. its stability.

Stability of rods according to euler, engesser, karman and shanley

The basic theory of slender rod lose stability in elastic state was worked out through Euler (1744, 1759). He introduced the concept of critical load and gave the formula for critical force of axially crushed rod. The loss stability theory of crushed rod in elasto-plastic state, basing on concept of tangent module, worked out Engesser (1895, 1889), Kármán (1908, 1910) and Shanley. (1947). According to Engesser-Kármán hypothesises, in critical cross-section of axially crushed rod, being found in elasto-plastic state, there are two zones: squeezed - deformed on concave side of neutral layer of rod and tensioned - deformed elastically on bossed side. From equilibrium of forces and of moments in relation to neutral layer of rod, before losing of stability, drew out the conclusion, that areas of triangles of tensioning and squeezing stresses have to be equal. Besides dependence between displacement and stress in elastic zone characterised with Young's module E and in plastic zone with so-called tangent module E_t, determined as Young's module from graph $\sigma(\varepsilon)$, but from non-linear range. Referring this hypothesises to case of cylindrical rod (fig.1), where distance $y_{1(2)}$ from neutral layer of segment dA of critical cross-section area, in moment of losing stability, you can express for squeezed and tensioned sides:

$$dA = t\,\overline{R}\,d\theta \quad , \qquad y_1 = \overline{R}(\cos\alpha - \cos\theta), \qquad y_2 = \overline{R}(\cos\theta - \cos\alpha), \tag{1}$$

where: $\overline{R}$ - the average radius of tube, t – the wall thickness, $2\,\alpha$ - angle describing plastic part critical cross-section, A – area of critical cross-section. The equilibrium of forces from stresses:

$$\int_{A_2}\sigma_t dA_2 = \int_{A_1}\sigma_1 dA_1 \quad , \quad \sigma_t = \frac{y_2}{\rho}E_t \quad , \quad \sigma_1 = \frac{y_1}{\rho}E \quad , \tag{2}$$

where: $A_{1(2)}$ - area of tensioned (plastic) part of critical transverse cross section, ρ - curvature radius of neutral layer. From equations (1) and (2) [2]:

$$\int_{\alpha}^{\pi}\frac{E_t}{\rho}\overline{R}(\cos\alpha-\cos\theta)\overline{R}d\theta = \int_{0}^{\alpha}\frac{E}{\rho}\overline{R}(\cos\theta-\cos\alpha)\overline{R}d\theta \;\Rightarrow\; \frac{E_t}{E} = \frac{\sin\alpha+(\pi-\alpha)\cos\alpha}{\sin\alpha-\alpha\cos\alpha} = 1+\frac{\pi}{\mathrm{tg}\alpha-\alpha} \tag{3}$$

Function (3) has physical point only for $\alpha \in (90°, 180°)$, because must be: $1 \geq E_t/E > 0$. The equilibrium of moments, has been described with formula: $\int_{A_2}\sigma_t y_2 dA_2 + \int_{A_1}\sigma_1 y_1 dA_1 = -Py$ (4)

After integrating, taking into consideration $J_{(1,2)}$ - axial moment of inertia (tensioned, plastic part), and analysing differential equation of neutral layer has been received its equation:

$$\frac{E_{EK}J}{\rho} = -Py, \qquad \text{where:} \quad E_{EK} = \frac{E_t J_2 + EJ_1}{J} \quad . \tag{4}$$

After that, has been received formula for critical stress: $$\sigma_{EK} = \left(\frac{\pi}{\lambda}\right)^2 E_{EK} \tag{6}$$

Taking formula (3) has been determined value of equivalent module in relation to Young's module as:

$$\frac{E_{EK}}{E} = \left(\frac{1}{\pi} + \frac{1}{\mathrm{tg}\alpha - \alpha}\right)\left[\alpha\left(1 + \frac{\cos 2\alpha}{2}\right) - \frac{3\sin 2\alpha}{4}\right] + 1 - \frac{\alpha}{\pi} + \frac{1-\alpha}{2}\cos 2\alpha + \frac{3\sin 2\alpha}{4\pi} \quad . \tag{5}$$

Unfortunately this function has physical point only for $\alpha \in (90°, 138°)$ what results from acceptances of foundation, that areas of triangles of tensioning and squeezing stresses have to be equal and from limitations of hypothesis to little deformations. How is apparent function $E_t/E(\alpha)$ is possible to apply in wider range of α than $E_{EK}/E(\alpha)$. Shanley took advantage of this putting in equation (6) instead E_{EK} directly E_t, what also was burdened with an error, and appointed course of function $E_t(\lambda)$ on the ground of this formula at acquaintances from experiment the function $\sigma_{kr}(\lambda)$ [3] is rather theoretical. Especially wakes reservations determining of function $E_t(\lambda)$ for row of rods on the ground of non-linear range of function $\sigma(\varepsilon)$ course, received during extension tests of one normative samples [4], [5].

The engesser-shanlay modified theory

In connection with above reservations has been conducted own analysis of Stability of thin-walled rods. The results [2] of strain gauges measurements obtained from researches on tube crushed through ball and socket joints with constants increase of power show that already little charges, next to *10%* P_{kr}, cause distinct turnover of centre line tube segment and testify to its deforming. Has been accepted so, that losing of stability follows already at minimum charges, and for losing of carrying capacity is responsible position of resultant (from superposition of compressions and of bending) neutral layer of tube in relation to critical outline of transverse section. On base of these observations has been accepted, that in elastic state losing of carrying capacity follows after exit resultant neutral layer from critical transverse section, however in elasto-plastic state, after entry resultant neutral layer in plastic zone. Has been accepted from here, that state of stresses in critical transverse section after loss of stability and before loss of carrying capacity, is as the result of clean compressions and bending superposition (fig.2). How apparently from drawing, in critical transverse section most is strenuous, because of normal stresses, extreme internal filament after concave rod side. Because of clean compressions and bending superposition resultant neutral layer shifts, together with growth of load, from central line toward concave, more weighted side of tube. Together with growth of load, grow up stresses from bending, but also from compressions, and the position of resultant neutral layer is as the effect of these stresses participation specific game, what depends from the form of rod (thickset - slender). State of stresses in critical transverse section of rod, before loss of carrying capacity, is characterised with flow plastic part of section, in concave squeezed side, after stresses rich yield stress. This results with additional decreasing of rod central line radius. On fig.3.a the position of neutral layer in critical transverse section before loss of carrying capacity has marked with angle β and position of plastic zone border - with angle α. How there was already sad, has been accepted, that loss of carrying capacity of rod follows when resultant neutral layer, at force P_{kr}, enters in plastic zone, that is $\alpha = \beta$ (fig.3.b) and flowing material does not place already resistance against bending (the lack of resisting moment). For λ_l has been accepted, that in moment of loss of carrying capacity full critical transverse section is in plastic state ($\alpha = \pi$ *rd*). In case of λ_{gr} whole critical transverse section, in moment of loss of carrying capacity, is in plastic state ($\alpha = 0$ *rd*). The position of resultant neutral layer, in moment of loss of carrying capacity, changes dependably on slenderness ratio. For the rod with slenderness ratio λ_l the resultant neutral layer covers the central line ($\alpha = \pi$, $\beta = \pi/2$ *rd*) and with λ_{gr} covers the edge of critical transverse section outline ($\alpha = 0$, $\beta = 0$ *rd*). For slenderness ratio between λ_l and λ_{gr} the resultant neutral layer lies between the central line and the edge of critical transverse section outline on

concave side of rod ($0 < \alpha < \pi$; $\pi/2 > \beta > 0$ *rd*). After cutting the rod in the critical cross-section and after investigation of state of stresses has been qualified equilibrium of forces. The force P_{kr} is equalised by elastic force P_H and plastic force P_m (fig.3,b). From here [6], [2] :

$$\Sigma P = P_{kr} - P_m - P_H = 0 \Rightarrow P_{kr} = P_m + P_H, \qquad \Sigma M = P_{kr}\, y - P_m\, y_m + P_H\, y_H = 0 \ , \tag{6}$$

where: $$P_H = \sigma_H\, A_H = \sigma_H\, (\pi - \alpha)\, \overline{R}\, t \ , \qquad P_m = \sigma_{kr}(\lambda_1)\, A_m = \sigma_{kr}(\lambda_1)\, \alpha\, \overline{R}\, t \ , \tag{7}$$

σ_H - limit of elasticity at compression , t - thickness of tube, $\overline{R}$ - average radius of rod, $A_{H(m)}$ - area of transverse section in elastic (plastic) state. From here:

$$\sigma_{kr} = \frac{P_{kr}}{A} = \sigma_H \frac{2(\pi - \alpha)\overline{R}t}{2\pi \overline{R}t} + \sigma_{kr}(\lambda_1)\frac{2\alpha \overline{R}t}{2\pi \overline{R}t} = \sigma_H\left(1 - \frac{\alpha}{\pi}\right) + \sigma_{kr}(\lambda_1)\frac{\alpha}{\pi} \ , \tag{8}$$

If for λ_{gr} is attained P_H, then $P_{kr}(\lambda)$ from range $(\lambda_1, \lambda_{gr})$ is attained for:

$$\lambda = \lambda_{gr} - \frac{\alpha}{\pi}\left(\lambda_{gr} - \lambda_1\right) \Rightarrow \frac{\alpha}{\pi} = \frac{\lambda_{gr} - \lambda}{\lambda_{gr} - \lambda_1}, \tag{9}$$

From here has been received: $$\sigma_{kr}(\lambda) = \sigma_H(\lambda) + \frac{\lambda_{gr} - \lambda}{\lambda_{gr} - \lambda_1}\left[\sigma_{kr}(\lambda_1) - \sigma_H(\lambda)\right] \ . \tag{12}$$

The stress $\sigma_{kr}(\lambda_1)$ has been acknowledged as characteristic parameter for given material and marked *Re**. How results from researches function $\sigma_H(\lambda)$ is of first degree, so received function $\sigma_{kr}(\lambda)$ is of second degree. The stress $\sigma_H(\lambda_1)$ has been acknowledged too as characteristic parameter and marked R^*_H. The lineal function $\sigma_H(\lambda)$, neglecting value λ_1, has been described with formulas:

$$\sigma_H(\lambda) = R^{Eu}_H + \left(1 - \frac{\lambda}{\lambda_{gr}}\right)\left[R^*_H - R^{Eu}_H\right], \qquad R^{Eu}_H = \sigma_H(\lambda_{gr}) = \sigma_{kr}(\lambda_{gr}) \ , \tag{10}$$

R^{Eu}_H-limit of elasticity in Euler's formula to determination λ_{gr}. Then:

$$\sigma_{kr}(\lambda) = \left(1 - \frac{\lambda}{\lambda_{gr}}\right)\left(R^*_e + R^*_H \frac{\lambda}{\lambda_{gr}}\right) + R^{Eu}_H\left(\frac{\lambda}{\lambda_{gr}}\right)^2 . \tag{11}$$

And after insertion the Euler's formula:

$$\sigma_H(\lambda) = \left(\frac{\pi}{\lambda_{gr}}\right)^2 E + \left(1 - \frac{\lambda}{\lambda_{gr}}\right)\left[R^*_H - \left(\frac{\pi}{\lambda_{gr}}\right)^2 E\right], \qquad \sigma_{kr}(\lambda) = \left(1 - \frac{\lambda}{\lambda_{gr}}\right)\left(R^*_e + R^*_H \frac{\lambda}{\lambda_{gr}}\right) + E\left(\frac{\pi\lambda}{\lambda^2_{gr}}\right)^2, \tag{12}$$

These formulas are suitable to uses on condition acquaintance of parameters: R^*_e, R^*_H, E and R^{Eu}_H or λ_{gr}. Two first you should determine from the compression test of thickset rod.

The engesser-shanlay modified theory for case rods made of birch plywood

In the stability analysis of thin-walled plywood cylindrical shape, according to own idea [1], made of birch has assumed, that $R^*_e = R_c \parallel$ (has assumed, that plywood cylindrical shape would be roll up with fibres parallel to roll axis) and also, according to [7]: $R^*_H = 0.6 R_c$ (for birch) and $R^{Eu}_H = 100$ [MPa] (for wood). Those values have assumed as hypothetical, which should be corrected during next research works, what is in the author's intention. Finally has assumed values: $R^*_e = 430$ [MPa], $R^*_H = 258$ [MPa], $E = 16\,500$ [MPa] and $\lambda_{gr} = 40.4$ (ρ=500÷900 [kg/m^3]). After that has determined the hypothetical curves $\sigma_H(\lambda)$ and $\sigma_{kr}(\lambda)$, which are presented on fig.6 next to similar curves but determined from own research [2] for steel R35: $R^*_e = 346$ [MPa], $R^*_H = 156$ [MPa], $E = 166\,614$ [MPa] and $\lambda_{gr} = 102.6$ (ρ=7 800 [kg/m^3]) and aluminium alloy Pa4: $R^*_e = 191$ [MPa], $R^*_H = 153$ [MPa], $E = 72\,387$ [MPa] and $\lambda_{gr} = 68.3$ (ρ=2 700 [kg/m^3]) [8].

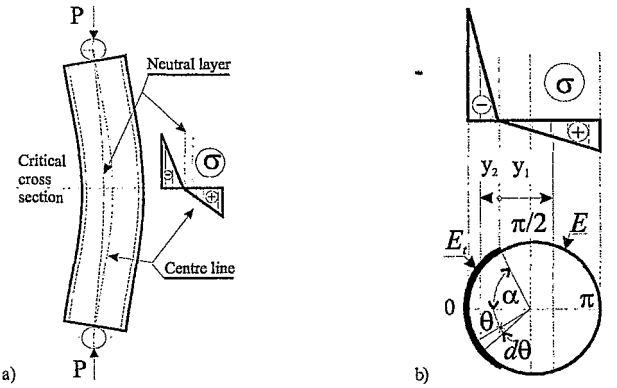


Fig.1. Critical cross-section axially crushed rod while losing of stability, according to Engesser-Kármán hypothesises.

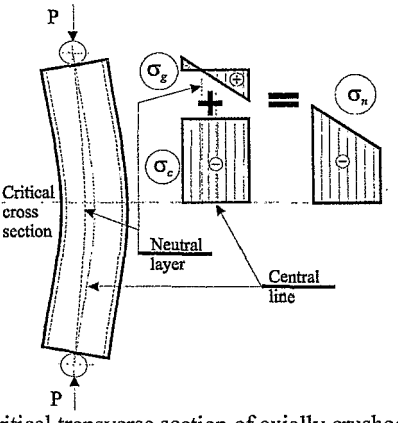


Fig.2. State of stresses in critical transverse section of axially crushed tube after loss of stability.

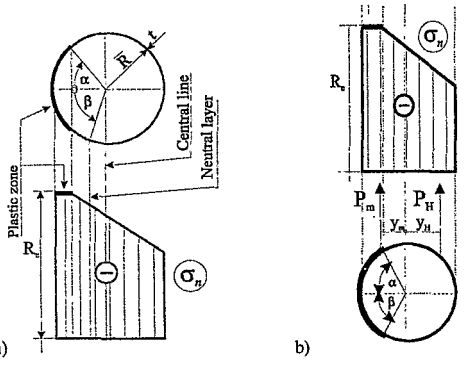


Fig.3. State of stresses in critical transverse section of axially crushed tube before (a) and in the moment (b) of loss of carrying capacity.

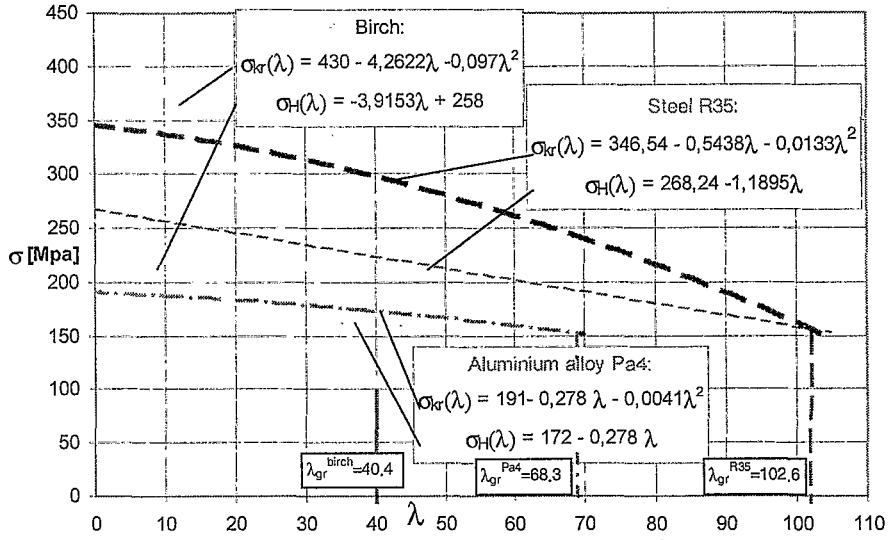


Fig.4. Hypothetical curves $\sigma_H(\lambda)$ and $\sigma_{kr}(\lambda)$ for thin-walled plywood cylindrical shape made of birch and similar curves for steel R35 and aluminium alloy Pa4 [8].

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Streszczenie: *Analiza stabilności prętów cylindrycznych wykonanych ze sklejki cienkowarstwowej.* W artykule przedstawiono zmodyfikowaną teorię Engesser'a-Shanley'a dla osiowo ściskanych cienkościennych cylindrycznych prętów w przypadku gdy są one zrobione ze sklejki (zgłoszenie patentowe P 353556). Rozpatrzono problem obciążeń krytycznych w stanach sprężysto-plastycznych. Część zgniataną w krytycznym przekroju poprzecznym określano kątem α, który powiązano ze smukłością pręta. Otrzymane teoretyczne krzywe $\sigma_H(\lambda)$ i $\sigma_{kr}(\lambda)$ dla cylindrycznych cienkościennych powłok ze sklejki z brzozy przedstawiono na tle podobnych krzywych dla stali R35 (normy PN-73/H-74240, PN-75/H-84019) i stopu aluminium Pa4 (standards PN-85/H-74592, PN-79/H-88026).

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Straw as raw material for production of hardboards by the wet method

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Abstract: Hardboards were made from straw pulp and from mixture of straw pulp and wood pulp. Their properties were examined. In results were found that straw pulp is the good substitute of wood pulp – properties of straw hardboards are this same like properties wood hardboards.

Key words: hardboard, straw, technology.

Introduction

Annual plants have been since a long time applied to production of pulp. The most ancient examples refer to the application of rice straw in China as raw material for paper-pulp production. Besides, rice paper is produced in China till today.

Globally, annual plants make not more than 10% of raw material in pulp technology, but there are countries and regions in which procession of annual plants fully satisfies local demand for paper-pulp and related stuff (Anon 1998, Dalen 1999, Rowell et cfo.).

An interesting application of annual plants is producing from them pulp useful for manufacturing of hardboards by the wet method. This technology is characterised by lower, in comparison with papermaking, requirements regarding the pulp quality, in particular it does not require delignification of the raw material.

The wet technology of hardboards undergoes currently a noticeable renaissance, because its product is particularly valuable from the ecological point of view. Hardboards produced by the wet method do not contain or contain minimum quantities of synthetics (glues), so they are safe in usage and easy to recycle by any method. In this area, especially interesting are attempts at production of hardboards from annual plants. Application of this raw material gives the boards another property, particularly valuable from the point of view of environment protection, i.e. the possibility of combustion of used boards without upsetting the balance of carbon dioxide in the atmosphere. It is possible due to the fact that in this case the raw material (straw, reed, etc.) from which boards are produced, arises in a short, annual vegetation cycle.

In the researches presented below, it was attempted to produce, in laboratory conditions, hardboards from the straw of rye, one of cereals most commonly grown in the temperate climate zone.

Production of pulp

The raw material was rye straw cut to chaff of length about 2 cm by means of a typical agricultural straw cutter. The humidity of pulp amounted to about 12%.

Several trials of defibration of this raw material were conducted. Initially, there were applied parameters and course of defibration similar to those applied in defibration of wood, i.e. a two-stage defibration. The first stage was defibration in saturated vapour of temperature 180°C, the second stage – extra grinding in a disk refiner. It turned out that the obtained pulp is characterised by a very high freeness, appropriate rather for papermaking applications than for hardboards production with regard to a very slow drain of pulp.

Therefore, several trials of defibration were conducted in differentiated parameters and different configuration of the equipment. It turned out that optimal is defibration of straw in an one-stage mode in temperature below 100°C. Pulp of relative humidity 70% was obtained. Its freeness was still high, about 90 DS, but the rate of drain already allowed for effective application of this raw material in typical technological conditions.

As additional and comparative raw material, pine-wood pulp was used. It was obtained in typical technological conditions and its freeness amounted to 28 DS.

Production of boards

It was scheduled to produce hardboards of nominal density 950 kg/m^3 and thickness 3.2 mm without hydrophobisation. The basic variants were:

1 – boards obtained without heat treatment from pure straw pulp,

2 – boards obtained in the same way from pine-wood pulp (comparative variant)

Additionally, it was scheduled to produce boards from a mixture of straw and pine-wood pulp containing 70, 50 and 20% of straw pulp as well as boards from pure straw pulp submitted to heat treatment in the temperature of 160°C and similar boards produced with an 1-percent admixture of the phenol-formaldehyde resin (PF) without heat treatment.

After drain, the boards were pressed in the temperature of 220°C for 8 minutes under the pressure of 5 MPa.

Boards test, disscusion of results

After a 48-hour seasoning, measurements of density, bending strength, thickness swelling and water absorption after 2 and 24 hours of water action were conducted. The results of these measurements are presented in the table below.

Properties of hardboards

Kind of boards	Density [kg/m^3]	Coeffi-cient of variable [%]	Ben-ding strenght [MPa]	Coeffi-cient of variable [%]	Thick-ness swelling after 2h soaking in water [%]	Coeffi-cient of variable [%]	Thick-ness swelling after 24h soaking in water [%]	Coeffi-cient of variable [%]	Water absorp-tion after 2h soaking [%]	Coeffi-cient of variable [%]	Water absorp-tion after 24h soaking [%]	Coeffi-cient of variable [%]
Standard	**942**	11,0	**38,0**	7,7	**41,5**	13,1	**48,4**	12,3	**72,5**	7,2	**80,9**	5,9
Heat treated	**968**	7,5	**33,0**	8,2	**40,8**	11,3	**46,7**	13,6	**73,1**	8,8	**79,5**	6,5
With 1% PF addition	**946**	11,3	**35,9**	9,2	**43,4**	7,9	**49,1**	11,6	**68,3**	10,0	**77,4**	9,7
Standard with 30% wood pulp	**961**	9,6	**34,7**	11,7	**39,1**	8,5	**43,9**	9,2	**67,5**	12,1	**73,8**	7,6
Standard with 50% wood pulp	**965**	12,3	**37,6**	10,7	**42,7**	9,8	**49,2**	11,0	**65,8**	10,3	**73,9**	9,9
Standard with 80% wood pulp	**968**	9,2	**37,2**	8,9	**40,5**	7,6	**45,7**	9,7	**70,2**	12,3	**77,3**	7,1
Normal wood hardboard	**969**	7,3	**38,0**	10,5	**41,9**	6,9	**50,2**	10,0	**66,0**	6,8	**78,0**	10,1

It is visible in the table that boards made of pure straw pulp have practically the same properties as those made of wood pulp and of mixture containing 30, 50 and 70% of wood fibres.

Interesting is the fact that heat treatment not only did not improve, but, on the contrary, made the properties of boards from straw pulp worse, in spite of the fact that it is a typical treatment applied in the technology of standard hardboards in order to heighten the product quality. It can be presumed that the cause of lowering the board strength in this case is a low thermal resistance of straw connected with a high content of hemicelluloses and low-molecular lignin.

Strengthening sizing of boards from straw pulp by means of the PF resin did not change the board properties in a statistically significant way.

Conclusion

It is visible from the presented results that pulp produced from rye straw is a full-value raw material for the production of hardboards by the wet method. It can be a stand-alone technological raw material or can make an admixture to wood pulp in a free proportion. A particular advantage of straw pulp is the fact that its production is less energy-consuming than the production of wood pulp (one stage and a low temperature of defibration) and boards needn't (and should not) be submitted to heat treatment.

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Streszczenie: *Słoma jako surowiec do produkcji twardych płyt pilśniowych metodą mokrą.*

Wytworzono i zbadano twarde płyty pilśniowe ze słomowej masy włóknistej i mieszaniny słomowej i drzewnej masy włóknistej. Stwierdzono, ze słomowa masa włóknista jest pełnym zamiennikiem drzewnej. Płyty wytwarzane z obydwu mas mają prawie identyczne właściwości.

A contribution towards the evaluation of the quality of woodworking by milling machines equipped with razor-blade knives

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Abstract: The first findings are evaluated from the introductory stage of research into sources for progressive methods of milling wood materials. Relations are studied of the increase in surface fluffiness and roughness to the degree of tool blunting. Based on measurements, the author gives values of the maximum blunting of razor-blade knives from cemented carbides by means of the blade edge radius ($\rho_{max} \cong 0.02$ mm) after attaining the permissible limit of fluffiness of the worked surface of pine scantlings. During milling, the surface roughness expressed by a mean arithmetic deviation R_a increased by 40.23% (from a value of R_a= 4.377 μm to 6.14 μm).

Keywords: milling, razor-blade knives, working quality, blunting, fluffiness, roughness

Specifics of evaluating the quality of wood working

As compared with working metal and many nonmetallic materials, in the majority of cases in wood and wood-based materials, the criterion for evaluating the quality of working is not the worked surface roughness but 'fluffiness'.

It is characterized by fine fibres – 'hairs', firmly connected with the machined surface. The fibres aggravate the final surface treatment requiring an additional working operation, i.e. sanding.

The number of 'hairs' on the workpiece surface is observed continuously by the machine operator during milling. Thus, the operator qualification decides on work interruption and exchange of blunt tools by sharp ones.

A view of a clean perfectly worked surface and a view of a surface with maximally admissible fluffiness is in Fig. 1.

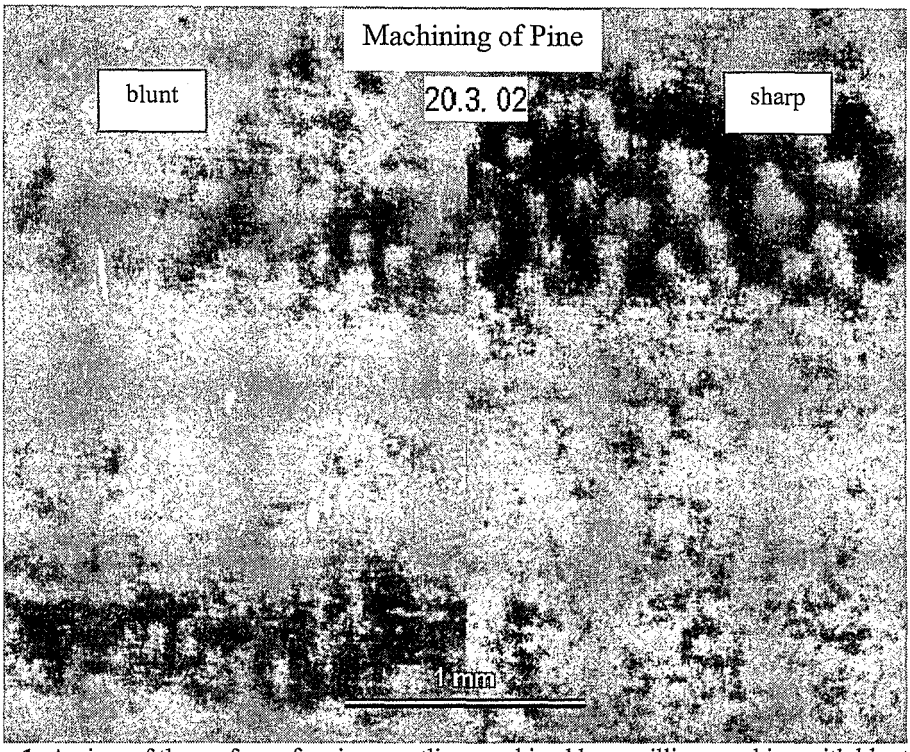


Fig. 1. A view of the surface of a pine scantling machined by a milling machine with blunt or sharp razor blade knives

The necessity of personal checking the quality of working hinders the automation of the manufacturing process. Increase in blunting during milling and relating increase in cutting resistance together with the increasing roughness of workpieces are potential sources of information on the gradual increase in fluffiness of the worked surface.

The course of blunting the razor-blade knives

The blunting of razor-blade knives (thereafter razor-blades only) was studied in relation to the change in the blade edge radius during milling Scots pine scantlings. Wood moisture was $w = 10\% \div 12\%$. Sharp edges of razor-blades show a radius of $\rho \leq 0.01$ *mm* (Fig. 2). In our study, we assessed the blunting of T04F razor-blades (manufactured by TIGRA Co., Germany).

After achieving a non-permissible fluffiness, the edge radius increased to a value of $\rho_{max} \cong 0.02$ *mm*. The milling machine showed a cutting rate of $v = 40.4\ m{\cdot}s^{-1} \div 40.7\ m{\cdot}s^{-1}$ and feed per one edge $u_z = 0.208$ *mm*. The total cutting length of one edge was 14637 m.

A detailed description of operation conditions was published in paper [3].

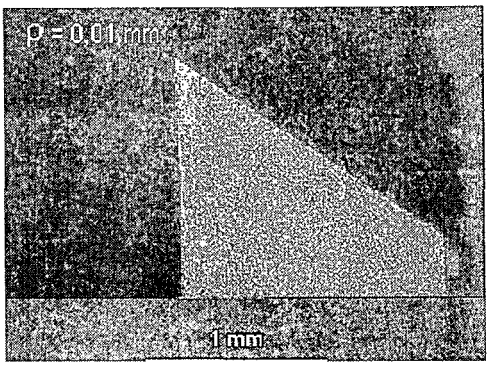


Fig. 2. The sharp cutting edge of a razor-blade

Increase in roughness

Samples of the machined pine wood in milling by sharp razor-blades were indicated by numbers 1 – 4 and in milling by blunt razor-blades 5 – 8. Dimensions of samples ranged about 120 x 60 mm.

The surface showed a certain inhomogeneity in the form of small depressions which could originate out of the process of machining during handling or due to other reasons. In sampling profiles places without these defects were taken. The origin and importance of these depressions is not the part of evaluation and, thus, it is necessary to assess them separately.

In each of the samples, 5 measurements were carried out, viz. in the centre and in four corners. The samples were measured by the SURTRONIC 3 English instrument which is equipped by a linear guide in a length of 25 mm so that it is able to evaluate parameters from the roughness profile (R – parameters) as well as from the waviness profile (W – parameters).

Parameters assessed according to the ČSN EN ISO 4287 standard:

- mean arithmetic deviation of the profile under evaluation: - R_a – for roughness
  - W_a – for waviness
- The largest height of the profile: - R_z – for roughness
  - W_z – for waviness

Note: the instrument evaluates the parameter according to the old standard R_y, W_y.

- The largest element of the profile R_{max}, W_{max} according to the DIN 4768 standard.

In all cuts, the record of an unfiltered profile is given containing elements of both roughness and waviness. The evaluation of a central cut is completed by the roughness profile (long-wave components are filtered out) and by the waviness profile (short-wave components of roughness are filtered out).

Mean values of roughness in milling by sharp and blunt razor-blades are given in Table 1

Table. 1. Mean values of R_a, R_{amax} in milling by sharp and blunt razor-blades

Roughness parameters [μm]	Surface roughness Razor-blades		Roughness increase in %
	sharp	blunt	
R_a	4.377	6.14	40.28
R_{amax}	36.678	42.937	17.1

Discussion

With the increasing blunting of a tool the quality of woodworking decreases which is evident from the increasing fluffiness of the worked surface and its increased roughness. When achieving the maximally permissible fluffiness in milling pine scantlings by razor-blades the edge radius increased from a value of $\rho \leq 0.01$ *mm* in sharp razor-blades to a value of $\rho \cong 0.02$ *mm*. The surface roughness increased on average by *40.28%*, viz. from a value of $R_a = 4.377$ μm to a value of $R_a = 6.14$ μm.

Acknowledgement

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Streszczenie: *Przyczynek do oceny jakości frezowania.* drewna głowicami nożowymi W pracy przedstawiono wyniki badań progresywnych metod frezowania materiałów drzewnych. Na podstawie pomiarów autor przedstawia wartości maksymalnego stępienia noży oraz zależności chropowatości powierzchni graniaków sosnowych od stępienia noży.

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Производство низкотоксичных смол на основе карбамидоформальдегидного концентрата, параформальдегида

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Содержание: В работе рассмотрены промышленные технологии синтеза карбамидоформальдегидных смол, обсуждены их недостатки. Приведён,разработанный авторами статьи,метод синтеза карбамидоформальдегдных смол из форконденсата, полученного на основе параформа. На основе ряда карбамидоформальдегидных смол, синтетизированных по этой технологии, создана экологическая продукция нового поколения.

При решении производственных и специальных проблем в деревообработке на первый план ныне выходят задачи по защите окружающей природной среды, здоровья работающего персонала и населения. Среди различных направлений производство древесных плит (ДСП, ДВП, МДФ) является одним из наиболее динамично развивающихся и связано с переработкой низкокачественной древесины и древесных отходов.

Основной причиной неустойчивой работы заводов древесных плит, спада промышленного производства является повышенная себестоимость продукции, морально устаревшие и экологически опасные технологические процессы синтеза смол, связанные с применением 37%-го метанолсодержащего формалина. В связи с этим большинство вырабатываемых плит не отвечает требованиям международных стандартов по токсичности и стабильности качества, недостаточен и ассортимент выпускаемой продукции.

Кроме того, метиловый спирт, присутствующий в формалине в качестве стабилизатора замедляет реакции, протекающие при образовании смол, приводит к увеличению потребления сырья [1].

В настоящее время заметно повысились требования к эмиссии формальдегида из изделий древесины, полученных с использованием карбамидоформальдегидных смол. По указанной причине широкое применение получили так называемые низкомольные смолы, характеризующиеся минимальным соотношением формальдегида к карбамиду. Их существенными признаками являются пониженные показатели качества, недостаточно высокая стабильность при хранении и низкая реакционная способность при отверждении, значительный объём формальдегидсодержащих надсмольных вод, высокая смешиваемость с водой и, как результат, токсичность смоляных композиций.

Синтез карбамидоформальдегидных смол осуществляется в три стадии:

I стадия – щёлочная конденсация карбамида и формальдегида до мольного соотношения 1:2 с целью получения метилолмочевины. Она проводится в присутствии щёлочных агентов при повышенных температурах.

II стадия – кислая конденсация, направленная на формирование метиленмочевины, перегруппировку метиленоксидных в метиленовые группы с одновременной эмиссией формальдегида. Данный процесс ведётся при pH < 7, его окончание определяется тестом на смешиваемость реакционной массы с водой. В

качестве кислых агентов наиболее широкое применение нашли хлористый аммоний, муравьиная кислота или её смесь в соотношении 9:1 с уксусной кислотой под названием «Мурукс», сульфат аммония и др.

III стадия – доконденсация. После завершения кислой стадии в реакционную массу вводится вторая порция карбамида для достижения требуемого мольного соотношения карбамид: формальдегид, формирование оптимального фракционного состава смолы, её свойств, содержания свободного формальдегида.

Каждая из перечисленных стадий характеризуется определённой длительностью, pH, температурным режимом. Их несоблюдение может негативно отразиться на клеящих показателях карбамидоформальдегидной смолы или же вызвать преждевременную желатинизацию продукта в самом аппарате.

Ю. Г. Дорониным, М. М. Свиткиной, С. Н. Мирошниченко [1] разработан метод получения карбамидоформальдегидной смолы, включающей в себя четыре основные стадии:

- получение метилольных производных мочевины (форконденсата) в слабощёлочной или нейтральной среде при температуре 80-100° С, продолжительностью 30-60 минут и мольном соотношении карбамида и формальдегида 1:(1,97-2,0);
- конденсацию смолообразных продуктов в кислой среде при pH 4,0-6,5 в течение 20-60 минут;
- концентрирование смолы под вакуумом при pH 6-7,5 и температуре 65-70° С;
- деконденсацию с дополнительной порцией карбамида при 60-65° С, pH 6,5-7,5 в течение 30 минут до конечного мольного соотношения мочевины с формальдегидом 1: (1,30-1,66).

В процессе охлаждения готовой смолы можно стабилизировать её с аммиачной водой, диэтиленгликолем, тетраборатом натрия.

Недостатком указанного способа являются его многостадийность и продолжительность, что снижает производительность технологического оборудования, а также низкая степень конверсии по формальдегиду, так как отгонная вода на стадии концентрирования смолы содержит 5-8% непрореагированного формальдегида. К тому же полученные смолы достаточно хорошо растворимы в воде, что препятствует выпуску экологически чистой продукции на их основе.

Структура карбамидоформальдегидных смол, синтезированных на основе формалина, с одной стороны, и карбамидоформальдегидного концентрата, с другой, не одинакова [2].

Среди описанных методов заслуживает внимания способ получения карбамидоформальдегидной смолы из карбамидоформальдегидного концентрата (КФК), содержащего 59% «общего» формальдегида и 21% общего карбамида. Он основан на добавлении к КФК первой порции карбамида с целью доведения соотношения формальдегид: карбамид 2,0:1, прогрев реакционной смеси при 40° С в течение 2 часов, вводе 10%-го раствора уксусной кислоты для достижения pH смеси 5,2 и проведения кислой конденсации до достижения вязкости 1000 m Pa сек.

После этого pH реакционной смеси устанавливают на уровне 7,5, вводят вторую порцию карбамида и при 60° С в течение 1 часа завершают процесс конденсации.

К недостаткам данного способа следует отнести повышенную вязкость карбамидоформальдегидной смолы на стадии кислой конденсации, длительность щёлочной конденсации из-за невысокой температуры ведения процесса, пониженную реакционную способность готовой карбамидоформальдегидной смолы, характеризуемой показателем «время желатинизации».

Применительно к форконденсату, вырабатываемого рядом предприятий, нами разработан метод синтеза карбамидоформальдегидной смолы из форконденсата полученного на основе параформа, скопившегося в значительных количествах на ряде формалинпотребляющих предприятиях.

В реактор ёмкостью 10 м^3 загружают 7000 кг форконденсата, 1200 кг карбамида и 700 кг воды. Включают мешалку. Перемешивая содержимое реактора до полного растворения карбамида, определяют pH реакционной массы, который составляет 6,8-7,2.

Нагревают смесь до 90-92° С, выдерживают при pH 6,1-6,4 в течение 35-40 минут. Далее снижают pH до 5,0-4,2 добавлением кислого агента РББ [3] и ведут синтез до начала коагуляции.

После окончания варки устанавливают pH 6,8-7,2.

Смолу охлаждают до 65-70° С. Добавляют 1800 кг карбамида.

Доконденсацию смолы проводят в течение 30 минут, охлаждают до 25-30° С и скачивают в стандартизаторы для последующего использования.

Дальнейшее развитие лесотехнического комплекса Украины требует широкого внедрения новых прогрессивных разработок и, в первую очередь, технологий получения и применения низкотоксичных карбамидофор-мальдегидных смол. Разработанная нами технология переработки параформа позволила синтезировать ряд карбамидоформальдегидных смол, создать на их основе продукцию нового поколения и существенно оздоровить экологическую обстановку в деревообрабатывающих регионах [4].

Conclusion.

The samples of production of ureaformaldegid resins which are used as the raw material of formalin and ureaformaldegid concentrated product are showed in this article.

Technology of getting lowtoxical ureaformaldegid resins from paraformaldegid is produced and filled in serial production for making of gluing production of new generation and for improvement of ecological situation in woodworking regions.

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Streszczenie: *Zastosowanie paraformu do produkcji żywic mocznikowo – formaldehydowych o małej toksyczności.* W pracy poddano analizie przemysłowe technologie syntezy żywic mocznikowo-formaldehydowych. Przedstawiona przez autorów metoda syntezy żywicy z przedkodensatu otrzymanego na bazie paraformu doprowadziła do otrzymania ekologicznej żywicy nowej generacji.

Some foundations for regulation of wood drying process

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Abstract: The problem of drying process regulation in optimal way without defects of wood is an open problem. The central ask consists in estimation of stresses which cause last deformation of wood and cause rise of cracks. A method for estimation of the moisture distribution, stresses and deformations in a dried board is presented here. The wood is considered to be cylindrically orthotropic material. It is supposed one directional movement of a water in the drying wood. Model of a moisture content distribution is proposed as a function of time. Elastic part of stresses in a cross section of a board is estimated for a different time like a plane stress problem by finite element method. In a used model moisture content is a function of time, elastic moduli and deformations of wood are functions of the moisture content. Stress is calculated with using of an incremental formulation.

Keywords: wood, drying, moisture content, stresses, deformation.

Introduction

Wood is usually green when it is cut from a log and must be dried for most uses to a moisture content suitable for use conditions. The problem of drying process regulation in „optimal way" without defects of wood is an open problem. Slowly process of drying increases the energetic exaction and too fast process reduce a quality of dried material. The process of drying can be considered as optimalization problem in which is required decreasing of wood moisture content below the fixed value in the shortest time and at the same time stress components during drying and ultimate values of warping of a dried timber must not exceed determined limits. Drying of wood is theoretically too complicated process. It is caused by properties of wood and that at drying is a synchronous heat and moisture transmission.

A result of moisture changes in the bound water area is hygroscopic shrinking and swelling of the wood. When the wood is dried, shrinkage occurs, the magnitude of which depends on numerous of factors. They follow from characteristic properties of wood and influence a state of stress and state of deformation. These factors include extent of moisture loss, structural direction (radial, tangential, or longitudinal), wood density and other factors. Dimensional changes of wood with moisture content changing are anisotropic and in the hygroskopic range they are linearly dependent on the moisture content changes. Longitudinal or axial shrinkage is essentially least as this one is in the radial and tangential direction.

Methodics

The central ask consists in estimation of undesirable stresses which cause lasting deformation of wood. The source of a stress is restrained strain ε

$$\varepsilon = \varepsilon_0 - \varepsilon_p \qquad (1)$$

where ε_p is a potential strain and ε_0 is a real strain. The potential strain is the unrestrained shrinkage strain, so-called free shrinkage strain. It would rise, if wood is dried without moisture gradient. Estimate of ε_0 is realised according to DEKRÉT and BODNÁR(1994b) of an average value of the moisture content $\overline{w}$ and for the one dimensional, with marking according to Fig.1, it is

$$\varepsilon_0 = \alpha_y(1-\frac{\overline{w}}{30}) \qquad (2)$$

where α_y is the coefficient of free shrinkage in the direction of the axis y and 30 is the value of the moisture content at the fibre saturation point. The restrained strain

$$\varepsilon = \varepsilon_0 - \varepsilon_p = \frac{\alpha_y}{30}(w-\overline{w}) \qquad (3)$$

is known for all time of drying, if the moisture distribution w is known at time t. It is supposed one directional movement of a water and only elastic part of the restrained strain in the drying wood.

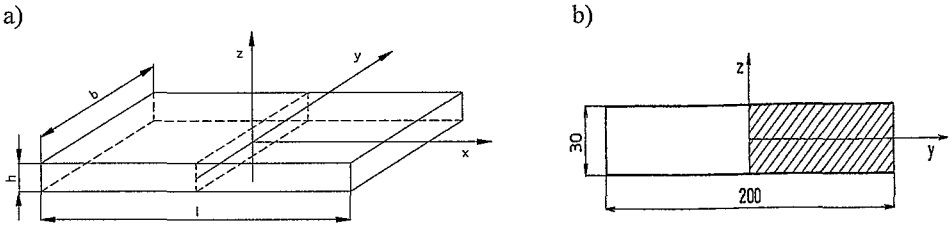


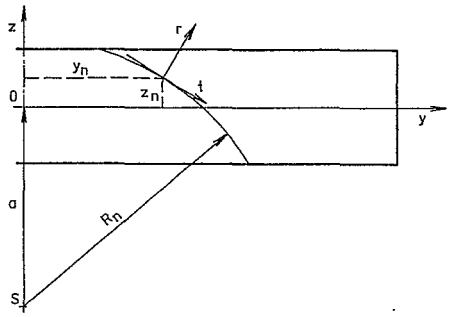
Fig. 1: a) Sketch of a dried board with used co-ordinate system.
b) Cross-section of the dried board; solved area is shaded.

Moisture content distribution in wood according to the conditions of drying shows to be very problematic. Therefore it is modelled (DEKRÉT and BODNÁR(1994b)) by function

$$w = \left(a - bz^2\right) e^{-\alpha t}. \qquad (4)$$

The unknown coefficients a, b, α are determined of check measurements. The drying process is divided into two periods. The first period $\langle 0, t_r \rangle$ takes while the surface moisture content of the wood achieves the equilibrium moisture content corresponding to condition of the drying. The second period $\langle t_r, t_e \rangle$ takes to the time t_e , when it is achieved the required terminal moisture content in the middle of the board. The moisture content on the surface of the board in this period is constant, equal to the equilibrium moisture content w_r.

Wood is considered as continuous, homogenous, cylindrically orthotropic material. The response in radial (r) direction differs from that in the tangential (t) direction. It is considered a symmetry of the solved board, so the origin of the material co-ordinate system for a timber (S) lies on the symmetry axis and may lie outside the cross-section in a distance a from origin (0) of a board co-ordinate system, see Fig.2. Restrained deformation is expressed in material co-ordinate system in a matrix form, it is $\{\varepsilon\}^{tr} = \{\varepsilon\}_0{}^{tr} - \{\varepsilon\}_p{}^{tr}$, where the potential strain matrix is



$$\{\varepsilon\}_p^{tr} = \begin{bmatrix} \varepsilon_t \\ \varepsilon_r \\ 0 \end{bmatrix}_p . \qquad (5)$$

Its components are dependent on the moisture content w from hygroskopic range and on the coefficients of the free shrinkage α_t , α_r in the appurtenant directions t, r as follows

$$\varepsilon_t = \frac{\alpha_t}{30}(30 - w),$$

$$\varepsilon_r = \frac{\alpha_r}{30}(30 - w). \qquad (6)$$

Fig. 2: Cross-section by the board solved part with used co-ordinate systems r-t, y-z.

A basic system of finite element equation equilibrium equations have been got using the principle of virtual work

$$\int_V (\delta\{\varepsilon\}_0)^T \mathbf{C} \left(\{\varepsilon\}_0 - \{\varepsilon\}_p\right) dV = 0 \qquad \text{or}$$

$$\int_V (\delta\{\varepsilon\}_0)^T \mathbf{C}\, \{\varepsilon\}_0\, dV = \int_V (\delta\{\varepsilon\}_0)^T \mathbf{C}\, \{\varepsilon\}_p\, dV . \qquad (7)$$

This virtual work equation has been written in global co-ordinate system x, y, z of the timber. There fore the potential strain tensor and constitutive tensor must be transformed from $t - r$ to $y - z$ co-ordinate system. Strain tensor is of rank two and constitutive tensor with stiffness parameters C_{ijkl} is of rank four. Their components transform in the following way

$$\begin{bmatrix} \varepsilon_y \\ \varepsilon_z \\ 2\gamma_{yz} \end{bmatrix}_p = \mathbf{T} \begin{bmatrix} \varepsilon_t \\ \varepsilon_r \\ 0 \end{bmatrix}_p \mathbf{T}^T \qquad (8)$$

$$C_{ijkl} = t_{im} t_{jn} t_{kr} t_{ls} C^*_{mnrs} \qquad (9)$$

where $\mathbf{T}$ is the transformation matrix, $\mathbf{T}^T$ stands for the transpose of this matrix. Its components t_{pq} are cosines of the angles between both co-ordinate systems (direction cosines). Elastic and shear modulus of wood are dependent on the moisture content w

$$\begin{aligned} E_t &= E_{t0} + a_1 w \\ E_r &= E_{r0} + a_2 w \\ G_{tr} &= G_{tr0} + a_3 w. \end{aligned} \qquad (10)$$

Solved task

This theory have been applied for calculation of deformations and of stresses during the drying process in a spruce board with cross section in Fig.1. A pith, which is an origin of the material co-ordinate system, lies in the z – axis in the distance a = 70 mm below origin of the board co-ordinate system, see Fig. 2. The board is hypothetically dried from the initial moisture content $w_0 = 30\%$ to terminal moisture content $w_e = 11\%$ in time $t_e = 20$ h, equilibrium moisture content $w_r = 10\%$, time increment $\Delta t = 0.5$ h. Some of the calculated

moisture contents profiles w are represented in the Fig.3 for the begin of drying, at time 4h, 8h, 12h, 16h of drying and on the end of the drying process.

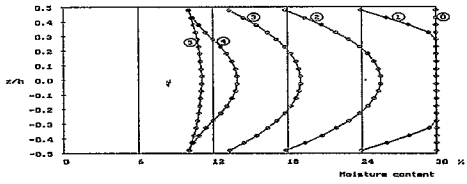


Fig. 3: Calculated moisture content distribution throughout the thickness of the dried board; 0 – on the begin of the drying, 1 – after 4h of drying, 2 - after 8h of drying, 3 - after 12h of drying, 4 - after 16h of drying, 5 - after 20h of drying.

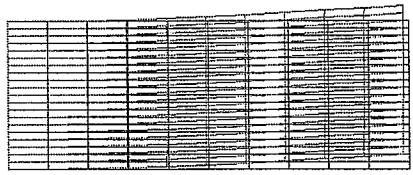
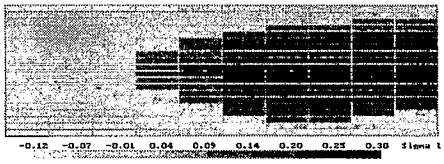


Fig. 4: Warping of the solved part of the drying.



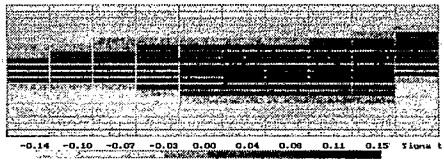


Fig. 5 Transformed stress component σ_t at 12h and 20h of drying time.

Conclusion

The presented procedure enables the discrete simulation of deformations and drying stresses development in the dried timber. The method enables to watch the influence of internal moisture content distribution history, influence of the timber position in the stem cross section and influence of the material characteristics on stresses. The accuracy of calculation depends on reliability of the used model parameters. It is used the elastic model of wood, because a weak point of all mechano-sorptive creep constitutive equations is problematical getting and verification of included parameters numerical values. Beside solving of the wood creep problems, the solution of drying process regulation requires also to solve the heat and moisture transmission.

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Streszczenie: *„Wybrane metody sterowania procesem suszenia drewna"*. W pracy podjęto próbę ustalenia optymalnych parametrów, procesu suszenia drewna. Przyjęto jako wzorcowy, model cylindryczny, ortotropowy zakładający jednokierunkową zmianę wilgotności.Ustalono optymalne parametry suszenia drewna, które skracając czas suszenia drewna nie powodują jednak uszkodzeń w suszonym materiale.

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Mixed adhesive on the base of uf and PVAC resin

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Introduction

It's well known, that ureaformaldehyde (UF) adhesives and standard polyvinylacetate adhesives (PVAC), are just partial water resistant. Their advisable combination, contingent addition of hardener, that are often salts of Al^{3+}, Cr^{3+}, account endurance gluing joints against water according to DIN EN 204 in the class D3. The effort of researches is to attain class D4, boiling-resistancy.

Today, we have known PVAC cross-linking adhesives, that include this category, but these are about three-times more expensive than mixed adhesives.

Ureaformaldehyde adhesives

Considering the ability of hardening at wide interval of temperatures, relatively short hardening time, application in form of aquatic solution, achromatism and partial water resistance, UF resins are most used adhesives in woodworking industry. Their disadvantage is freeing of formaldehyde by the making boards and during their storage and application or use.

Polyvinylacetate adhesives

PVAC dispersions are extremely applicable for gluing of wood. They define itself with good affinity to wood and provide strong and elastic joints.

PVAC adhesives are possible to use direct without addition of hardener, it is not neccessary to dilute either heat. From the sanitary aspect the action with them is nondefect, because adhesive does not contain harmful solvent. They are fireproof, immune against microorganism and provide transparent joints. General disadvantage of adhesives is low resistance of adhesive-joint against action of water.

Mixed ureaformaldehyde - polyvinylacetate adhesives

Mixed adhesives are compositions, based on a mix of thermoreactive and thermoplastic or elastomeric adhesives. Following this contact it is possible to join positive facilities of two polymers and achieve mixed adhesives with necessary and expected characteristics. In some cases the quality of joints increases, resistance of joints against action heat and moisture, mount up exhaustion strength of joints, life-time or shape stability of parts. These positive properties are conditional in a great measure, that plastomeric and elastomeric components of mixed adhesives represent polymers with linear or cross-linked molecular composition, that deliver to adhesive their bond elasticity. At application of mixed adhesives there is possible to improve some technological properties, i.e.: regulate viscosity, increase durability of adhesive mixtures, short hardening time, minimise amount of free formaldehyde etc.

From plastomer water-dispersed systems, for modification of UF resin is the most used PVAC dispersion, which has good mix-ability at arbitrary mixing ratios.

After mixing PVAC dispersion with UF resins overcome chemical reactions between different reaction component. From PVAC dispersion, polyvinylalcohol (PVA) input into reakction, which is emulsifier and occur at dispersion environment. From UF resin, monomethylolurea and dimethylolurea and as well free formaldehyde inputs into reaction.

Reaction PVA with dimethylolurea formates cross-linked molecular composition and reaction with free formaldehyde formates polyvinylformal, which is less soluble.

UF - PVAC mixtures have gelatination consistency, what enable easy application on glued surfaces, where generate uniform layer. Dynamic viscosity of mixtures differs of viscosity of initial materials. Limit shear strength considerably depends on brand of ureaformaldehyde resin.

Consequential advantage of UF-PVAC adhesive is lowering of free formaldehyde at context therewith, that formaldehyde is bound on PVA, which is in PVAC dispersion. This abatement capacity represent up to 40%. Its consequence is shortening of hardening time of composition, especially at adhesive bonding at increased temperature.

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Streszczenie: *Mieszane kleje na bazie UF i PVAC.*

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Resinas fenol-formaldehido para la produccion de tableros de particulas

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Sumario: En este trabajo se ofrece el estado actual de la produción de tableros en Cuba asi como la produción de tableros de bagazo. Se compran estas propiedades con tableros de madera y se ofrece un estudio sobre la sintesis de resina fenol-formaldedehido (PF) a escala de laboratorio. Se presenta el estudio realizado sobre el ciclo de presentado de esta resina asi como sus propiedades y la de los tableros de particulas de bagazo confeccionados con la misma.

Introduccion

Es conocido las limitaciones de la resina urea-formaldehído (UF) en la producción de tableros de partículas por su baja resistencia a la humedad y alto contenido de formaldehído libre.

Por estas razones y para darle un uso más amplio a los tableros de partículas principalmente en la construction (encofrados, etc.) y en lugares donte exista alta humedad, se hace necesario la utilización de la resina fenol-formaldehído (PF). Es necesario senalar que la resina PF presenta la desventaja de alto costo de producción el cual duplica al de la resina UF como se puede apreciar en la tabla No. 1.

Tabla 1

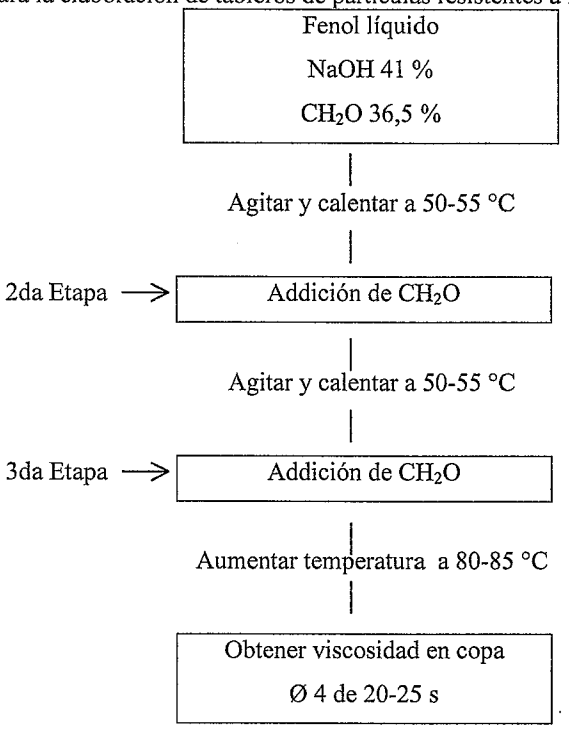
Variación del costo de materials primas y materiales por tonelada de tablero en resina UF y PF

	Con resina UF		Con resina PF	
	Insumo material/ton	Importe pesos	Insumo material/ton	Importe pesos
Bagazo desmeollado 50 %	2,04	28,88	2,04	28,88
Resina	0,137	137,82	0,178	370,24
Parafina	0,0075	5,40	0,0075	5,40
Cloruro de amonio	0,004	0,51	-	-
Electricidad [$kW.h^{-1}$]	350	22,75	350	22,75
Combustible	0,32	11,22	0,32	11,22
Total		206,58		438,49

En Cuba se vieme estudiando hace algún tiempo la produción de esta resina, pero recientemente debido el crecimiento de la industria de tableros de partículas este estudio se hace más necesario.

Sintesis y caracterizacion de resinas PF

A continuación se muestra el diagrama de la síntesis de una resina PF elaborado en el ICIDCA para la elaboración de tableros de partículas resistentes a la humaded.



Con esta síntesis se obtiene una resina denominada PF-4 cuyas propiedades se muestran en la tabla No. 2 donde también se compara con resinas producidas en otros países.

Estudio sobre de prensado y porcentaje de resina aplicada a los tableros

Con esta resina PF-4 se realizó un estudio completo sobre el ciclo de prensado mediante el cual se define el mejor para esta resina. Se estudio también diferentes por cientos de resina aplicada (tabela No. 3 y figura No. 1).

Tabla 2

Propiedades de diferentes resinas fenólicas

Parámetros	Exter-A Finlandia		SFZ 3014 Russo		F-5243 Checo	Fenokol 43 Eslovaco	CIBA-GEIGY	PF-4
	Según Firma	PND fábrica 16-536-68	GOST 20907-75	PND 16-536-68	PND 16-536-68	PND 11-059-84	Técnica Cubana	Técnica Cubana
Peso seco [%]	41	36,80	46-52	43,30	43,20	43-47	47,10	44,20
Viscisidaded 20 °C, Ø 4 mm [s]	15-40	25	17-90	33	27	20-80	37 1/	45 1/
Alcalinidad [%]	-	6,35	6,5-7,5	7,22	7,44	8	-	7,18
Fenol libre [%]	< 0,2	0,18	<0,1	0,09	0,041	max. 0,1	0,0068	0,005
Formaldehído libre [%]	< 0,15	0,048	<0,15	0,038	0,037	max. 0,1	0,08	0,05
Alcalinidad referido a peso seco de resina[%]	-	17,23	-	16,67	17,22	8,0	-	16,24
Formaldehído libre método FESYP [mg CH_2O/100g b.s. tableros]	-	-	-	-	3		-	2,5
Adhesión [MPa], AW-100	-	-	-	-	-		-	2,7
Tiempo de gelatinización a 150 °C [min]	-	-	-	-	-		7,1	5,25

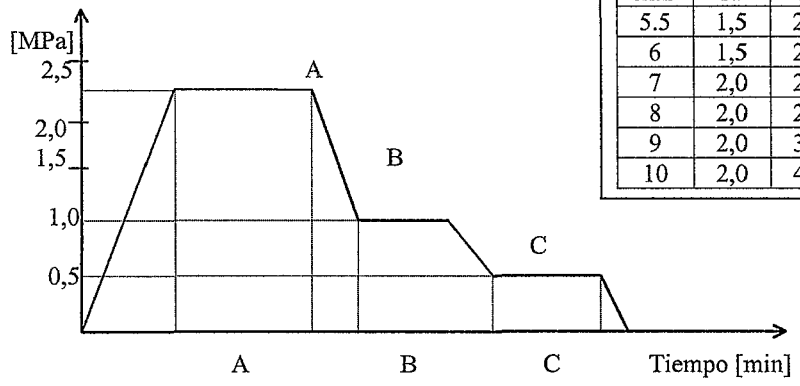
1/ Para 30 °C

Tabla 3

Propiedades de tableros de bagazo aglutinados con resina PF-4 (espesor 16 mm, 160 °C, 1 % emulsión de parafina)

Tiempo de Presión [mm]	Cantidad de Resina [%]	Dilatación en H_2O 30 °C [%]		Absorción en H_2O 30 °C [%]		Tracción perpend. [MPa]	Humedad [%]	Densidad [$g.cm^{-3}$]	Módulo de ruptura [MPa]	Tracción después de V-100 [MPa]	Dilatación después de V-100 [%]
		2 h	24 h	2 h	24 h						
6	8	10,8	22,9	40,78	91,52	0,24	9,9	0,666	18,0	0,102	31,67
7	8	10,1	21,9	36,78	91,15	0,19	9,7	0,669	19,6	0,113	30,02
6	10	8,8	11,6	60,6	82,0	0,28	8,7	0,622	18,4	0,109	25,61
7	10	9,7	12,4	62,4	81,6	0,37	8,2	0,632	20,9	0,125	23,54
8	10	9,5	12,7	64,2	83,3	0,37	7,9	0,639	22,9	0,143	21,02
6	11	3,9	7,6	22,37	57,11	0,27	9,9	0,643	17,9	0,126	19,60
7	11	3,5	8,2	24,04	59,94	0,39	9,7	0,662	19,7	0,187	19,20
8	11	3,7	8,1	20,30	53,86	0,41	9,4	0,672	20,1	0,202	16,40
9	11	4,3	8,4	22,86	54,96	0,41	8,9	0,672	21,2	0,215	16,10
10	11	3,9	8,8	22,36	54,61	0,44	8,8	0,675	21,2	0,232	15,96
6	12	8,7	10,7	59,9	76,3	0,37	8,7	0,639	20,8	0,122	21,88
7	12	6,6	9,0	48,2	65,6	0,38	8,6	0,662	23,3	0,163	17,87
8	12	8,5	10,4	53,9	70,6	0,48	8,1	0,661	23,4	0,192	17,95
9	12	8,6	11,7	47,8	66,3	0,51	7,5	0,672	24,6	0,221	17,51
10	12	8,3	11,3	43,7	63,3	0,48	7,7	0,669	25,5	0,219	17,48

De la tabla anterior se puede observar que para por cientos de resina entre 8 y 10 las tracciones perpendiculares son relativamente bajos, así como estas después del ensayo V-100, aunque se lagran buenos resultados en el módulo de ruptura. La dilatación y absorción en agua son también altas.



Leyenda

min	A	B	C
5.5	1,5	2,0	2,0
6	1,5	2,5	2,0
7	2,0	2,5	2,0
8	2,0	2,5	3,0
9	2,0	3,5	3,5
10	2,0	4,0	4,0

Fig. 1. Ciclo de prensado utilizado para la resinata PF-4

Con por cientos entre 11 y 12 los resultados son buenos y muy semejantes tanto en absorción y dilatación, como en módulo de ruptura y tración perpendicular.

El ensayo V-100 da buenos resultados para estos por cientos de resina a partir de 7 minutos. Como las diferencias no son tan marcadas y son además buenas a partir de 7 minutos y 11 % de resina consideramos estos parametros buenos para este tipo de tableros cuyos resultados son mostrados más adelante.

Conclusiones

Se obtuvo una resina fenol-formaldehído con excelentes propiedades para ser utilizada en tableros de partículas resistentes a la humedad.

Las propiedades de la resina PF-4 son comparables a las fabricadas mundialmente.

Los resultados obtenidos del ciclo de prensado y por ciento de resina aplicada son satisfactorios para este tipo de resina.

Las propiedades de los tableros de partículas con bagazo y con madera dan resultados similares.

La síntesis de obtención de la resina PF-4 sencilla y fácilmente reproducible.

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Streszczenie: *Zastosowanie klejów fenolowo-formaldehydowych do produkcji płyt z bagassy.* W pracy przedstawiono produkcję płyt wiórowych z bagassy, klejonych klejem fenolowo-formaldehydowym wykonanym w warunkach laboratoryjnych.. Własciwości wytworzonych płyt okazały się porównywalne z klasycznymi płytami wiórowymi.

Possibilities of increasing the water resistance of glue joints

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Abstract: In the paper the methods of increasing the water resistance of the joints of various glues used for gluing homogeneous materials, e.g. wood, metal, glass as well as the composed ones, e.g. metal-glass, metal-rubber, wood based material, synthetic ones and other. These methods are: using additions to glues, nodifying glues in the course of synthesis, improving the surfaces to be glued with various methods and other.

Increasing the water resistance of glue joints can be achieved with various methods. For instance with surface coating the protection layer which reduces the penetration of moisture,the diffusion and porosity of the glued materials and of the joints through improving the properties of linked materials and of glues, the reduction of moisture stresses of the joint and increasing the resistance and strength of polymer substrate bonds. Protecting the surfaces of the glued products through painting makes the most common way of increasing the water resistance of glue joints.

Though surface painting is a immediate method it is ever an effective one. Most often this way is applied to wood whereat the protection does not affect so much the joint as, first of all, the wood. Decrease of the swelling posibility ensures the reduction of stresses in the joint.

Hydrofobization of adhesive by use of various additions is also a good method of increasing the water resistance. These additions should be distinguished by a good tolerance towards the glue and they can not cause the reduction of its cohesion and adhesion.This can be achieved by using additions with diffile properties. A small addition of vinylsterate (1 to 15 weight ps. for 100 w.p.of glue mass) rises the resistance to boiling water. Increasing water resistance can be also attained not only through hydrofobization but also by plastification which reduces the moisture stresses. Addition of elastomer is the most common method .Using special glues: the resorcin-rubber and epoxy-rubber increases the resistance of joints exposed to the permanent or cyclic moisture changes in the constructions from materials of various moisture thermal expansion. Instead of additions which make the joint more elastic other methods are applied: two adhesives are layed separately on two faces to be glued or two layer adhesive foils are prepared. One layer is of hard adhesive e.g. of epoxy one and the other of elastic or rubber adhesive. In the same joint the moisture thermal stresses can undergo relaxation revealed in practice by an increased load resistance of the joint. In order to increase the water resistance the modification is already done in the synthesis process. (For example: polyestermaleinates are modified by esters of abietic acid, polyetyleneterftalates by adusts of pyromellite anhydride and polyisocyanate, epoxy resins by organo-phosphor compounds of P(NCO)3 and PO(NCO)3 types).

Mixture epoxy and organo-silicate resins or the synthesis of epoxy-organo-silicate ones is a pretty practical method of increasing the water resistance of the glue joints of metals.

In the recent years the method of increasing the water resistance of epoxide glues by their modification by the black-coal rersins has been used. It should de however added that such a modification involves the decrease of strength of joints depending upon the quantity of the added black-coal resin. The products of coal origin can be mixed not only with the

epoxide resins. It is known that the mixture of polyester with the addition of diiso-cyanates and bitumens gives an increased strength and water resistance. Water resistance and the chemical stability of the glued metals can be increased by adding inhibitors to the gluing mass. Such inhibitors which can be reciprocally absorbed by metals are added. In practice chromate complexes of guanidine and some esters of chromic acid are used. Chromates compounds of lead. zinc and some other chromates cause the increase of water resistance, in particular to the salt water, of the majority of glues.
The inhibition of corosion appears with the use of glue on the base of resorcine and alkyloresorcine resins. The inhibition effect is in this case connected with the properties of the polyphenols which are raw materual for the production of DFK type resins.

It is possible that the inhibition properties towards the corosion of metals have also the phosphor compounds which are used in the mixtures destined for the preparation of the metal surfaces for gluing. It is commonly assumed that the oxide layer appearing on aluminium at the chemical oxydation in acid bichromates and at the anodizing in sulphuric acid is weakened by moisture diffusing into the glue joint. The elements undergoing anodizing in the phosphoric acid do not show such defaults.

The water resistance of aluminium glued joints is connected not only with the effective protection against corosion. It is known that in the pickling process the thickness of the oxidizing layer on aluminiumm amounts at most to 1 to 2 m what is not enough for protecting the metal against corosion. As to spite it the best strength and water resistance of the glue joints is attained in comparison to the anodized aluminium where the oxidizing layer attains the thickness of 20 to 30 m.

Increase of the water resistance of the metal rubber joints can be attained with activating surface as well as by increasing machanically the roughness of the metal surface.

Water resistance of the glue joints can be also increased by treating the faces to be glued with substances the surfface bond energy of which is greater than that of bonding water. For gluing nonactivated surfaces special oligomers, other hardeners or components which are chemically active or neutral towards the glue should be used.

The epoxy glue which contains apart from the diane epoxy resin and the hardener the dietylenetriaminometylphenol also, which is the product of condensation of the oligodietylenglykolsebacinate with the epoxydiane oligomer is the example of the glue containing such an oligomer. II Table 1 the influence of this glue on the shear strength at stretching joints of this glue within the 6 month soaking of samples in water is presented.

Table 1

Influence of applying conditions on shear strength at Mpa joints of the epoxy glue in the glass laminate .

Conditions of applying	Time of testing (days)			
	7	30	90	180
air	10,0	11,1	12,2	11,1
fresh water	10,0	10,6	11,1	9,0
salt water	10,0	10,7	11,3	9,0

The strength of aluminium glued joints at gluing in air attains 24 MPa in the stretching test , 12,7 MPa at shearing by stretching and in gluing under water 19 MPa and 10MPa corespondingly in the same tests. After one year soaking in water of 20o C the strength decreases by 20 %. Approximate testing results are obtained with applying reciprocal reaction of m-phenylenediamine with diaminodiphenylmetane as the hardener.

The polybutylmetakrylate-metylmetakrylate glue with addition of reactive substance: alylalcohol with toluene diisocyanate or fluorinated ethylalcohol can be presented as the next example. According to the authors the strength of joints with this glue at gluing the organic and silicate glass, the glasslaminate and wood does not get decreased even after 4 months soaking in water.

The waterproof glues used in stomatology are distinguished by a good wettability through the glue of moistened surfaces with removing simultaneously the water from the substrate.

With the use of the polyestermaleinate based glue asbestos cement, glass laminates and similar materials can be glued under water when attaining waterproof joints but the degree of waterproofness of the joints gained in these conditions does not attain always the expected level. The strength of the glue joints obtained in water or in other liquid media is approximately twice smaller than that in air gluing.

Methods based on using various basic paints, first of all on the silane base, in applying for gluing ffbre glass or other fibres in composed materials prove a high level of increasing the water resistance The selection of additions which increase the waterproofness of the joints of plastics with mineral materials is rather difficult. AI gluing polyetylene and polypropylene with glass and aluminium the water resistance is obtained through the modification of the substrate, unsaturated silane , which has the aminohydrochloride in the molecule.

In this connection it should be remebered that the amines are catalysts of the surface reactions of sialnes. Since the silane does not contain function groups the increase of water resistance can be obtained when uaing peroxides, similarly as in gluing tin with the lead base alloy and etylene copolymer with the acrylic acid with addition of γ-metacryloxypropyltrimetoxysilane.

The opinion is assumed that silanes should contain function groups which ensure their reciprocal links with the glue. This argumentation is proved in reference to gluing glass but often it is not confirmed in aluminium joints linked with epoxy glues, phenol-formaldehyde, polyuretane and others. For instance: in gluing aluminium with epoxy glues the water resistance gets improved through the addition of vinylsilane but the aminosylane gives negative effects.

Testing hydroliticaly induced destruction of the polymer on the interface:epoxy glass - glue, with the methods of marked atoms has shown that that improving the surface of the - aminopropyltri -etoxysilane causes a spontaneous appearing of areas of chemically and physically absorbing finishing on the substrate surface. At determining the time for load shearing glass joints in water, depending upon the conditions of finishing the substrate it appeared that the the life of the joint does not depend on the presence of the physically absorbed component of the hetero-
geneous finish layer. The longest life is attained with the highest degree of the chamical sorbtion of silane. The highest life of the joint is ensured by the thickness of the layer which equals two monomolecular layers .whereat the number of the function groups of the finish apt to reciprocal chemical links with the epoxy resin is limited. That is the next example which proves the limited possibilities of reciprocal linking the finishing matters with adhesive. That is proved by the stabile resistance of glue joints of materials of silane improved surfaces in dry state. At moistening the silanes hydrolize and the appearing silanols enter the reaction with the substrate, That is recompensated by the hydrolitic destruction of polymer-substrate links what is characteristic for polyuretane glues.That is why the moisture resistance of the glue joints is increased.

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Streszczenie: *Możliwość zwiększenia odporności spoin klejowych na działanie wody.* W artykule przedstawiono sposoby zwiększenia odporności na działanie wody, spoin różnych klejów stosowanych do klejenia materiałów jednorodnych, np.: drewno, metal, szkło jak też kompozytów np.: metal-szkło, metal guma, drewno- materiały syntetyczne i inne. Te sposoby to np.: stosowanie dodatków do klejów, modyfikowanie klejów na etapie syntezy, ulepszanie sklejanych powierzchni różnymi metodami.

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Using ultrasounds for gluing wood

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Abstract: On the base of the presented results it can be stated that using ultrasounds for gluing in wood working can be effectively applied when replacing in some fields traditional gluing. In particular ultrasound gluing will be applied in cases where the time of gluing should be shortened or thick elements be glued.Economic calculation will be desicive .

Introduction

Ultrasounds are used in various fields. Using them in medicine, building, chemistry etc. is commonly known. For instance the 505 type viscosimeter, Polish produce, for continuous measuring the viscosity of glues is well known. In wood working industries ultrasounds are also applied for non destructive determination of strength of products. For this purpose methods known for instance in metal flaw detection are adapted. Since a long time plastics and metals are welded by use of ultrasounds. Examples of applying ultrasounds in the mechanical working of hard ceramic materialsare also known. In the scientic Institute of Wood Technology at Drazdany in Slovakia investigations on various uses of ultrasounds in wood working industries have been carried out within the past 4 years. It was done within the framework of the target project sponsored by the well known BMW firm and executed by the GmbH, GEWIPLAN Society for supporting the economy and planning, The results of investigations of this Institute have shown the prectical possibilities of using ultrasounds for gluing various materials. of natural origin as well and in particular the wood. The Institute has established cooperation in this scope with the German firm Dr Hielscher, GmbH, located at Teltow, near Berlin. The firm having at disposal own laboratories is engaged in investigations, in scientific development , in production and completing sets of devices for gluing by use od ultrasounds. It has a well extended trade net and scientific information one.

Apart from, that the the method of linking by use of ultrasounds, called WoodWelding technology has been prepared at SH Biel in Switzerland. It was honored in Switzerland by the reward for innovation in technology,

Pasting of edges and gluing squarewood

Using the modern glues in wood working with the traditional methods of gluing ensures a high linking strength but it has some drawbacks also. The fact that at the beginning of the gluing process the strength of linking the assembled elements is zero and does not attain high values before hardeing is one of these drawbacks. To initiate the glue hardening the material to be liinked should be overheated. It requires a considerable time and thereby the production process is prolonged and made more expensive. When suppliying heat to the joint the time of linking can be sped up. Gluing large elements requires considerable quantity of heat and that of the construction of complicated forms is practically impossible.

By applying ultrasounds the adhesive and the surfaces to be linked can be intensively heated in a short period of time. That is ensured through the absorption of ultrasounds in the joint. There disappears also the necessity of overheating the whole set and thereby the demand for heat decreases considerably.

In the course of gluing the dispergizing liquids (e.g.water) should be evaporated from the joint, the gluing substance should be plastified or the reaction of chemical hardening of

gluing components of the joint should be initiated. With using e.g.the PVAC type adhesive for gluing solid wood elements only water should be evaporated from the joint. For this purpose smaller quantity of heat is required than for melting plastic components. It is proved by investigations that during the continuous gluing with the 10m/min travel rate a higher joint strength can be attained than in cold gluing. Overheating of the joint causes appearing of blowholes which decreas the strength. Therefore the adequate dose of energy supplied from the ultrasounds producing equipment should be selected according to the concrete gluing conditions. In the continuous gluing process it can be adjusted by the travel rate. Devices for ultrasound gluing have still the advantage of using energy only in the working time. Ultrsound gluing agregates do not need protection shields in comparison to the use of high voltage currents.

Wood Welding technology

This method is based on applying pins of thermoplastic glue introduced into the previously milled holes instead of the wood pins. Points where are pins are treated (3-5 sec) by use of ultrasounds and thereby the linking of plastic with wood is ensured as well as a stabile bond of the elements of the strength which corresponds with that of wood pins. This method has been applied in various technologies , in particular in the production of windows.

Resume

In the paper the up to now achievements in the field of gluing wood with use of ultrasounds for hardening the joint and the firms and institutions which contributed to apply in practice this still scarcely popularized are presented.

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Streszczenie: *Stosowanie ultradźwięków do klejenia drewna.* W artykule przedstawiono dotychczasowe osiągnięcia w dziedzinie klejenia drewna przy wykorzystaniu ultradźwięków do utwardzania spoiny oraz firmy i instytucje, które się przyczyniły do praktycznego stosowania tej na razie mało spopularyzowanej metody.

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Stresses in the glueline of laminated furniture boards

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Abstract *Stresses in the glueline of laminated furniture boards* The performed investigations were of theoretical nature and their objective was to determine the effect of swelling and shrinking of wood on the strength of gluelines in laminated furniture boards. The studies allowed to determine that the factor that caused damage of the glueline could be attributed to the generation of ordinary stresses developing in the result of flaking or detachment, which exhibited clearly their nature as localised extremes.

Key words: wood, swelling and shrinking, glueline, stress

Introduction

Manufacture of laminated furniture boards from solid wood requires gluing together of timber slats or blocks. Appropriate choice of dimensions, grain and moisture content of the above mentioned elements can affect directly the quality of the final product such as a piece of finished furniture. Differences in the grain of individual board component elements as well as changes in wood equilibrium moisture content are among the principal direct causes of differentiation in linear elongations leading to stresses in wood slats glued together. This, in turn, results in cracks developing both inside and on the surface of wood as well as cracking of board gluelines (Fig.1) [1, 2].

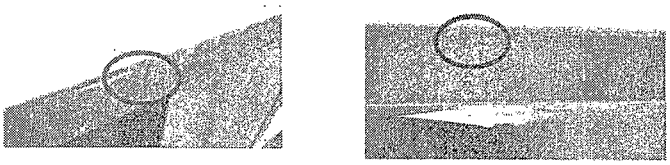


Fig.1. Fracture in a glueline of a laminated furniture board.

Objective of research project

The performed investigations were of theoretical nature and their objective was to determine the effect of swelling and shrinking of wood on the strength of gluelines in laminated furniture boards.

Research methodology

The object of studies was a laminated furniture board manufactured from beech slats which was assumed to be made of adjacent elements characterised by different distribution of grain so as to assure two adherends to adhere to one another along the following planes: longitudinal-tangential (LT-LT) and longitudinal-radial (LR-LR) (Fig.2).

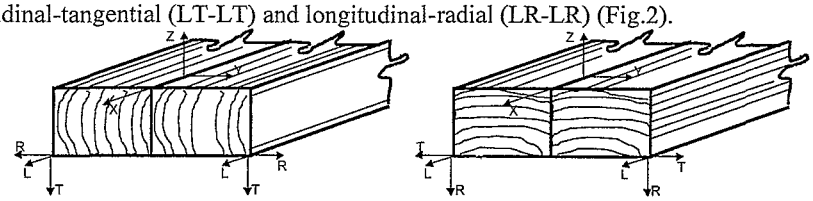


Fig.2. Main anatomical directions of glued adherends

For calculation purposes, the author assumed mechanical data for beech wood and glue as shown in Table 1.

Table 1.

Mechanical properties of beech wood and glue.

Type of material	Young's modulus [Mpa]	Poisson's coefficient
Beech wood	16 000	0.3
Glue	400	0.3

Investigations of the effect of changes in moisture content on the strength of glueline required the determination of a unit wood shrinkage/swelling along the glue bond and the estimation of the value of the total shrinkage/swelling at moisture content changes in wood ranging from 8% to 12% taking into consideration the fact that dimensional changes can occur in extreme radial and tangential directions. On this basis, for the assumed numerical data, it was found that, in the result of wood moisture changes by 4%, beech wood slats increased or decreased their thickness by 0.12 mm for tangential shrinkage/swelling and by 0.06 mm - for radial direction.

The performed experiments were carried out numerically employing the Algor® software using the algorithm of the finite elements method. In order to determine the value and distribution of stresses in the glueline, a numerical model was developed corresponding to the combination of two timber elements connected together by means of a thin glue bond 0.1 mm thick (Fig.3).



Fig.3. Numerical model of a glue bond of two timber slats of a laminated furniture board.

Results of numerical calculations showing distributions of stresses in the glueline are presented in Figures 4, 6.

Analysis of results

It is commonly believed that a glueline should be characterised by a high shear strength, which is widely described using the following equation:

$$\tau_x = \frac{Q}{bl}\frac{\delta_1 m}{(1+S)\sinh(ml)}\left[S\cdot\cosh(mx)+\cosh(1-x)\right] \tag{1}$$

where:

Q – force destroying the bond,

b – width of glueline,

l – length of glueline and,

$$S = \frac{\delta_1 E_1}{\delta_2 E_2} \tag{2}$$

δ_1 – thickness of the first element,

δ_2 – thickness of the second element,

E_1 – Young's modulus of the first element,

E_2 – Young's modulus of the second element as well as,

$$m = \sqrt{\frac{G_k(\delta_1 E_1 + \delta_2 E_2)}{\delta_k(\delta_1 \delta_2 E_1 E_2)}} \tag{3}$$

δ_k – thickness of the glueline,
G_k – Kirhchoff's modulus of the glueline.

In the analysed case, tangential stresses in the glue bond caused by wood shrinkage or swelling did not reach values, which could result in damage of the board (Fig.4)

The largest from among the determined stresses did not reach localized values exceeding 1.5 Mpa, which constitutes barely 10% of the shear strength of gluelines. Therefore, this kind of stresses is not essential to ensure the quality of bonds between glued slats of furniture boards because, as evident from the performed calculations, dimensional changes caused by wood shrinkage or swelling ranging from 8 to 12% do not generate shear stresses critical for the glueline. However, reviewing deformation characteristics of gluelines, it is possible to observe typical features of flaking or detachment (Fig.5).

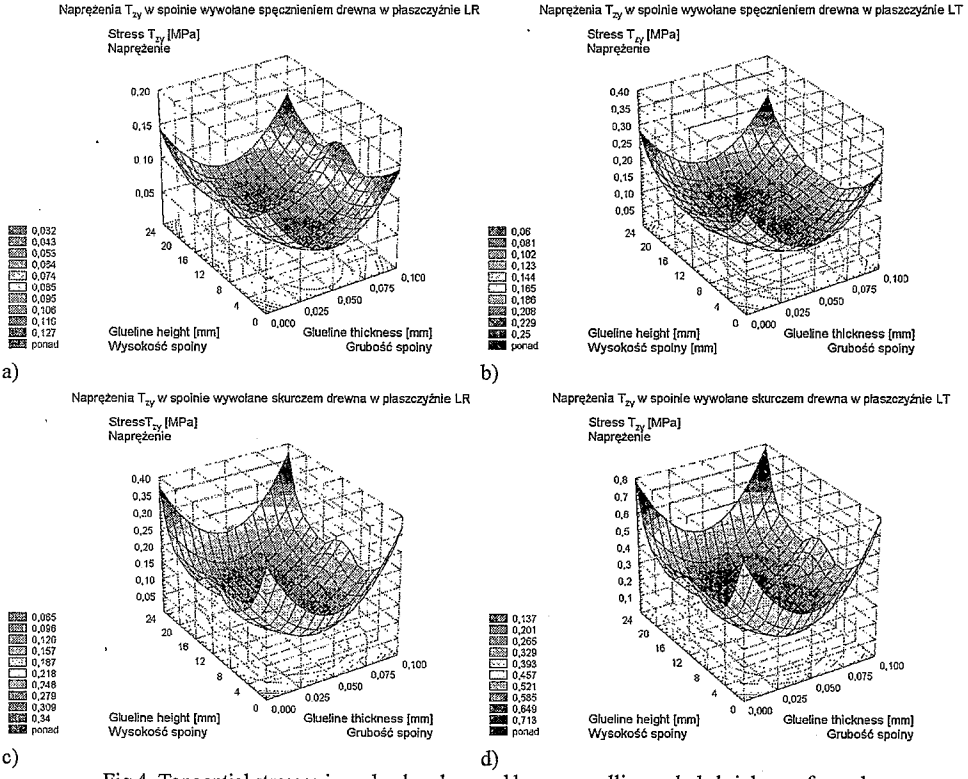


Fig.4. Tangential stresses in a glue bond caused by: a,c swelling or b,d shrinkage of wood



Fig.5. Instances of glueline damage by: a) flaking, b) detachment

In these cases of adherend deformations, we observe ordinary stresses. Their value depends on the case of effort. For flaking (Fig. 5a), the maximum tensile stress σ_{max} is expressed by the following equation:

$$\sigma_{max} = \frac{P}{bl}\left(1+6\frac{e}{l}\right) \tag{4}$$

where:
P – flaking strength,
b – width of the element,
l – length of the element,
e – eccentric.

On the other hand, in the case of detachment (Fig. 5b), the strength of the bond is described by the following equation:

$$\sigma_{max} = \frac{M_g}{b}\sqrt{\frac{12E_k}{E\delta^3\delta_k}} + \frac{P\sqrt{2}}{b}\sqrt[4]{\frac{12E_k}{E\delta^3\delta_k}} \tag{5}$$

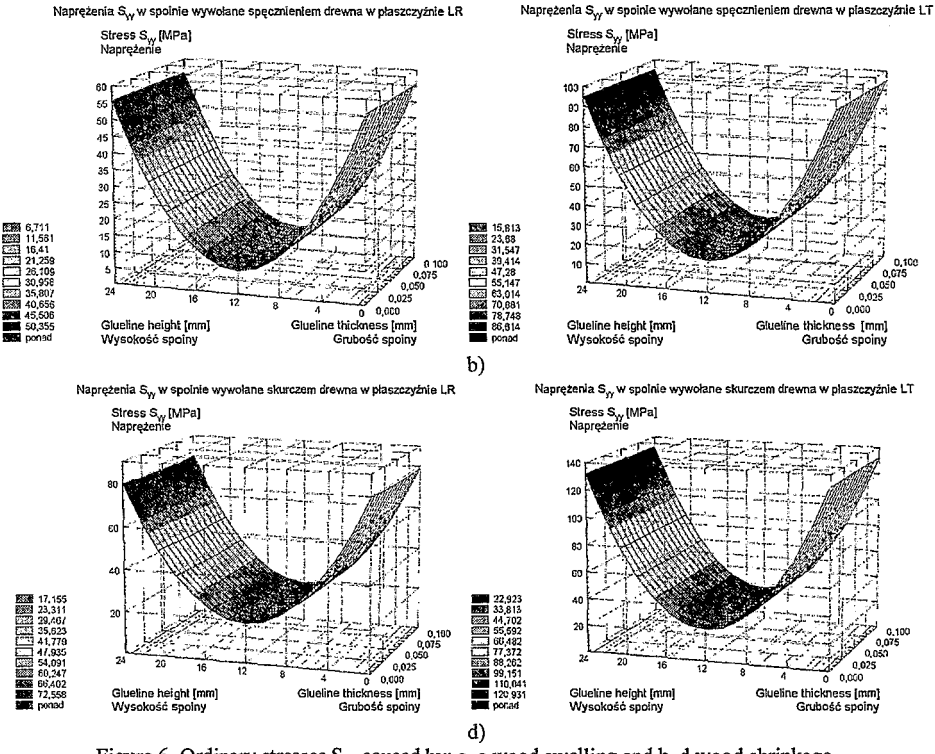


Figure 6. Ordinary stresses S_{yy} caused by: a, c wood swelling and b, d wood shrinkage.

Courses of ordinary stresses shown in Figure 6 indicate that localised values exceed considerably acceptable flaking and shear strengths for wood and glueline. The highest values from those calculated in this study were values generated during adherend shrinkage by systems consisting of wood glued along longitudinal-tangential planes LT. Therefore, damages observed in laminated furniture boards used to manufacture cabinet or skeleton furniture develop not in the result of their utilisation but are rather caused by slight changes in wood moisture content following inappropriate storage conditions or keeping them in unsuitable humidity conditions in a flat or house. In order to ensure the highest quality of

laminated furniture boards it is, first and foremost, necessary to guarantee for them stable conditions of hygroscopic equilibrium with the environment and to avoid joining together of elements characterised by distinctly different linear shrinkage traits resulting from water sorption and desorption from the environment in the form of water vapour.

Conclusions

1. The factor, which causes damage of glueline in laminated furniture boards, is generation of ordinary stresses resulting from wood swelling and shrinkage.
2. Ordinary stresses in glueline develop in the result of flaking or detachment and are characterized by distinctly localized extremes.
3. Tangential stresses in the glueline do not attain values significant for the strength of the bond.

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Streszczenie: *Naprężenia w spoinach klejonych płyt meblowych.* Podjęta praca badawcza ma charakter teoretyczny, a jej celem było ustalenie wpływu pęcznienia i kurczenia się drewna na wytrzymałość spoin w klejonych płytach meblowych.

AE phenomena from wood adhesive bonds

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Abstract: *AE phenomena from wood adhesive bonds* The study presents results of investigations of acoustic signals generated by loaded overlap solid and glued samples (polyoctanevinyl glue). On the basis of the obtained acoustic emissions, in the form of the number of accounting, the authors established characteristic places and stages of accumulation of structural defects. The obtained results indicate that it is possible to predict the course of destruction of glued and solid elements on the basis of observation of the accumulation of the accounting sums of acoustic signals.

Key words: wood, adhesive joints, glueline, acoustic phenomena

Introduction

Wood glue joints constitute one of the most important methods of connecting together of individual elements in furniture industry. Very often these connections are places, which have a decisive effect on the strength of the entire construction. They are expected to be appropriately strong and durable, maintain their shapes and dimensions without negatively affecting the appearance of the product. Hence, the designer is faced with a number of contradictions and constraints, which make the entire designing process extremely difficult. That is why it appears very important to identify phenomena that occur in various joints during furniture utilisation. There is, therefore, a need to search for such research methods which would inform directly about efforts in constructions, whereas information about destructive changes e.g. in the glue bond would be obtained from the source itself at the moment the load occurred. Such measurement conditions are fulfilled by the method of acoustic emission (AE), which offers possibilities of examining processes taking place in a joint through the prism of changes occurring in the material. According to Moliński (1998), AE measurements open up possibilities of direct coordination of information contained in AE signals with causes that induced them. Despite the fact that there are reports in literature concerning the utilisation of AE phenomena in investigations of this type of constructional joints, Ayarkwa et al., 2001 Byeon et al., 1990, 1992, Niemz et al., 1983, Suzuki et al., 1987, Porter et al., 1972, the field, especially in the area connected with furniture joints, appears to have been studied insufficiently. It seems that a closer inspection of AE phenomena generated in loaded wood glue joints could help us build a fuller and better understanding of processes occurring in them, in particular, those which take place in their crucial places, i.e. gluelines. The above considerations encouraged the authors to undertake investigations with the aim to describe acoustic phenomena generated in gluelines of loaded adhesive joints.

Research methodology

One of the most common wood materials used in production of skeleton furniture is beech wood (*Fagus sylvatica* L.). Raw material for investigations was sampled from dried and seasoned beach heart planks 60 mm thick from places free of defects and colour changes. It was assumed that investigations would be carried out on the following two types of samples: glued overlap and solid, as shown in Figure 1.

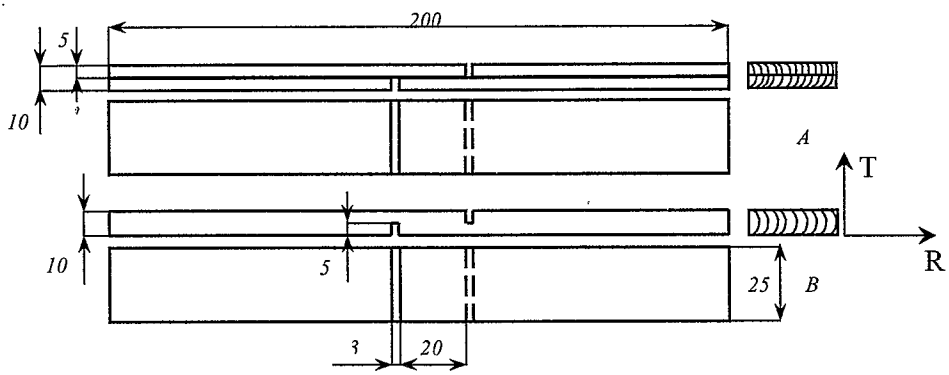


Figure 1. Dimensions of samples used in investigations: A – glued sample, B – solid sample

Appropriately prepared beech wood slats were glued together along their radial planes. Solid samples were prepared in such a way that their shape matched the shape of glued samples. Part of samples was used to determine their density and wood moisture content which were found to be: 420 kg/m^3 and 8%, respectively. Samples were glued using Rakoll® Express 25 poly-octane-vinyl glue with parameters as shown in the table below.

Table 1.

Properties of the Rakoll® Express 25 glue used in investigations

Property	Unit	Mean value
Viscosity accord.to KF-10	[s]	35
Dry matter content	[%]	40
PH	-	7

Loads were applied, employing a numerically controlled ZWICK 1445 testing machine, by stretching samples along their fibres so as to cause shear stresses in the plane of glueline or its corresponding wood surface in solid samples. The velocity of the traverse movement was set at 0.4 mm/min. at the initial load of 50N. AE signals generated in the examined samples were collected by means of a piezoelectric head with its own induction of 100kH that was mounted on the examined sample on its radial plane using a gum element. Acoustic feedback between the head and the examined material was assured thanks to laboratory silicon grease. Parameters of the measuring pathway were, respectively: amplification – 85 dB and the level of noise discrimination – 0.75 V. A counting sum was used as a descriptor characterising acoustic signals.

Research results and their analysis

Complete courses of counting sums in time function for samples of solid and glued woods are shown in Fig. 2.

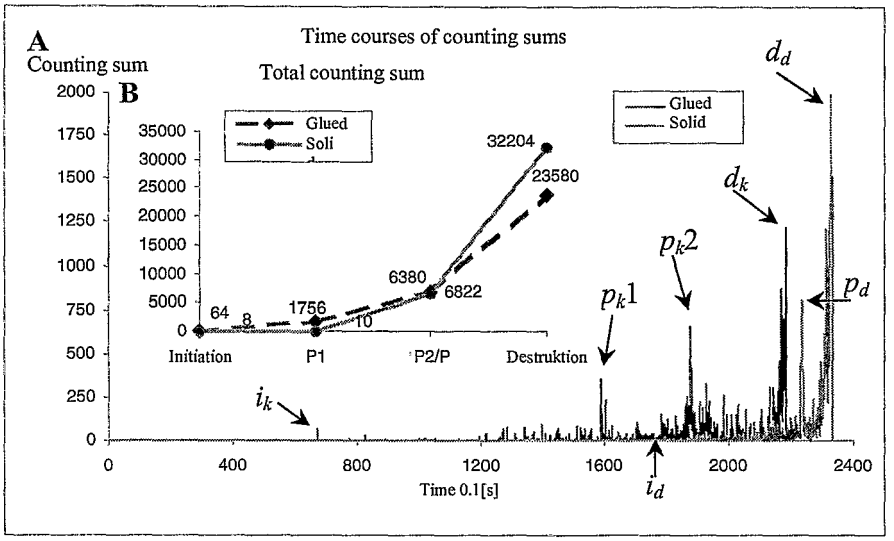


Figure 2. Example courses of counting sums – A and accumulation of total counting sum – B.

Analysing processes of the accumulation of AE counting sum shown in Figure 2A during loading of glued overlap samples as well as those prepared from solid wood, it is possible to notice characteristic places present in all recorded courses. However, it is quite evident that they are distributed differently for each type of sample. It can be assumed that these places correspond to certain important changes occurring in the effort material and divide the whole course of counting sum accumulation into certain stages. A stage-like character of the accumulation of acoustic signals during bending of pine planks was reported by Suchorski (1997). He described the following three stages of accumulation of structural defects: steady initiation, steady propagation and dramatic defect increase. Although in the case of solid wood, the above statement can be confirmed by results of our studies, in the case of overlap glued samples it is quite evident that there were more phases. Therefore, the following conclusions can be suggested:

1. in the case of solid samples, the following characteristic places were selected: point (i_d) - initiation, point (p_d) – amplification and point (d_d) – destruction. They mark out the following three intervals – from 0 to (i_d) – absence of acoustic activity above the discrimination level, i.e. operation below the level of discrimination during which no significant destructive changes can be noticed; next is the interval from (i_d) to (p_d) during which material destructions begin to appear and increase and, finally, interval from (p_d) to (d_d), i.e. the area of sudden amplification and dramatic increase of defects until complete destruction of the sample.
2. in the case of glued elements, the following characteristic places were chosen: initiation (i_k), amplification point (p_k1), intensification point (p_k2) and destruction point (d_k). In this way, we obtained the following intervals: from 0 to (i_k) - absence of acoustic activity, from (i_k) to (p_k1) – first stage of symptoms and increase of defects in material, from (p_k1) to (p_k2) – further intensification of AE, stage two and from (p_k2) to (d_k) – rapid increase of defects culminating in a complete destruction.

The value of the total counting sum presented in Figure 2B confirms that solid wood samples generated a higher number of impulses (on average – 32 040) in comparison with samples from glued material (on average – 23 580). It should also be emphasised that the time

of acoustic activity was longer in the case of glued samples and averaged 150 s. In the case of solid wood, where the time of AE generation reached approximately 80 s, the density of impulses exceeding the level of discrimination was higher which could have contributed to obtaining higher values of the total counting sum, despite a shorter time of activity.
Relationships between forces causing acoustic amplification p_k1, p_k2, p_d and the destructive force for glued and solid systems in the function of the force initiating the process of AE generation are presented in Figure 3.

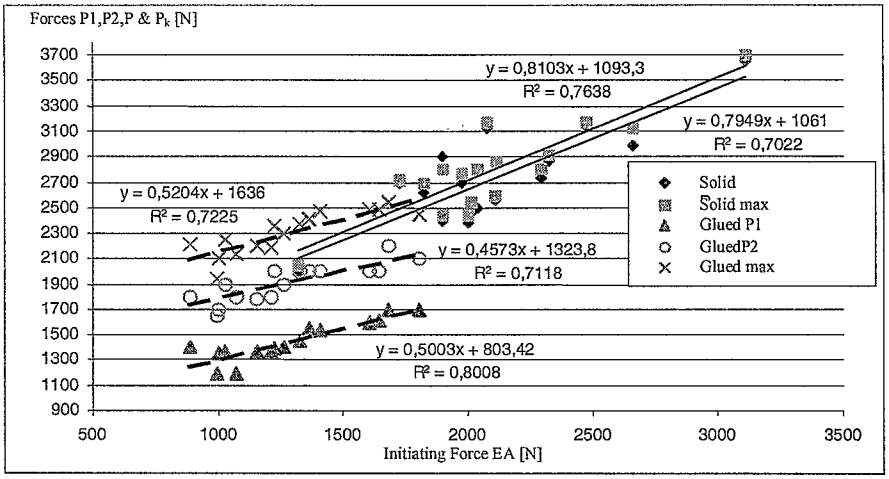


Figure 3. Interactions between forces causing acoustic amplification p_k1, p_k2, p_d and the destructive force and the force initialising AE.

The obtained results prove that there are linear correlations between values of forces initiating AE and values of local counting sums of acoustic amplification situated in points (p, p1, p2). These relationships, both in the case of solid and glued woods, reach the level of correlation contained in the interval 71-80%. When analysing research results, it is possible to observe that destruction symptoms in glued material were visible already at the level of load equalling 45% of the destructive force, while in the case of solid wood samples, they occurred only when it reached 75% of the value of the maximum load. On the other hand, values of forces corresponding to points of temporary amplifications of counting sums were as follows: for solid wood - point p_d - about 91% of the force corresponding to complete destruction; for glued samples, on average - p_k1- 73%, p_k2 - 82% of the maximum destructive force.

Conclusions

Research results and correlations obtained in the course of performed studies allowed authors to draw the following conclusions:

1. the process of destruction of both glued and solid material occurs in stages,
2. loading overlap glued and solid samples, different courses of AE counting sums are obtained. In the case of solid material, the following three stages can be distinguished: absence of acoustic activities, next – their steady propagation followed by a dramatic increase of signals. Characteristic points include: initiation, sudden momentary amplification and destruction. In the case of glued material, the following four stages are observed: lack of acoustic activities, steady propagation, moderate increase of the counting sum and an unstable phase of increase of acoustic signals terminating in destruction. The characteristic places in the course of counting sums include two

extremes: initiation and destruction separated by the first and second acoustic amplifications.
3. despite a longer emission of the acoustic signal from the moment of its initiation to the destruction of glued samples, the total accounting sum is higher in the case of solid material.
4. it is possible to predict the development of destruction of glued and solid elements on the basis of observations of the accumulation of the accounting sum of acoustic signals.

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Streszczenie: *Zjawiska EA z drewnianych połączeń klejowych.* W pracy przeanalizowano sygnały akustyczne jakie generują się z obciążonych próbek zakładkowych, zaklejanych klejem polioctanowinylowym oraz litych.. Na podstawie otrzymanej emisji akustycznej w postaci liczby zliczeń, ustalono miejsca charakterystyczne i etapy narastania defektów strukturalnych. Otrzymane wyniki dowodzą, że istnieje możliwość przewidywania rozwoju zniszczenia elementów klejonych i litych na podstawie obserwacji narastania sumy zliczeń sygnałów akustycznych.

Indirect system of cutting and feed power measurement in milling of wood and wood products

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Abstract: *This paper presents the double channel, microprocessor-controlled, digital wattmeter for indirect power measuring system in multi sensors diagnosis of wood and wood products milling process. Digital wattmeter could measure power of the milling and feed mechanism electric motors with accuracy up to +/- 1 W.*
Key words: wood, wood products, milling process diagnosis, power measurement.

Introduction

Power consumption measurement is a significant operation in wood and wood product cutting process diagnosis. The value of power consumption informs us about: cutting tool wear, increase of the cutting forces, incorrect cutting parameters, local materials structure faults etc. During wood and wood products milling process a variable thickness chip is formed by the edge of cutting tool on small part of the cutting period only. This event caused that there is an periodically repeated non – ordered cutting phenomenon. Changes of the cutting phenomenon frequency are sum of chip formation and free running of the cutter and are product of rotation speed and number of cutters fixed on cutting tool. The flow of cutting force and cutting power values is real. Power input supply of the milling machine spindle or feed electric motors are monitored usually by one phase wattmeter, as average of the cutting and free running power. Next full power supply is calculated accordingly to the following formula:

$N = 3\ I\ U\ \cos\varphi$ [W] where:

N – power supply [W] , I – current intensity [A] , U – voltage [V], $\cos\varphi$ – power factor.

Up to now this system of power measurements was efficient only in the woodworking machines control and feed units. If the cutting force and cutting power increase or mechanical catastrophe occurs in the cutting process, electric motors power consumption rises enormously high and that event is signalised by wattmeter indication and often safety system. The cutting process is automatically stopped. But this indirect cutting power measurement is useless for the cutting process diagnosis, especially tool wear diagnosis. The differences between cutting process values in machining with low or high tool wear are often comparable to power measurements accuracy.

Double channel, microprocessor, digital wattmeter

In Woodworking and woodworking Machinery Department original stand for milling process and tool wear diagnosis was built. Unfortunately producers of the electric equipment didn't offer any high accuracy three phase wattcmeters. The three phase wattcmeters usually have low accuracy ranging from 10 to 20 W, so they were un acceptable for this type of measurement. There was no possibility of applying filtered circuits and the separate transformer station. So new power measurement unit for the spindle and feed electric motors power supply was designed and built.

The following measurement principles was carried out:

- power measurement and analysis of the electrical motors should be done in situ (in real time).
- power measurement of the electrical motors should be measured with accuracy up to 1 W.

- power measurement of the electrical motors must be resistant against outer circuit disturbances.

The basic element of new power measurement unit had to be a device for evaluating power supply in spindle and feed electrical motor simultaneously, by identical two channel circuit meter. The scheme on the three phase digital wattmeter is shown on figure 1.

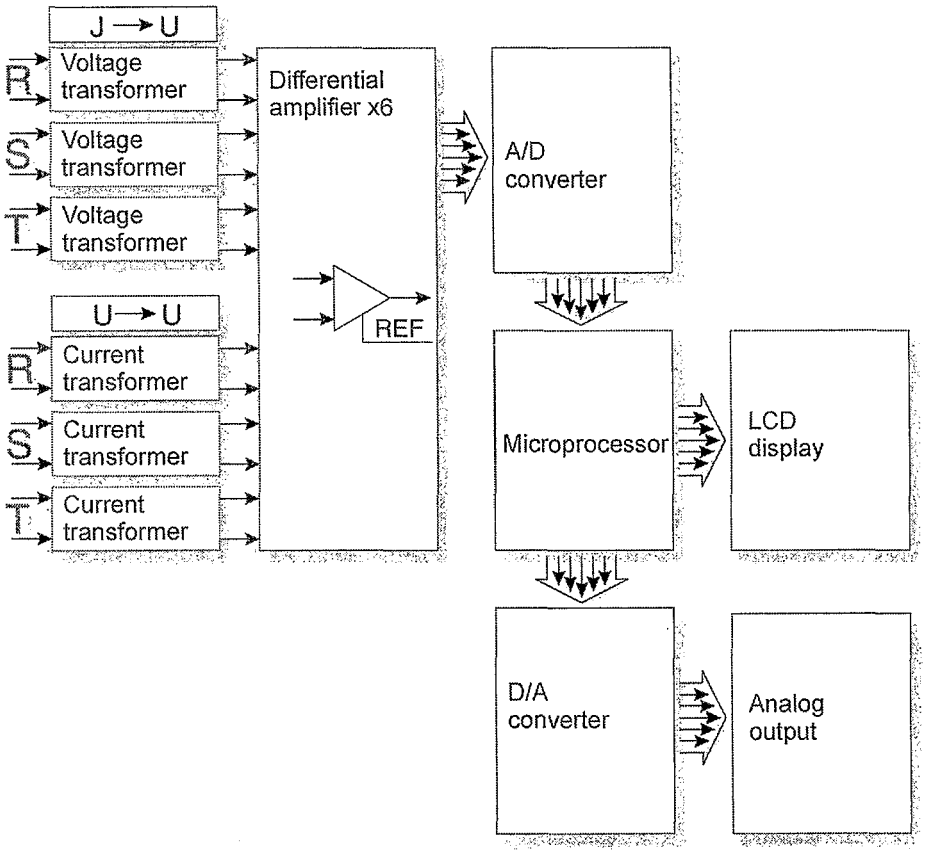


Fig. 1. Tree phase digital wattmeter.

An algorithm to eliminate current disturbances was formed:

- Continuously measuring of current voltage and intensity by current ratio and current transformer of the input.
- Measurement results are given to differential current multiplier for comparison against referential level.
- Measurements results from current multiplier are probed in 32 kHz A/D. The frequency of 32 kHz is the base value for wattmeter.

- Results of measurements are transferred to the buffer of 1024 samples capacity. The buffer capacity is connected to the one phase current period equal to 512 samples, so 1024 will fit whole period.
- If the buffer is full, the current period is evaluated by measurement of 0 for the first current phase. If the period has value less than 512 samples, he is recognized as current disturbance and cancelled. The procedure is now carried from the initial point.
- When all three phase current period are evaluated, the phase shift is corrected with a constant for elimination of differences between for all three phases.
- After for every phase is corrected the second correction is done for phase delay leveling. The phase delay are caused by the work of measurement transformers.
- After all corrections the power supply are evaluated with formula:

$$P = \int_{0}^{512} JUdt$$

- The final power supply value is transformed in A/D converter, in analogue form 0 – 5 V with 0,05 accuracy
- Simultaneously power supply value is transferred in digital form to the buffer of 0,5 second capacity.
- When the buffer is full, the power supply value is averaged and with 0,5 second period and sent to digital display with accuracy +/- 1 W.
- The non averaged power supply values are also send as an input to the computer data acquisition system - Dasy Lab.

Double channel microprocessor, digital wattmeter is shown on figure 2.

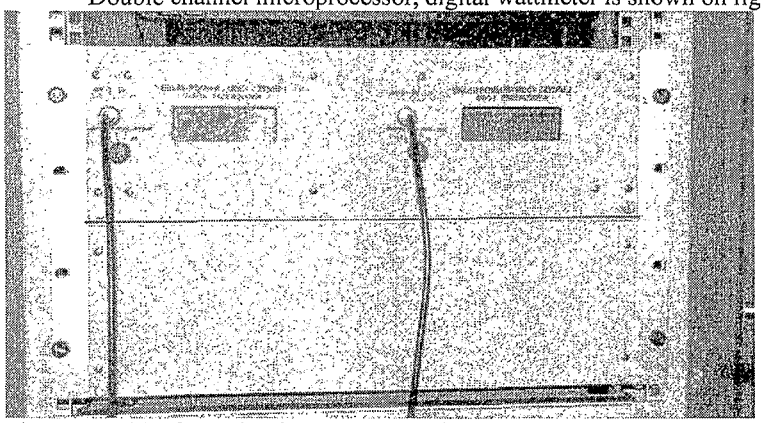


Fig. 2 . Double channel, microprocessor, digital wattmeter.

The primary experimental works for testing new wattmeter were carried out successfully during milling of wood products with different wear of cutter mounted in cutter head. Digital wattmeter was connected to computer with data acquisition system simultaneously with other measurements (mostly force and temperature). The values of the power consumption for milling machine spindle and feed electric motors in milling of MDF and chipboards was registered in every 1/5000 sec. The results of experiment show that digital wattmeter is very useful as a sensor for complex diagnosis of the tool wear and cutting process in milling of wood and wood products. Chosen computer print of the power supply of the milling machine spindle electric motor (cutting power) and feed electric motor (feed power) is shown on figure 3.

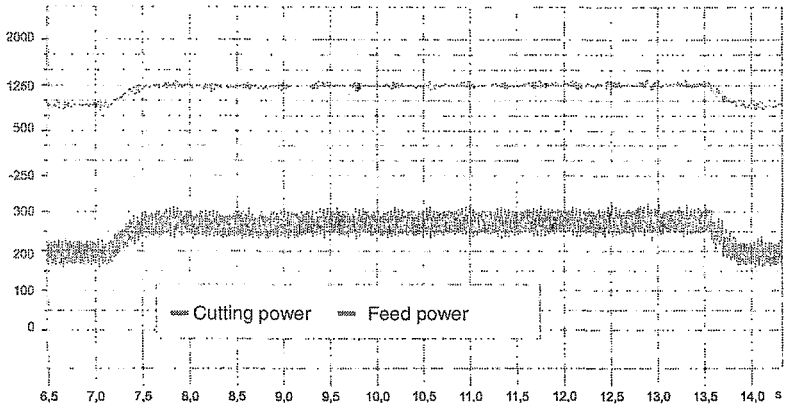


Fig. 3. Computer print of the power supply of the milling machine spindle and feed electric motors (from Dasy Lab data acquisition system).

Conclusion

- Double channel, microprocessor-controlled, digital wattmeter is a proper measuring unit for indirect power measuring system in multi sensors diagnosis of wood and wood products milling process, especially in "in situ" diagnosis of the tool wear.
- Double channel, microprocessor, digital wattmeter is fully resistant against the input current circuit disturbances. That's why this wattmeter in useful not only in laboratory tests, but also in industrial diagnosis experiments.
- Double channel, microprocessor, digital wattmeter could measure power of the milling and feed mechanism electric motors with accuracy up to +/- 1 W.

Streszczenie: *Pośredni pomiar mocy skrawania przy frezowaniu drewna i tworzyw drzewnych.* W artykule opisano nowy dwukanałowy, cyfrowy watomierz zbudowany specjalnie na wyposażenie stanowiska badawczego do diagnozowania procesu frezowania drewna i tworzyw drzewnych, a zwłaszcza procesu tępienia narzędzi. Watomierz jest odporny za zakłócenia sieci. Mierzona jest moc silników napędowych wrzeciona frezarki i zespołu posuwowego, z dokładnością +/- 1 W.

Watomierz zaprojektowano i wykonano w ramach grantu promotorskiego 7T08E 038 19.

Pull strength of the screw joint relative to the angle of screw axis

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Abstract: The article presents several experiments from the area of wood screw joints. The text analyzes the affect of the angle of screw axis in relation to the direction of wood grain and annual rings on the magnitude of pull strength, in some works referred to as screw or joint bearing capacity.

Introduction

Distinct properties of a wood material in different directions in relation to the direction of wood grain are generally known. Equally known is the difference in the bearing capacity of a wood joint that uses a screw as linking element, if this screw is anchored in the direction perpendicular to the grain or parallel to it.

During the fabrication of a screw joint, the angle of screw axis to the grain may be often difficult to define by the use of a particular material since, in practice, it is nearly impossible to prepare the material in a precisely defined cutting direction, for instance a radial or a tangential direction; also a situation may arise during the mounting process when the screw is inaccurately mounted at an angle different than perpendicular to the plane of the material. This may affect bearing capacity of the joint.

Under the grant task 1/8119/01, experiments were executed aiming to study the affect of the angle of screw axis to the grain on the pull strength of the screw. The following text presents a part of the experiments carried out in the study of this topic.

Methodology of experiments

Screw joints present a type of dismountable joints where a wood screw creates a thread in the wood of the linked elements during the mounting of a joint, hence allowing for an occasional dismounting and a subsequent reassembly.

The holding capacity and the yield strength of a screw joint are affected by several factors, most importantly, among others, by:

- properties of the wood screws
- physical and mechanical properties of the wood (density, moisture, strength, direction of grain)
- correct dimensioning of the joint
- proper mounting technique
- application of stress on the particular joint in a finished product. [1]

To facilitate the experiments and observation of the affect of the screw axis angle in relation to the direction of grain and annual rings, two cylinders of 50mm in diameter and 150 mm in length from Spruce (Picea abies) and Beech (Fagus silvatica), dried and acclimated to 12% humidity, were produced.

The 4x40 mm wood screws used in the experiment conform to specification STN 02 1815 (the Slovak Technical Standard).

The experiments were divided into two basic groups:

a) radial-tangential plane (R-T)

b) radial-axial plane (R-A).

Experiments in both groups started in radial direction and the angle of screw axis repositioned by 10 degrees from 0° to 90°. In order to reach an accurate anchoring of the screw, holes were pre-drilled in the cylinder at a given angle. Mounted screws were pulled by a conventional pulling machine, with the scale ranging to 5kN and 10kN with addional fixture.

The results

The strength of each screw joint is based on the factor of friction between the linked parts and tension produced during the assembly. The balance between all factors is created by a controlled moment of tightening – for instance by using a moment wrench. In our experiments the holes were pre-drilled by a bit of 3 mm in diameter, which created a hole constituting 1.07 of the screw core's diameter. As shown in different experiments [1], pre-drilling results in only approximately 8-10% decrease in the bearing capacity of a screw joint. This fact does not anyhow influence the study of the affect of the angle of screw axis related to the direction of grain, as pre-drilling was identical in all cases and of importance in the given experiment was only the change in pull strength at the angles different than 0° and 90°. All previous experiments were conducted under these two angles and their results are presented in other works.

Ten measurements were conducted in each positioning of the experimental cylinder.

The values of pull strength and of tightening moment obtained in the experiments are presented in the following tables and charts.

Wood species spruce (picea abies)

Table 1: The affect of the angle of screw axis on the pull strength

	The point of research – angle of screw axis [°]									
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
	angle of screw axis in plane R - T									
Pull strength [kN]	1,96	1,72	1,81	1,95	2,07	1,75	1,74	1,69	1,77	1,84
Standard deviation [kN]	0,40	0,05	0,28	0,59	0,51	0,29	0,32	0,31	0,38	0,59
Coefficient of variation [%]	20,2	3,5	16,0	30,2	22,1	16,8	19,5	20,1	21,6	29,2
Tightening moment [Nm]	4,5	3,7	4,0	3,8	4,2	3,2	4,3	3,3	3,6	3,8
Standard deviation [Nm]	0,011	0,01	0,008	0,007	0,008	0,013	0,013	0,006	0,011	0,011
Coefficient of variation[%]	25,1	27,4	19,5	18,6	17,8	30,7	25,3	17,8	27,3	29,4
	angle of screw axis in plane R - A									
Pull strength [kN]	2,09	1,92	1,92	1,90	1,68	1,66	1,58	1,37	1,28	1,20
Standard deviation [kN]	0,19	0,14	0,14	0,20	0,17	0,33	0,33	0,25	0,29	0,32
Coefficient of variation [%]	9,1	7,4	7,2	10,5	10,4	20,2	21,0	17,5	18,6	29,1
Tightening moment [Nm]	6,7	5,8	5,9	6,5	6,1	5,5	5,9	5,1	5,2	5,9
Standard deviation [Nm]	0,006	0,009	0,012	0,006	0,007	0,012	0,01	0,01	0,009	0,012
Coefficient of variation [%]	9,2	15,7	19,7	8,7	10,9	19,9	17,8	20,5	17,5	19,4

Wood species beech (fagus silvatica)

Table 2: The affect of the angle of screw axis on the pull strength

	The point of research – angle of screw axis [°]									
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
	angle of screw axis in plane R - T									
Pull strength [kN]	3,53	3,82	3,73	3,80	3,89	3,83	3,59	3,65	3,52	3,63
Standard deviation [kN]	0,56	0,43	0,29	0,45	0,44	0,37	0,47	0,42	0,27	0,29
Coefficient of variation [%]	15,8	11,3	7,9	12,0	11,3	9,7	13,2	11,6	7,7	8,1
Tightening moment [Nm]	10,1	12,7	12,3	9,3	13,2	12,0	10,8	12,4	13,0	13,3
Standard deviation [Nm]	0,020	0,032	0,028	0,023	0,044	0,034	0,029	0,033	0,024	0,037
Coefficient of variation[%]	20,1	25,1	22,4	25,3	29,3	28,8	27,0	26,4	18,1	23,2
	angle of screw axis in plane R - A									
Pull strength [kN]	4,26	4,08	3,72	3,63	3,45	3,34	3,16	3,02	2,71	2,49
Standard deviation [kN]	0,67	0,31	0,37	0,39	0,34	0,31	0,49	0,38	0,32	0,46
Coefficient of variation [%]	15,8	7,7	10,1	16,5	12,9	21,5	18,8	15,4	21,8	22,6
Tightening moment [Nm]	12,7	12,8	11,1	12,2	9,8	12,4	13,3	12,0	12,1	12,2
Standard deviation [Nm]	0,029	0,022	0,021	0,021	0,006	0,010	0,012	0,021	0,017	0,028
Coefficient of variation [%]	22,6	16,8	18,8	17,4	6,2	8,4	8,8	13,7	14,0	212,1

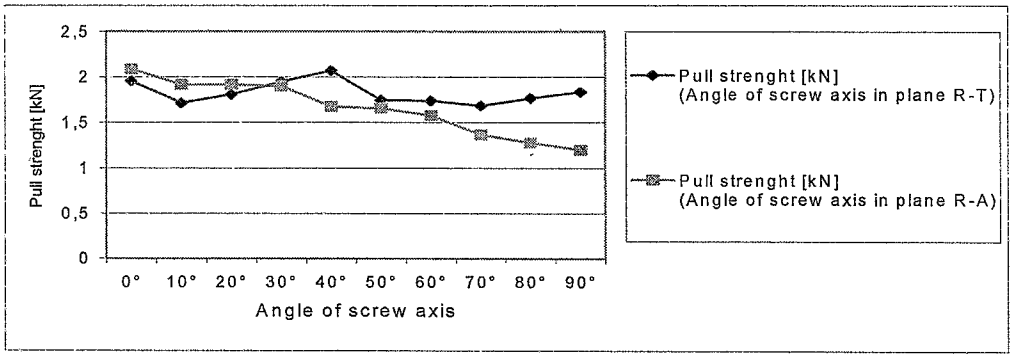


Fig. 1: The affect of the angle of screw axis on the pull strength – wood species spruce

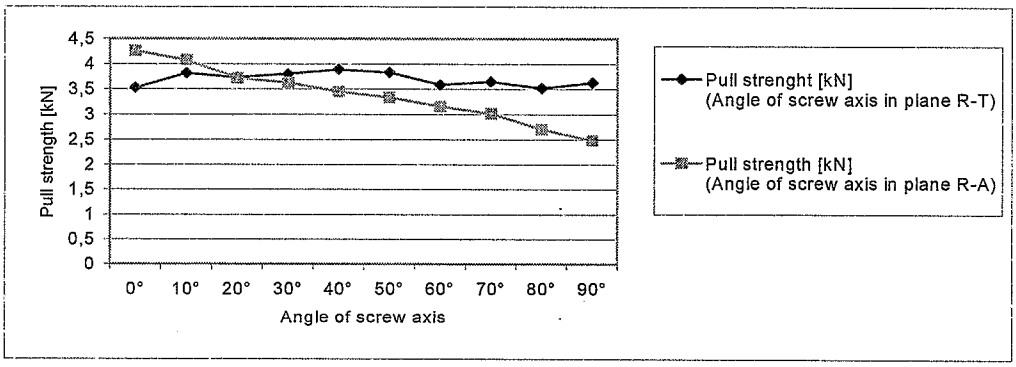


Fig. 2: The affect of the angle of screw axis on the pull strength – wood species beech

Discussion

The values of bearing capacity measured in the basic, perpendicular and parallel directions to the grain, at the given pre-drilling under [2], were as follows:

	Pull strength in direction:	
	⊥ to grain	// to grain
Spruce (Picea abies)	1.85 kN	1.25 kN
Beech (Fagus silvatica)	4.02 kN	2.25 kN

The change in magnitude of the pull strength in the transient directions, as illustrated in the charts in Fig. 1 and 2, translates into markedly different results in the studied transient planes.

a) The radial-tangential plane

The change in the angle of screw axis from the extreme position in radial direction to the final position did not translate into a definable change in the pull strength. We may conclude that the angle of screw axis to the direction of grain in the transient plane of radial and tangential directions does not result in a change of the pull strength and, hence, of the screw joint's bearing capacity. The values measured in this experiment were analogous with results of previous experiments. This may be explained by the fact that the stress is distributed equally on all wood fibers.

Minor oscillations in the magnitude of the pull strength were discovered in spruce, which may be explained by an accidental mounting of screw along the of annual rings and anchoring of one part of the screw into young wood only. This brings up the most important factor influencing the pull strength, which is the density of wood. With a straggle-porous species like beech, this factor does not play a role and, therefore, the transition of the screw joint from radial to tangential direction did not translate into a change in the pull strength, neither did it result in a more significant oscillation in the pull strength.

b) The radial-axial plane

A change in the angle of screw axis to the grain from an extreme position in an accurate radial direction to the final position in axial direction resulted in a significant change in the pull strength. The values of the pull strength in extreme positions corresponded with the values ascertained in previous research. A gradual change in the angle of screw axis resulted in a nearly linear decline in the pull strength in the direction from the initial radial to the final axial direction. This finding facilitates the prediction of a decline in the screw joint's bearing capacity if it will be inaccurately fabricated in this transient plane.

The values found in 0° and 90° positions wholly corresponded with the values measured in previous experiments in the directions perpendicular and parallel to the grain (axial direction).

Conclusion

Wood screws are steel linking elements used in mechanically dismountable joints utilized in the production of furniture and sports goods as well as in interior and exterior elements of wood structures.

The screw holding capacity is affected by several factors, of which the most important in relation to wood material is the density of wood and the angle between the grain and the screw axis.

The article presents results of experiments carried out at a gradual change in the angle of screw axis to the grain starting from 0° to 90°, repositioned by 10°. The transient planes, radial-tangential and radial-axial, were followed separately in the two selected wood species of Norway spruce and European beech.

The experiments demonstrated that the angle of screw axis in the R – T plane has no affect on the pull strength (bearing capacity of the joint), since this plane is identical with the basic direction – perpendicular to the grain.

In the R – A plane, the bearing capacity of the joint decreased linearly with the change in the angle of screw axis from the values at perpendicular position to the values at the position parallel to the grain. This significant decrease in the bearing capacity of a screw joint may occur in practice during the fabrication and it is necessary to eliminate it by dimensioning of the screw joint with the appropriate coefficients.

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Tytuł: Wytrzymałość na rozciąganie połączeń śrubowych w zależności od skoku gwintu.

Anisotropy of mechanical properties of fibreboards in bending

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Kazimierz Wielki University in Bydgoszcz

Abstract: Investigations of the anisotropy of the elasticity modulus in bending and of the bending strength of fibreboards: hardboard, HDF and MDF are presented. Three directions of the bending axis: the mat forming direction, the direction perpendicular to the mat forming and the direction perpendicular to the board face were taken into account. The strong anisotropy of bending properties of tested fibreboards in the planes perpendicular to the board was found out.

Key words: fibreboard, bending strength, modulus of elasticity, anisotropy.

Introduction

Fibreboards are characterised by anisotropy of mechanical properties. It results from their structure and process engineering. First of all the value of each mechanical property in the direction perpendicular to the board face differs considerably from that in the parallel direction. The differentiation of the properties in two basic directions tangential to the board face, namely, in the direction of the mat forming of the board and in the direction perpendicular to it, is much smaller and the plane of the board is often assumed to be the plane of isotropy of these properties (Bodig and Jayne 1982, Tydryszewski et al. 2000).

Three characteristic directions can be distinguished in fibreboard (Fig. 1): the direction of the mat forming of the board (x), the direction perpendicular to it (y), and the direction perpendicular to the board itself (z). Structural members made of fibreboard are usually bent by forces perpendicular to the board and then the x- or y - axis is the bending axis. It is also possible that the z-axis is the bending axis. Thus the knowledge of mechanical properties of fibreboard for these bending axes is needed. The aim of the study was to determine the modulus of elasticity in bending as well as the bending strength of some kinds of fibreboard for the three bending axes: x, y, and z.

Materials and methods

Three kinds of fibreboard made in Poland were evaluated: hardboard, high density fibreboard (HDF) and medium density fibreboard (MDF). Properties of these boards are given in Table 1.

Table 1. Physical properties of fibreboards used in tests

Kind of fibreboard	Thickness [mm]	Density [kg/m^3]	Moisture content [%]
Hardboard	3.2	975	8.0
HDF	3.0	920	7.5
MDF	18.0	760	6.9

Three types of test specimens were used. The test specimens with x-or y-axis were monolithic and were cut in accordance with EN 310 standard (Fig. 2a). The test specimens

with z-axis were glued from the layers with the thickness t (Fig. 2b). Thirty specimens for each kind of fibreboard and type of specimen were prepared. Both the modulus of elasticity in bending and the bending strength were fixed in accordance with the procedures specified in EN 310 standard.

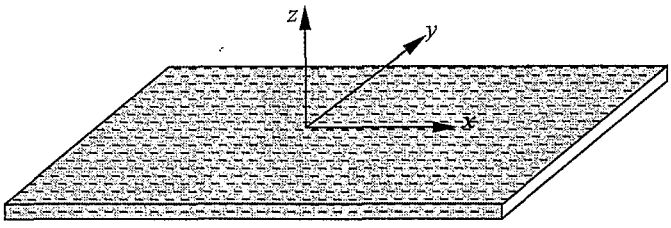


Fig. 1. Directions of fibreboard: x–mat forming direction, y–perpendicular to it, z–perpendicular to the board

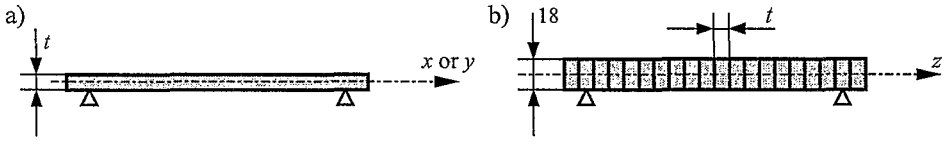


Fig. 2. Test specimens for determination of bending properties of fibreboards: a) for x-or y-bending axis, b) for z-bending axis; t – board thickness

Results

The results – mean values and variation coefficients of the modulus of elasticity in bending and the bending strength of the examined fibreboards for the three directions of bending axis are given in Table 2. The comparison of these values is shown in Fig. 3 and 4. The values of mechanical properties for x-bending axis were assumed to be the basis for this comparison.

Table 2. Modulus of elasticity and bending strength of tested fibreboards for three directions of bending axis

Kind of fibreboard	Direction of bending axis	Modulus of elasticity in bending		Bending strength	
		mean value [MPa]	variation coefficient [%]	mean value [MPa]	variation coefficient [%]
Hardboard	x	3150	7.0	33.2	6.2
	y	2850	7.4	30.0	5.2
	z	190	14.5	0.79	14.2
HDF	x	3630	3.4	39.3	4.0
	y	3300	10.5	35.3	9.8
	z	220	14.4	1.15	13.3
MDF	x	4000	1.6	34.2	3.5
	y	3850	1.5	32.2	3.8
	z	270	8.0	0.98	8.8

For each kind of tested fibreboard these properties in bending the test specimens with y-axis are smaller than in bending those with x-axis. However, relative differences of these properties are rather small, ranging from 9.1 to 10.2 % for hardboard and HDF, and from 3.7 to 6.7 % for MDF. Thus, it can be stated that the anisotropy in the plane of the board, specified by x-and y-axis, is insignificant and assumed that tested fibreboards are isotropic in their planes. The values of mechanical properties in bending the test specimens with z-axis are, just as it was expected, very small. They range from 6.0 to 6.8 % of those in bending the test specimens with x-axis for the modulus of elasticity and from 2.4 to 2.8 % for the bending strength. This last comparison shows strong anisotropy of mechanical properties in bending of fibreboards. The z-axis is perpendicular to the board, and thus this strong anisotropy refers to the planes perpendicular to the board.

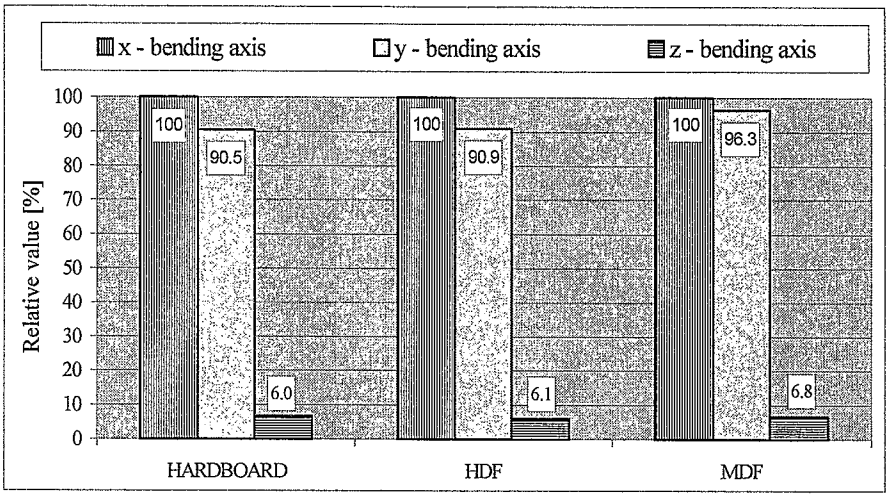


Fig. 3. Comparison of the elasticity modulus for three directions of bending axis

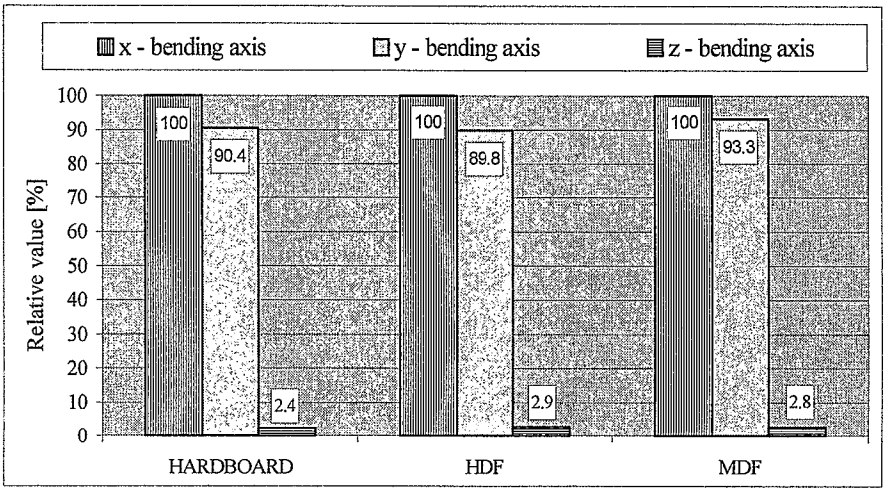


Fig. 4. Comparison of the bending strength for three directions of bending axis

Conclusions

1. The mechanical properties of fibreboards in bending little depend on the direction of bending axis provided that the axis is in the plane of the board.
2. Fibreboards can be recognised as isotropic in the plane of the board.
3. The values of the modulus of elasticity in bending and the bending strength determined for the bending axis perpendicular to the board are many times smaller than those determined for the bending axis tangential to the board.
4. Fibreboards show strong anisotropy in the planes perpendicular to the board.

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Streszczenie: *Anizotropia właściwości mechanicznych płyt pilśniowych przy zginaniu.* Przedstawiono badania anizotropii modułu sprężystości przy zginaniu i wytrzymałości na zginanie płyt pilśniowych: twardej, HDF i MDF. Uwzględniono trzy kierunki osi zginania: kierunek formowania kobierca płyty, kierunek prostopadły do kierunku formowania kobierca i kierunek prostopadły do płyty. Stwierdzono silną anizotropię właściwości mechanicznych w płaszczyznach prostopadłych do płyty.

Mechanical properties of wooden beams strengthened with fibre glass strip

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Faculty of Wood Technology SGGW

Abstract: The paper present research of wooden beams strengthened with fibre glass. Received results prove, that load capacity of reinforcement beams was increased by 49% and strength by 41%.

According to Krzysik [3] the tension strength of knotty pine wood equals about 15% strength of wood without knots. Due to structure disadvantages of knotty pine wood, characteristic strength of constructive wood is much lower than average strength of pine wood, and coefficient of variation mechanical properties can reach even 20-30%. To upgrade strength of wood and lower dispersion of results, the section could be made by gluing of several layers of timber to receive so called glued laminated lumber, which is used in timber constructions or to strengthen wood in extending area of bended elements. Than neutral axle of the element moves closer to the material with better mechanic properties – compression area of bended element extend and influence of wood disadvantages on load capacity lowers. Research were carried out for many years on applying reinforcement of wooden bending elements. From a point of view of used reinforcement material research could be divided into two groups – with application of steel or fibre glass strip.

Reiforcment of wood with steel strip was the subject of research of R. Ganowicz and others [1], [2] and Z. Mielczarek and K. Piotrowska [4]. Summarize above mentioned works, could be maintained, that as a result of strengthening of bended wooden elements with steel strip improving of load capacity about 30% and reducing beams deformation max by 20% can be achieved. During long-lasting research [2] it was observed, that in hot summer days tested samples reinforcement with steel strip had visible increase of deformation and after decreasing temperature reduction of deformation was observed with the same load. It was a result of different thermal extension of steel and wood (this coefficient is normally 3 times higher for steel than for wood).

Research of wooden beams with cross-section 55 x 100 mm strengthened with polyester-glass rods diameter 8 mm were conducted by T. Socha [6]. He proved that load capacity of bended elements increased 46% compare to wooden elements.

In research presented in this paper authors carried out research of bended beams strengthened in tension area with fibre glass strips glued to the wood. In research carried out up to now, rods were glued into grooves, cut out in the wood. It was difficult to make and didn't assure enough adhesion between reinforcement and wood.

The aim of authors research was determination the value of load capacity and MOE and strength of reinforcement beams and comparison results with the same value for wood beams without reinforcement.

Methods

MOE was determined according to the PN-EN Standard [8]. Used samples were made of pine wood. Sample dimension were: length 2400 mm and cross-section 40x120 mm. Quantity of samples was 28. Samples were seasoned in normal condition (temperature 20 ± 2^{0}C and air relative humidity $60 \pm 3\%$). The scheme of sample's loading is presented on Fig. 1.

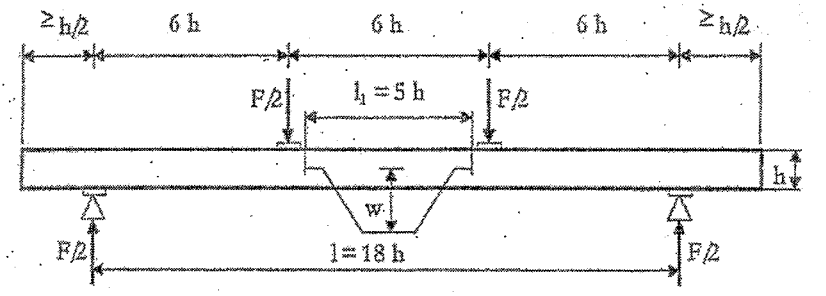


Fig. 1. Scheme of loading of tested element

MOE of wooden and strengthened beams was calculated according the formula:

$$E_m = \frac{a\, l_1^{\,2}\, \Delta F}{16\, I\, \Delta w} \qquad (1)$$

where: a – distance between strength F/2 and the nearest support [mm]
l_1 – length of measure base [mm]
ΔF – increase of load [N]
Δw – increase of deformations [mm]
I – moment of inertia [mm^4]

In the case of strengthened beams reduced moment of inertia was additionally calculated according the strength of materials methodology. Overall the bending strength was determined according PN-EN [8]. Wood used for test was different quality.
Elements strengthened were made on Wood Technology Faculty. Used strips were made of fibre glass with cross-section 40x2 mm, length 2000 mm and tension strength 340 MPa and MOE 24000 MPa. Used glue was epoxy resin Epidian 5. Elements and strip were pressed for 48 hours up to absolute hardening of the glue.

Results and analysis

The results of mechanical properties of strengthened beams and beams without strengthening are presented on Table 1. Wood humidity level was 12%.

Table 1. Mechanical properties of strengthened beams and wooden beams.

Mechanical Properties		Average	Coefficient of Variation
MOE E_m [MPa]	wooden element	14750	3070
	strengthened element	14770	2150
Load Capacity P [N]	wooden element	13010	5500
	strengthened element	19430	4030
Bending Strength [MPa]	wooden element	46	19
	strengthened element	65	14

Increase of MOE of strengthened elements compare to wooden elements was not observed. Probably it's the result of applying strip made of fibre glass with similar MOE as the wood. Proportion MOE of strip made of fibre glass to MOE of wood was from 1.15 to 2.2. Cross-section of the strip was equal 1,6% cross-section of the wood. Comparing load capacity of strengthened wood beam and wood beam increase by 49% was observed and lower dispersion of result. Also bending strength was increased by about 41%. Huge increase of load capacity and bending strength was caused by partial elimination influence of smaller wood knots in tension area, what makes the material was more homogeneous.

Characteristic of destructions

In most of strengthened beams, a the end of elastic phase, appeared characteristic folds running from the edge of the element inside it. It proves the destruction of compressive area of bended element. In other cases destruction of bales took place inside the tension area, however the glue line was never destructed. When separation of the strip and the wood was observed, it took place in the area of knotty wood destroying. During analysis of curves load-deformations the curves for strengthened wood were more steep, laying over curve for wood and plateau before destroying was observed.

Conclusions

1. Gluing of strip made of fibre glass to wood elements on tension side is successful method of wood strengthening.
2. Using fibre glass strip with mechanical properties determined above load capacity increase by 49% and bending strength by 41%.

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Streszczenie: *Badania właściwości mechanicznych belek wzmocnionych płaskownikami z włókna szklanego.* W pracy przedstawiono wyniki badań belek drewnianych zbrojonych płaskownikami z włókna szklanego. Płaskowniki mocowane były do drewna przy pomocy kleju epoksydowego po stronie włókien rozciąganych elementów zginanych. Nośność elementów zbrojonych wzrosła o 49% w stosunku do elementów litych zaś wytrzymałość o 41%.

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Why narrow-kerf technologies are justifiable in modern sawmills?

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Abstarct: The cost distribution in a regular sawmill shows that raw material has the main effect upon the sawmill economy. It is hard to assume that in the near future log costs will drop, whereas there is observed shrinking raw material resources. One solution to these problems would be to increase the number of narrow-kerf technology applications in both the primary and secondary processing of wood. The use of thinner saws significantly cuts down kerf losses and simultaneously increases raw material yield. The best profits are visible if thinner elements are produced. However, beyond doubt in every case sawmills could be benefited by the use of narrow- kerf technologies.

Introduction

Economic development of sawmills is affected by a number of factors. Amongst them the cost structure in a sawmill is an important issue in deciding how to achieve maximum production output. An example of the cost distribution in the regular sawmill is presented in Figure 1. The uppermost bar of the chart shows that raw material amounts to 70%, labour to 15%, fixed assets to 10%, other costs to 4% and the tool costs to 1% [12]. It could be supposed, that in Polish conditions the manpower costs might be a bit higher because of it that the labour consumption in Polish sawmills is approximately five times larger than in the European Union [2].

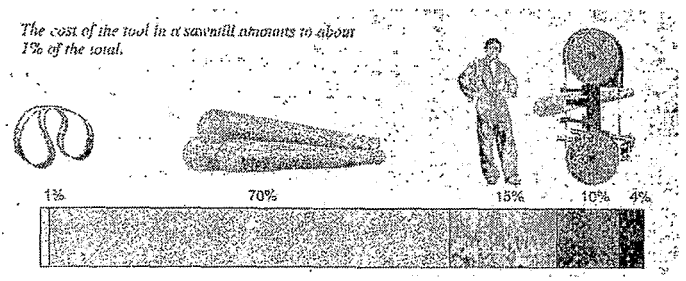


Figure 1. The cost distribution in a regular sawmill [12]

However, in every sawmill the price of log is by far the most important factor influencing the competitiveness of sawmill industry. This, in combination with high personnel costs makes it vital to make efficient use of the available resources.

One solution to this problem would be to increase the number of narrow-kerf technology applications in both the primary and secondary processing of wood. Better utilisation of raw materials is the main advantage of these kind of sawing technologies. Therefore, I will be focussed on some chosen problems of great importance if one is to reduce the raw material costs.

Shrinking raw material resources

Timber as a natural material is still a very attractive raw material to a man nowadays. There is observed the rise in wood consumption [2, 3], notwithstanding high raw material costs and wood product prices [10, 13] in comparison to prices of substitutes for wood [4].

Currently, global consumption of wood approximates 3.23 milliard m^3 annually, or 0.54 m^3 per capita per year (Figure 2) [1]. About 55% of the latter is consumed as a fuel by the developing tropical countries [6]. For example developing countries cut down 65,1 million hectares of woods for the last five years of the twentieth century, what is mainly connected with the rising birth rate of people. They consume wood not only as fuel but also for building engineering necessities. Moreover, they need new free cultivated areas [1, 6]. Satisfying demand for wood is obtained by excessive deforestation. The net effect of these various factors is that supplying global needs is becoming increasingly problematic. For data shown in Figure 2, which were estimated based on sources of the Food and Agriculture Organisation of the United Nations (FAO) [1], it can be noticed that the annual growth of wood would soon be insufficient to support current per-capita consumption.

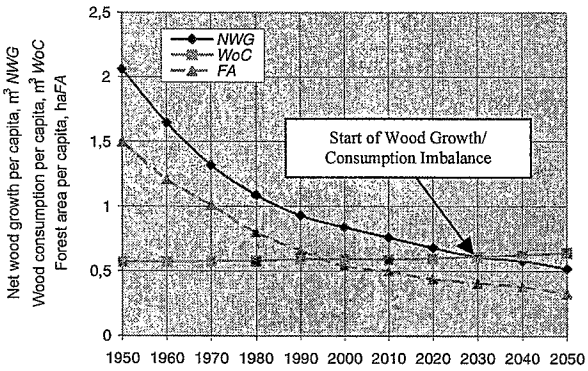


Figure 2. Per capita data for forests and wood

Taking these data into account it is hard to assume that in the near future raw material costs will drop. So, in this connection processing and machining of wood should be carried in both a lean and an efficient way. For example, in the manufacture of lumber, the sawmill costs can be decreased by reduction in the kerf dimension.

Raw material yield

In the Western United States it is known, for example, that reduction in either kerf or sawing variation by 0.8 mm will result in an increase in lumber yield of 1 to 3% [11]. As long as saw stability can be maintained, kerf losses can be reduced by using thin saws [7, 8, 9, 11]. Advantages of narrow kerf technologies are best visible if kerf losses during production of layers of Engineered Wood Products [15] such as structural glued-laminated timber (glulam), 3-ply profiles for window sashes and window frames, and glued 2-ply or 3-ply parquet are compared. These layers are very often thin and their thickness is equal to overall set (kerf) if out of date sawing technologies are applied.

For gang circular saws and mini frame sawing machines relative kerf losses Q_m can be calculated as a ratio of the total loss volume and the stock volume:

$$Q_m = \frac{n \cdot S_t + \sum_{j=1}^{j=2} S_{bj}}{n \cdot S_t + \sum_{j=1}^{j=2} S_{bj} + (n+1)g_E} \tag{1}$$

where: S_t – kerf, S_{bj} – extra losses due to the planning allowance of external pieces, n – number of main saws in the gang, g_E – element (layer) thickness.

The raw material yield for the analysed sawing method can be determined as follows:

$$W_m = 1 - Q_m = 1 - \frac{n \cdot S_t + \sum_{j=1}^{j=2} S_{bj}}{n \cdot S_t + \sum_{j=1}^{j=2} S_{bj} + (n+1) g_E} \tag{2}$$

The comparison of kerf losses during re-sawing operation with the use of mini gang saw blades (S_t=1.4 mm) and circular saw blades (S_t=3.5 mm) is presented in Figure 3a. Assuming that extra losses due to the planning allowance of external pieces are S_b = 0,5mm, there were calculated for these methods relative kerf losses Q_m and raw material yields W_m (Figure 3b).

a) b)

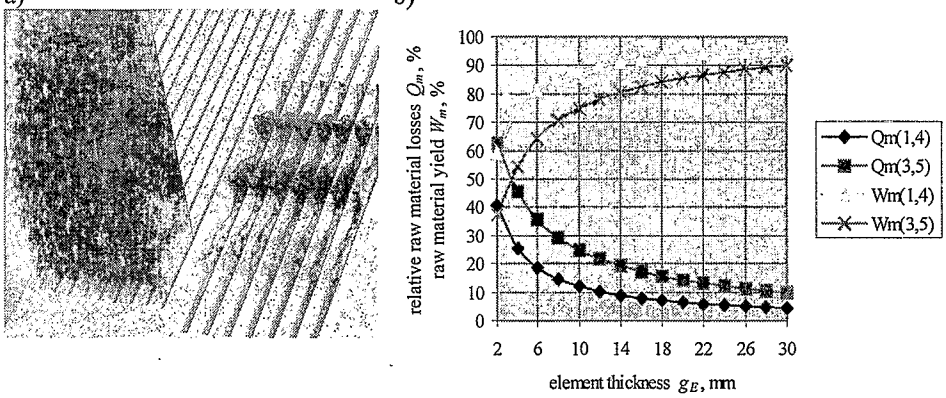


Figure 3. Comparison of kerf losses during re-sawing operation with the use of mini gang saw blades (S_t=1.4 mm) and circular saw blades (S_t=3.5 mm), where: a) general view, b) relative kerf losses Q_m and raw material yields W_m

Results of computation presented in Figure 3b revealed that sawmill can be at a significant advantage in the cost raw material reduction if one of the narrow-kerf sawing technology is used, i.e. a mini frame sawing machine [14], especially for thin sawn elements. In that case, there is a difference for thinner elements in material losses approximately up to 20% for compared sawing technologies.

Summary

The application of narrow kerf sawing technology has a great influence upon the sawmill economy because narrower kerf saws would allow more sawn material to be taken out from each workpiece in both the primary and secondary processing. What is more, these technologies are environmentally friendly. However, if the sawmill is going to reduce the raw material costs by the narrow kerf technology application it will have to face other new challenges yet. The latter has been confirmed by findings of investigations, which had been carried out at Gdansk University of Technology in the area of narrow kerf cutting on mini frame sawing machines [7, 8, 14].

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Streszczenie: *Dlaczego w nowoczesnych tartakach piłowanie za pomocą cienkich pił jest uzasadnione ?*.Analiza struktury kosztów produkcji w tartaku wykazuje, że największy wpływ na ich wartość mają koszty surowca. Przy występującej tendencji kurczenia się zasobów drewna dobrej jakości trudno jest przypuszczać, iż jego ceny zaczną spadać. W związku z tym należy dążyć do stosowania w tartakach materiałooszczędnych technologii, w których stosuje się cienkie piły, gdyż przy prawidłowo prowadzonym procesie cięcia zapewniają one redukcję strat materiałowych i znaczące korzyści finansowe. Szczególnie wysokie oszczędności występują przy pozyskiwaniu przedmiotów o niewielkiej grubości,

będących elementami składowymi drewna warstwowo klejonego (Engineered Wood Products).

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Relationship between saw blade teeth wear and kinematics of frame sawing machines

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Abstract: In the paper shown are results of saw blade teeth wear tests and influence of kinematics of frame sawing machine on distribution of wear of particular tooth blade.

Introduction

Cutting blades of machining tool usually work in difficult and specific conditions. Mechanical and thermal loads acting on the cutting edge during machining cause changes of blade characteristics and decrement of its material. This worsens the capability to machining. That in-time progressing loss of machining capabilities is called the cutting edge wear [1]. Together with increase of wear conditions of cutting blade work are becoming worse. Finally they are unsatisfactory. State of the cutting edge which makes it useless for further work is called cutting edge blunt.

Many factors influence on cutting edge wear. One of the most important ones decisive for cutting edge wear is area of cut. Very specific kind of machining is parting-off wood on frame sawing machines because every single tooth of saw blade machines another and time-changeable area of material [2]. Different conditions of work for particular blade teeth make that the wear of teeth differs.

Saw blade teeth wear

Saw blade teeth wear tests wear conducted based on geometrical measurements of blade teeth' geometry. The teeth were working for 5,5 hours parting of pine-tree logs on frame sawing machine with following characteristic :

- feed of material on single rotation of saw frame driving crank f= 8,4 mm,
- saw frame stroke H= 520 mm,
- blade teeth pitch for swaging saw set t=30 mm,
- inclination of saw blades in frame on stroke of saw frame z=3,85 mm.

Basic kinematical and geometrical parameters of cutting process for above presented setting of frame sawing machine were shown on Fig.1 in form of relative travel of saw and material in direction of feed Z_f and feed for teeth during one cycle of work. These parameters were determined basing on computer simulation program for parting-off wood on frame sawing machines with rectilinear trajectory of leading of saws and continuous feed of material [2].

As it is on Fig.1. feed value for tooth in cycle of work is changeable. Blade teeth come into contact with bottom of saw cut with crank rotation of $\varphi \approx 30^0$. Feed for tooth f_z reaches the highest value with rotation of $\varphi = 180^0$. In idle stroke of saws $(\varphi > 180^0)$, where trere should not be any contact between saw blades and bottom of saw cut, kinematics of frame sawing machine makes that that in initial faze of idle stroke appears sudden press of teeth into material and it comes to friction between tool flank and bottom of saw cut.

These diversified work conditions for particular blade teeth cause diversification of wear values for every particular tooth.

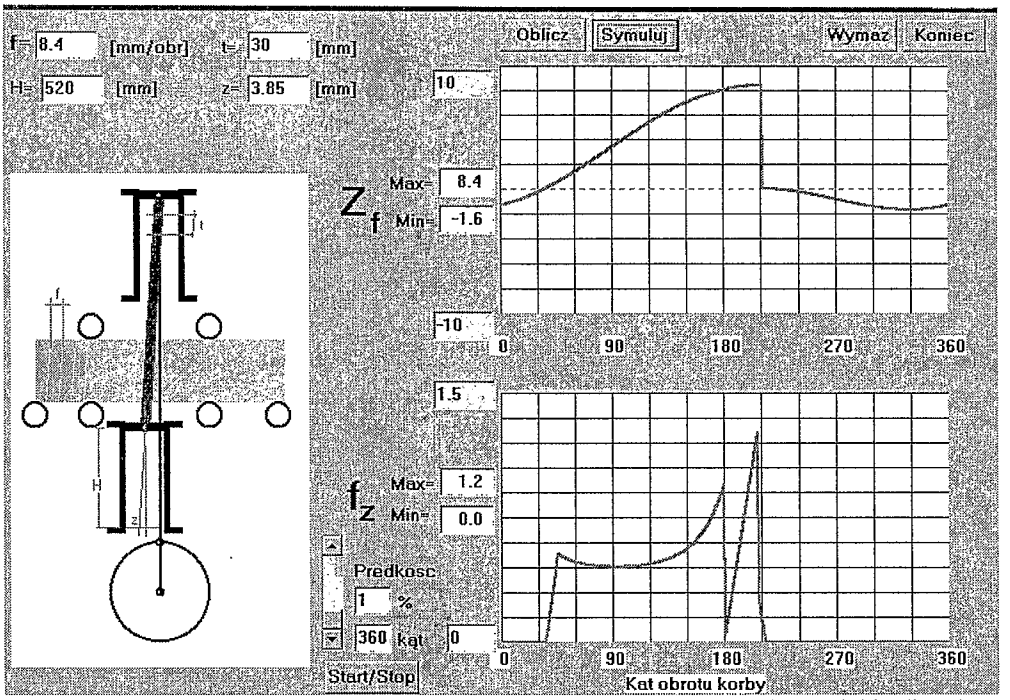


FIg.1. Results of computer simulation in form of relative travel of saw and material in direction of feed Z_f and feed for tooth f_z during one cycle of work versus crank rotation angle for setted parameters of frame sawing machine

Direct factors which are measure of geometrical tooth wear were used for assesment of saw blades wear during conducted tests. Among many of them only few were chosen. The ones that describe form and type of saw blades wear and also decide over their blunt what determines their ability to work.

Example of typical saw blade wear is shown on Fig.2.

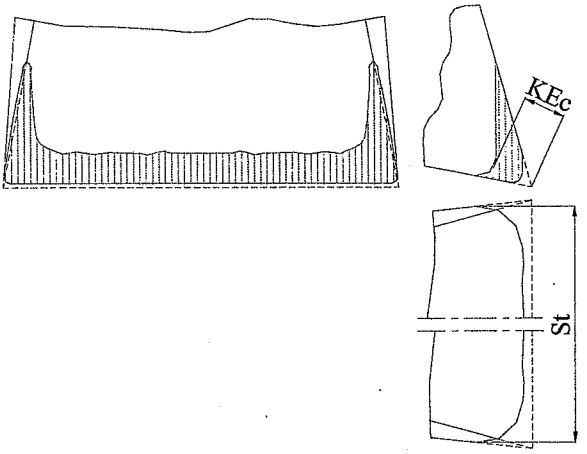


Fig.2. Diagram of saw blades teeth wear

During process of parting off wood blades are worn mainly on tool flanks. Tool wear land causes shortening of tooth and rounding of main cutting edge. Very characteristic for wear land in saw blades is that the wear land is not equal on length of main cutting edge. Wear land is concentrated in tooth corners which makes rounding of corners. And that is the reason for change of total saw set. Concentration of wear in tooth corners and the fact that this wear is decisive over saw performance in parting-off wood caused that only two factors were chosen to determine tooth corners wear – shortening of tooth in the corner KEc and total saw set St (Fig.2).

Results of measurements in form of total saw set St and tooth corner shortening KEc for particular teeth of exemplary saw blade used during tests were shown on Fig.3.

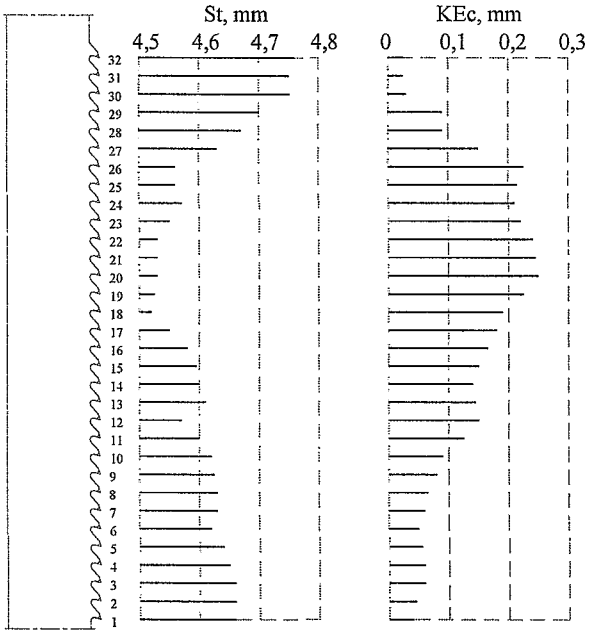


Fig.3. Total saw set St and tooth corner shortening KEc for particular teeth of saw blade

Presented test results indicate that wear of particular teeth changes significantly with length of the saw blade. That is the result of kinematics of frame sawing machine. Comparing value of tooth wear for particular teeth (Fig.3) and run of feed for tooth in cycle of work (Fig.1) one can see tight connection between them. Initial teeth of saw blade (nr.1-7) cut into material and go through and the further tooth the longer way in material to go through (up to log height) and wear of following teeth is bigger. Teeth from second quarter of saw blade (nr.8-15) cut material on whole height with very similar conditions of work. The worst conditions of work have teeth from the third quarter of saw blade length (nr.16-23). These teeth are in touch with material in final faze of saw blades working-stroke where cutting speed suddenly falls down and it comes to stoppage of saw blades in material with the maximum value of feed for tooth in saw blades working-stroke. Moreover, these teeth in initial faze of idle stroke are clamped in material and friction between tooth flank and bottom of saw cut appears. Value of pressing teeth into material during initial faze of idle stroke is bigger than maximum feed for tooth during working stroke. These disadvantageous conditions of cutting cause that wear for these teeth is the biggest. Teeth from the forth quarter of saw blade length (nr.24-32) depending on log height cut the

material or not. In tested saw blades, initial teeth from this part cut the material and the further tooth the quicker goes out of material so the wear is much lower. Last teeth (nr.30-32) did not take part in cutting which makes that we can treat them as not used and not worn.

Conclusions

Kinematics of frame sawing machine significantly influence the wear of saw blade teeth. Change of feed for tooth during cycle of work makes that every particular tooth work in different conditions.

Comparison of measurements results for tooth wear factors in form of corner shortening KEc and total saw set St indicates that there is large conformity between them. Therefore one can assess saw blade wear only by one of the factors. Measurement of corner shortening is complicated, time-consuming and requires special measuring apparatus. Measurement of total saw set is simple, quick and can be conducted by means of standard measuring equipment. However, this measurement has some limitations because can be used only for swaging saw set and requires knowledge of saw set before use.

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Streszczenie: *„Zależność pomiędzy kinematyką pilarki ramowej a zużyciem krawędzi tnących zębów pił".* W pracy przedstawiono rezultaty badań zużycia ostrzy pił trakowych i wpływ kinematyki pilarki ramowej na rozkład zużycia poszczególnych ostrzy pił.

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Mapping of beech wood surface before and after rolling press

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Abstract: Preparing boards for finishing process contains wood sanding of the layer surface. To eliminate wood sanding we can use compression rolling of particle boards by means of hot roller at temperature of about 120°C. The research shows changes of surface roughness in beech veneered particle boards after compression rolling. The results show surface roughness before rolling after the process of refining and dampening the surface by water. The results indicate that changes obtained by compression rolling considerably decrease surface roughness. However after long term dampen, surface roughness is higher than at the beginning of the process. Roughness changes were shown by means of three parameters recommended for wood and wood products standards.

Key words: surface roughness, compression rolling

Introduction

The main purpose of furniture elements surface is its decorative function. To fulfil this function all elements are refined in the following processes: facing, dying and lacquering. Substrate prepared to finish should be smooth and level and its quality shouldshow:

- geometrical structure of surface (GSS),
- physical, chemical and mechanical properties of surface or surface layer,
- surface exterior [8]

As far as particle board is concerned the first group is of major importance as it decides about the surface outlook. This is the reason why particle boards are sanded. Sanding causes calibrating of boards thickness and corrects their surface roughness. However outer layer sanding from microchips causes the process of chips swelling later during for example facing process. It results in irregular chips swelling on boards surface layer and its waviness and roughness are higher. This process can cause necessity of re-sending, which can spoil facing. Sanding process causes also some other inconveniences that is, considerable usage of abrasive materials, problems with dust during production. To complete, or at least partly eliminate, the above mentioned problems connected with sanding compression rolling was introduced. It gives higher density of fibre structure and better surface smoothness of veneer and corrects thickness uniformity of a given board [1,2,3,4,6,7,10,]. Compression rolling has not eliminated sanding completely however limited it considerably. Additionally usage of lacquering materials was limited and quality of surfaces was better.[12,13].

The aim of the research

Although quality advantages of compression rolling were confirmed by using this technology in industry [2,7,11] the research concerning roughness changes under the influence of compression rolling are considerable. There was no research testing for example stability of smoothed surfaces in this way under changing moisture conditions that is under the influence of colours of lacquers and their dissolvents and so on. That is why the aim of the research was to find the influence of compression rolling machining on the surface roughness changes of veneered particle boards and determine stability of such changes after long term moisturing.

Research description tested material

Typical furniture elements from furniture factory were chosen to be tested. These were beech veneered elements with following dimensions - 0.8 x 0.35 m and thickness of 19 mm; density was of 678-694 kg/m^3 The boards fulfilled E 1 norm concerning content of formaldehyde. Beech veneer was of 0,65 mm thick. The boards were veneered in multi-opening press with usage of 135 g/m^2 urea glue and sanded in wide belt sanding machine with grain sizes of 100 and next 150 and cleaned from dust.

Sanded boards were air - conditioned for thirty days in laboratory in temperature of 20 + 2° C, and air relative humidity of 60 + 5 %. Next, surface roughness measurement was taken. Measured boards were compression rolled and next measurement was taken in the same places as the first one tool placed.

The compression rolling process

Refining of boards surface was made in boards roll stand which was driven by an electric engine with set of gear wheels. The refining process was made in conditions similar to industry that is :

- feed speed of roller material was u = 9 m/min.,
- the temperature of rolls was T== 120 + 10 °C
- clearance between rolls shorter than 2 mm from board thickness.

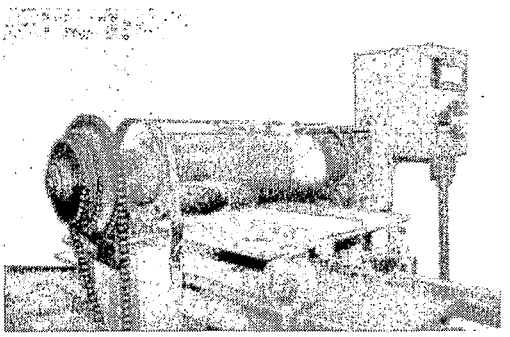


Fig.1. Laboratory roll stand

Roughness measurement

Surface roughness measurement was made by contact method at special stand using analogue inductive gauge. Its measuring head was equipped with contact slipper having radius of R=80 mm which eliminated shape errors and necessity of precise set of a fasted sample to sideways. The tip of penetrator's vertical angle was a == rad (90°) and curvature radius was r = 100 μm. Measurement was made in E system which enables filtering of components Geometrical Structure Surface. The analogue output of inductive gouge was connected with computer by means of analogue -digital transducer, which enables calculation of chosen roughness parameters /recommended by Polish Standard PN-84/D-01005 [9]/ such as:

arithmetical mean of max. peaks of the given surface roughness - Rm:

maximum height of the profile - Rmax

arithmetical mean of deviation of the profile - Ra:

$$R_a = \frac{1}{l_m} \int_{x=0}^{x=l_m} |y| dx$$

in which :

y_i — max. height of single roughness profile [mm],

l_m -evolution length [mm]

On boards surface in 1cm intervals measurement lines were marked. They were perpendicular to fibres of veneer. There were 15 such lines marked, which were 100 mm long.

Each measurement cycle was taken in the same place as the first one.
Before tests boards were air-conditioned for thirty days.

Research results

The obtained results let me make diagrams - fig. 2. and 3 - showing average values of roughness parameters for each measurement cycle of a given board before and after rolling and after dampening of rolled surface.
The obtained results show that after compression rolling decreases surface roughness of veneer layer facing a particle board. Plasticity of veneer grows but its elasticity decreases. In such a case arise loosen chemical bonds as a result of plasticity of pectic substances. Swelling hemicellulose felting increases ability and sizing of tissue. Under pressure of rolls plastified lignin partly fills pores creating thin surface layer in which also are forces and glued fibres after sanding which influence surface roughness. After cooling lignin hardness again becoming natural adhesive in wooden tissue. [12]. Humidity and pressure of rolls are agents intensifying heating. The final effect of considerable increase of surface quality disappears, after long term humidity action. These results were obtained during short contact of veneered board with heated rolls that is why intensity of plasticity was smaller.

Conclusions

The results of the research show that compression rolling results in considerable smoothening of veneer surface. It results especially in pores vanishing, which exist in beech anatomic structure. Stability of surface obtained in such a way is high at short term dampen action , but decreases with increase of dampening time.

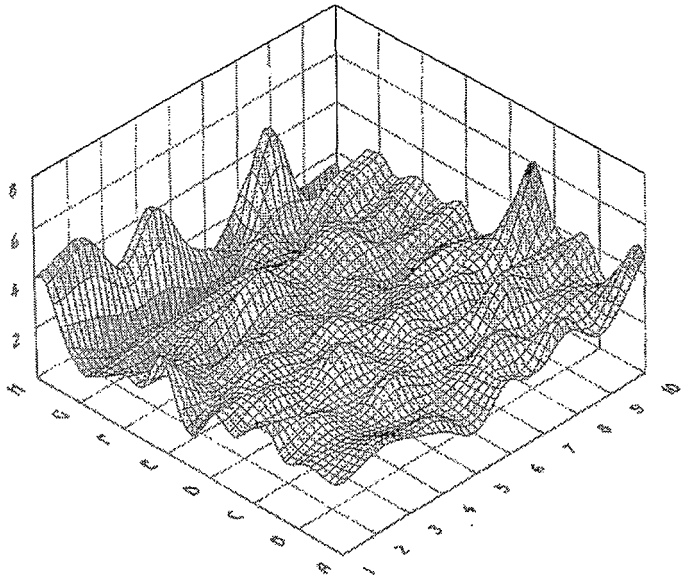


Fig.2. Distribution of Ra parameter on the surface of beech board before rolling

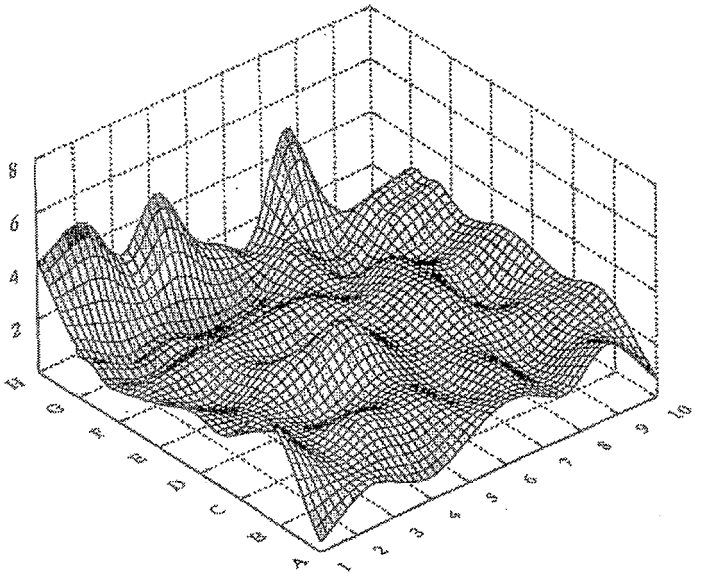


Fig.3. Distribution of Ra parameter on the surface of beech board after rolling

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Streszczenie: "*Stan powierzchni oklein z drewna brzozowego przed i po obróbce gorącymi walcami*". W rezultacie nagniatania wywartego przez gorące walce uzyskano znaczne wyrównanie powierzchni okleiny bukowej na płycie wiórowej. Uwidacznia to szczególnie obraz trójwymiarowy powierzchni elementów płytowych, na którym widać wyrównanie pofałdowań wynikających z budowy anatomicznej drewna. I choć niektóre wartości maksymalnych wierzchołków nierówności pozostają prawie bez zmian, to na całej powierzchni widać zanik dolin(wgłębień) – efekt uplastycznienia powierzchni i zapełnienia ligniną nierówności w porach drzewnych. Większego wyrównania należy oczekiwać przy zastosowaniu wyższych temperatur jak również większego zgniotu powierzchni przy walcowaniu.

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Surface roughness of wood beech after dressing with fixed planer knife

Grzegorz Wieloch , Milan Bansky

Abstract: During milling of wood the most frequently used method is tooth planing. To eliminate defects occurring during planing /for e.g. waviness/ a mechanical planing with stationary knife was introduced. Such a method of machining can be more widely used because of progress in tools preparation as well as materials for production process. With this method processed elements have no trace of waviness and smaller surface roughness than when tooth planned. The best results were obtained when the knife was fixed at 60-75^0 to grain flow /feed direction/ for both beech and pine wood. There was no trace of roughness on the machined surface. Dressing eliminates dust formation during machining.

Introduction

The finishing processes of wood surfaces require high quality of wood smoothness. This is caused among others by necessity of gaining ideal background for varnishing, natural and artificial veneering, at the same time minimalizing the usage of varnishes and lacquers. It also enables good adhering of linked surfaces by means of glue and influences the apperance of a given product. High quality of surface smoothness is required in the hi-tech of finishing, for example in coating with foil during so called dry method "Touchwood" [6].

It is necessary however to stress that the most important requirements according to surfaces are the aesthetical ones [1,4].

Dressing -Method of finishing

One of the ways of obtaining high quality of surface is usage of dressing. This way of planing has been well-known for ages and was popular in the times of benchwork that is leveling of surface and was called planing – fig.1. Draw knives up till now days were used when planing along fibres especially when it was without defects such as for eg. knots. However, they were displaced by machines with rotation tools. At the same time planing methods across fibres have been developed. As well as dressing across fibres of wood in production of (among others) veneers and fillets enabling production without loss (such as chips and dust). Cutting was performed with a knife moving in a reciprocating way or stationary knife fixed to machine frame during material movement. [3,7]. The above mentioned method of planing was developed by Japanese company MARUNAKA which introduced machines with a knife set in support between feeding and acceptance tables. The material is pressed and conveyed by band troop-carrier placed in front of the knife. The knife support having a shape disk has a possibility of changing location of knife according to feed direction of machined material. The above enables possibility of regulation of knife position according to features of planed material. There are two pssibilities of setting up the knife; either upper or lower – fig. 3. This type of machine wasn't widely used in woodworking industry as it unabled machining

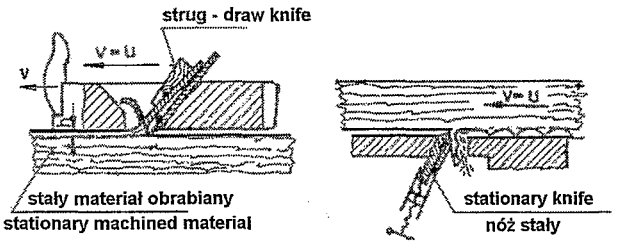


Fig.1. Scheme of dressing – planning /3/
Rys.1. Schemat skrawania płaskiego /3/

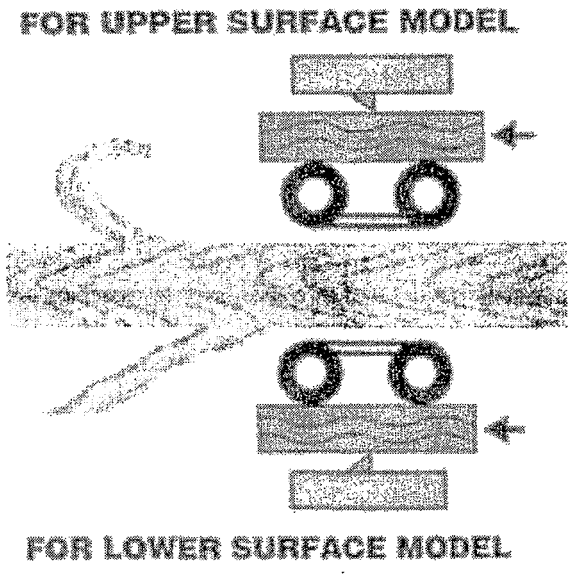


Fig.3 Principle of planers operation of MARUNAKA
Rys.3 Zasada pracy strugarek f-my MARUNAKA

material containing ranged density as well as machining of thick layers only from 0,04 to 0,1 mm. When a surface was very rough it had to be machined several times, which even at very high feed speed /75 m/min/ caused bottle-neck in technological process. Since wood started beeing high processed product so called EWP (Engineered Wood Products) creation of new groups of products and advance in their preparation enables revision of previous statements about their uselessness for European timber. [3,7]

Such elements are used in production of high quality windows and doors. Such products can be finished with dressing which eliminates sanding.

So it is very justified to research quality of surface after dressing.

Experiment

As the consequence of shown above advantages of processing ways a heated planning knife was used in surface processing. It planns a thin layer of wood and at the same time causes microburnishing plastified with heat of surface.

To support the assumptions a special knife carriage was made in which in cutter holder and plate clamp of the knife resistant heaters were situated The runner pressing wood before the knife was also heated. The runner was heated to heat wood surface before planning. Knife carriage was situated on the planning machine table after cutter block for tooth planning wood to come under the heated immovable knife [7]. During the research the following parameters were obtained:

During planning with heated planner knife the angles of knife parameters:
clearance angle $\alpha = 5^0$, included angle $\beta = 30^0$, angle of attack $\gamma = 55^0$
radial runot knifes 0,1 mm,
diameter rounding knife-edges $\rho = 5$ μm.

For cutting a knife with cements carbides H40 edge and with chipbreaker groove was used to eliminate a creation of interstice forwarding cutting. [2, 7].

The knife orientation towards feed direction of worked elements was variable: from ideally longitudinal to longitudinally – lateral. Directional angle of main cutting edge φ **r**, to direction of fibres was changed in the range from 90^0 to 30^0 with intervals every 15^0.

The working movement φ **r** . was compatibile with fibre direction in the material.

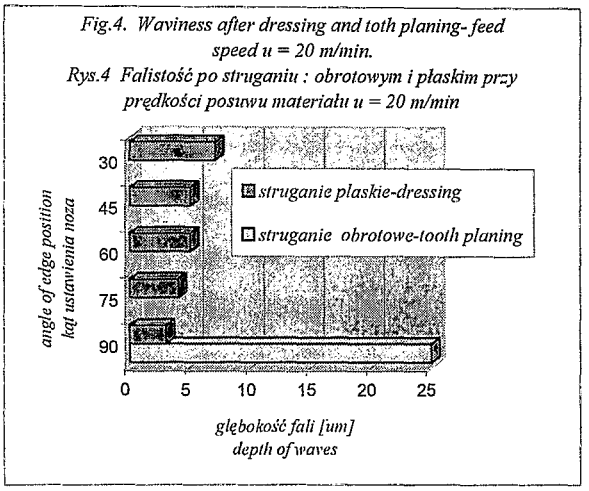


Fig.4. Waviness after dressing and toth planing- feed speed u = 20 m/min.
Rys.4 Falistość po struganiu : obrotowym i płaskim przy prędkości posuwu materiału u = 20 m/min

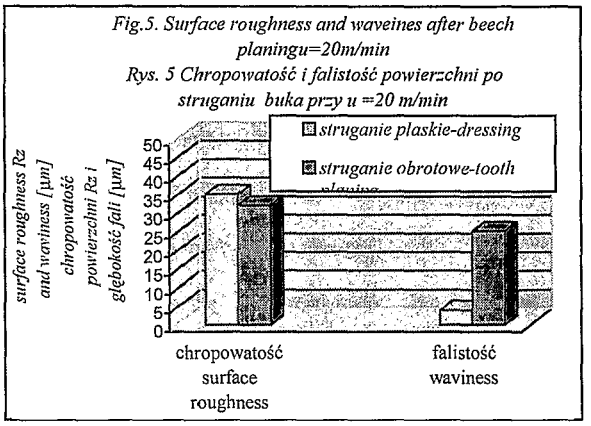


Fig.5. Surface roughness and waveines after beech planingu=20m/min
Rys. 5 Chropowatość i falistość powierzchni po struganiu buka przy u =20 m/min

The surface was examined with a contact method after planing. Surface roughness was measured by a profilographometer with computer programming support [8]. Research was conducted according to Polish Standards for surface roughness of wood and wood products [9].
The research was carried on beech wood /because of very equal anatomic structure and pine being very easily accessible / with moisture content of about 10 %. The worked samples annual rings were parallel to longer side of the sample.

Investigation results and discussion.

The research results are shown in fig. 4, 5 and 6. They show that decrease of directional angle of cutting edge φ_K causes decrease of value Rx.
For each cutting variant wood cutting with head enables obtaining better geometrical structure of surface than tooth planing.

Average differences between surface roughness values Rz as it is shown in fig. 4 are of 4 - 5 µm in the whole range of tested samples.
The best results were obtained at inclination angle of cutting edge from 50–60^0 which is caused by advantageous kinematics of cutting – softly emerging of the cutting edge in worked samples. It seems that in such case the interstice forwarding cutting is shaped in different way.

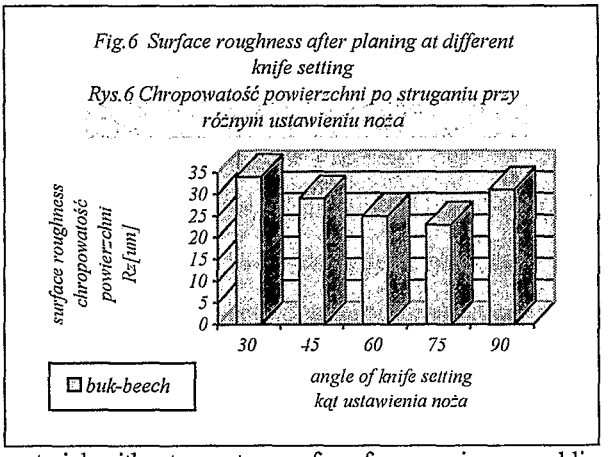


Fig.6 Surface roughness after planing at different knife setting
Rys.6 Chropowatość powierzchni po struganiu przy różnym ustawieniu noża

The greatest advantage of using this cutting method is obtaining material without any trace of surface waviness enabling obtaining high quality geometrical structure which doesn't require further sanding. The above is illustrated by surface roughness profile made by stylus method. The picture of profile

after dressing shows the lack of waviness which usually is a consequence of tooth planing. There was also lack of down and roughness on dressed surface.

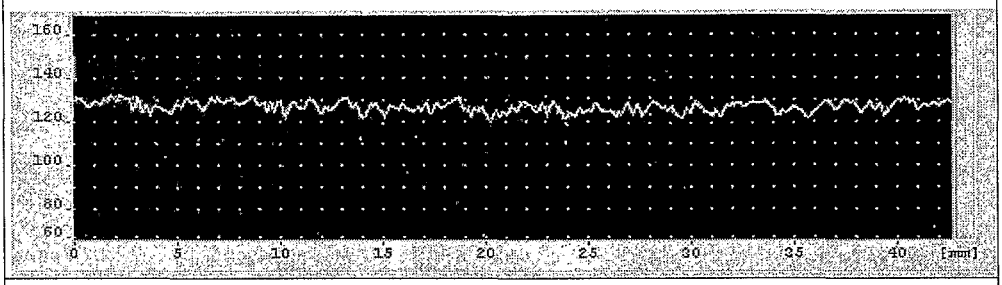


Fig.7. Examples of profilogrames of beech wood surface after tooth planing
Rys.7. Przykładowe profilogramy powierzchni drewna buka po struganiu nożem stałym

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Streszczenie: "*Chropowatość powierzchni drewna brzozowego po obróbce nożem stałym*". Przy obróbce powierzchni drewna dominuje metoda frezowania głowicami obrotowymi. Aby eliminować wady powstające w czasie obróbki /np. falistość / wprowadzono mechaniczne struganie nożem stałym. Sposób obróbki rozwinięty przez f-mę Marunaka, nie przyjął się w Polsce ze względu na np.:duże zróżnicowanie właściwości materiału drzewnego w jednym elemencie, znaczne wady w materiale –szczególnie iglastym, stosunkowo małą wydajność itp. W obecnym czasie może znaleźć szersze zastosowanie ze względu na postęp w przygotowaniu narzędzi jak również w przygotowaniu materiału do procesu obróbki /elementy z wyciętymi wadami, sklejone ze zorientowanymi włóknami/. W przypadku zastosowania strugania płaskiego uzyskuje sie elementy praktycznie bez śladu falistości i z mnieszymi chropowatosciami niz przy głowicach obrotowych. Najlepsze wyniki uzyskano przy ustawieniu noża pod katem ok 50-60^0 względem kierunku przebiegu włókien. Nie stwierdzono zbyt duzego wpływu prędkości strugania na chropowatość powierzchni.

Struganie nożem płaskim eleiminuje powstawanie frakcji pylastej jako odpadu dając wiór do ewentualnego wykorzystania technologicznego.

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Mechanical properties in bending of medium density fibreboard as heterogeneous material

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Abstract: Investigations of the modulus of elasticity in bending and the bending strength of the medium density fibreboard layers are presented. It was found out that these properties for the core layer amounted to only about 40% of those for the surface layer. The relative difference of the density of the compared layers was much smaller.

Key words: MDF, layer, bending strength, modulus of elasticity.

Introduction

Medium density fibreboard (MDF) is widely used in furniture. Typical commercial MDF is heterogeneous material. The vertical density profile of this MDF is not uniform but has a shape of a U-letter. The density of the surface layers is high, while the core layers within the board is low. That is why the MDF is characterised by good performance in bending (Tydryszewski and Wilczyński 2001). The vertical density profile influences board properties, among others on the modulus of elasticity (Xu 1999) and the internal bond (Schulte and Fruhwald 1996).

The MDF is monolithic material but can be regarded as a hypothetical three-layer panel. In this case it consists of a low density core layer and two high density surface layers. Mechanical properties of such layers of the MDF have not been studied yet. The knowledge of these properties is needed to the analysis of stress in the construction members made of the MDF, and to application of the layered systems bending theory (Bodig and Jayne 1982).

Studies on mechanical properties of the layers of wood based panels have been carried out in the Institute of Technology at Bydgoszcz University for a few years. An earlier paper (Kociszewski et al. 2002) presented the results of the experiments of bending properties of particleboard layers. The objective of this study was to determine the modulus of elasticity in bending as well as the bending strength of the surface and core layers of the MDF.

Methods

Raw commercial MDF was used in this study. It was 18 mm thick, its density averaged 760 kg/m^3, and moisture content averaged 7%.

Strips of layers were isolated from the board using appropriate mechanical processing. The surface layers were 2 mm thick and the core layer was 12 mm thick. Thirty specimens for both kinds of a layer were prepared. Both the modulus of elasticity in bending and the bending strength were fixed in accordance with the procedures described in EN 310 standard.

Results

The results – mean values and variation coefficients of the modulus of elasticity in bending, the bending strength, and the density of the examined layers of the MDF are given in Table 1. The comparison of these values is shown in Fig. 1. The values of the surface layer properties were assumed to be the basis for this comparison. Both the modulus of elasticity and the bending strength of the core layer are much smaller. They amount to only 42.7% and 35.7%, respectively. The relative difference of the density of the surface and the core layer is much smaller. The density of the core layer amounts to 70.4% of that of the surface layer.

Table 1. Modulus of elasticity and bending strength of the surface and core layer of tested MDF

Assumed layers of MDF	Density		Modulus of elasticity in bending		Bending strength	
	mean value [kg/m^3]	variation coefficient [%]	mean value [MPa]	variation coefficient [%]	mean value [MPa]	variation coefficient [%]
surface layer	966	0.8	5180	2.7	51.8	4.6
core layer	680	2.6	2210	8.0	18.5	11.9

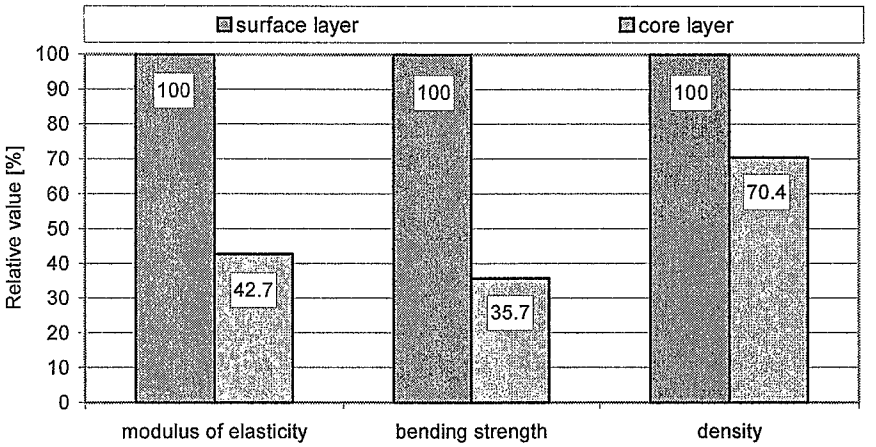


Fig. 1. Comparison of the mechanical properties in bending and the density of the surface and core layer

The next comparison of mechanical properties in bending of the assumed layers of the MDF is connected with their density (Fig. 2). The ratio of the elasticity modulus to the density for the surface layer is 1.65 times bigger than for the core layer. Similarly, the ratio of the bending strength to the density is 2.0 times bigger for the surface layer. These comparisons show that the mechanical properties of the assumed layers of the MDF are not proportional to their density. The properties of the surface layer are higher than those expected to be the result of its density.

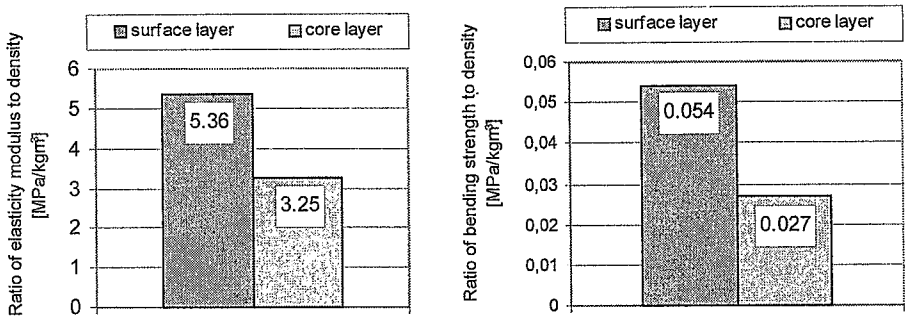


Fig. 2. Comparison of the ratio of the mechanical property to the density for the surface and core layer

Conclusions

1. Typical commercial MDF is characterised by sharp differentiation of the mechanical properties of the hypothetical layers: the surface and the core ones.
2. The modulus of elasticity in bending and the bending strength of the core layer amount to only about 40% of those of the surface layer.
3. The relative difference of mechanical properties of the MDF layers is bigger than the relative difference of their density.

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Streszczenie: *Właściwości mechaniczne przy zginaniu płyty pilśniowej o średniej gęstości jako materiału niejednorodnego.* Przedstawiono badania modułu sprężystości przy zginaniu i wytrzymałości na zginanie warstw płyty MDF. Stwierdzono, że właściwości warstwy wewnętrznej osiągają jedynie około 40% właściwości warstw zewnętrznych. Względna różnica gęstości porównywanych warstw jest znacznie mniejsza.

Technical quality of Polish softwood round timber in the light of European standards

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Abstarct: Process of integration of Poland with European Union influences on establishing standards harmonized with European standards.
In the near future a prospective standards for provisional application will be implemented for softwood round timber.
The Forest Research Institute conducts research on consequences of eventual application of European standards for pine. Initial results show almost entire elimination of higher-grade timber (A and B) even in stands with the present big share of veneer wood.

Keywords: timber, timber classification, standardization, European standards.

Overview

Standards for softwood round timber had been definitely changed nine years ago. Up to 1993 destination classification was in force in Poland. On 1 July 1999 a new system, so-called KJW, taking into account quality and dimension of timber was introduced. System took into consideration structure and quality of Polish stands, applied technologies of harvesting and transportation of timber as well as harmonization with international standards (ISO) and German standards (DIN). European standards were not elaborated at that time; they started to appear in the second half of nineties. Polish Standardization Committee, having regard to all required procedures of standard elaboration, respectively enforced standards implemented in European Union.

In 1999 first standards harmonized with European standards were implemented in Poland. Apart from general standards concerning, among others, terms and measurements of features, several standards determining qualitative classification of round wood were elaborated. These are standards for oak, beech, poplar, ash, maples and sycamore. For the coniferous species only one standard specifying dimension of raw material was established. This standard (PN-EN 1315-2) is grading timber into ten dimensional classes according to diameter and four dimensional classes according to length.
On 3 December 1998 CEN (European Committee for Standardization) approved European prestandard (ENV) as a prospective standard for provisional application. The period of validity of this ENV was initially limited to three years, but later was increased to five years. Introducing of ENV permits to keep national standards, in parallel to ENV, until the final decision about converting ENV into EN will be reached.

Taking into account the species composition of Polish stands, where pine is dominant, as well as consignee's expectations The Standardization Forest Economy Task Committee No 181 undertook works (now close to finalization) on implementing also in Poland, on above mentioned principles, European prestandards for softwood round timber.
The Forest Research Institute conducts comparative analyses of Polish standards (PN) for pine round timber against European standards (PN-EN). The essential difference between standards is a system difference. European standards for round timber, for pine also, are standards for logs only. Standard applied in Poland (PN-92/D-95017) is so-called long wood standard, where butt part decides about the quality. In Polish Standard (PN-93/D-9500) raw material is graded into three classes according to diameter.

Comparative analyses are conducted on entire territory of Poland. In this paper only results from three sample plots located in RDLP Szczecinek are presented (see Table 1).

Quality of stand 1 is approximate to average while the quality of two others (stand 1and stand 3) is very high.

Table 1. Sample stand characteristics

Characteristics	Stand No		
	1	2	3
Site	BMśw	LMśw	LMśw
Age	100	165	150
Stand density index	0.9	0.8	0.8
Canopy density	moderate	discontinuous	discontinuous
Site index	II.5	I	I.5
Stand quality	3	2	3

Research results

On each sample plots raw material in a form of long wood was classified according to PN-92D-95017 and PN-ENV 1927-2 and additionally to technical specifications elaborated in DGLP (Directorate-General of State Forests). Achieved percentage share of qualitative classes of pine round timber are presented on Fig. 1-3.

Classification of timber by currently applied standards (KJW) in stand 1 contributed to identification of 17.03% of class WB timber and 82.97% of class WC. Identical results were achieved when using DGLP technical specifications. Classification of the same timber by European Standard resulted in 0.81% of class B 90.34% of class C and 8.85% of class D.
As a result of classification by Polish Standard in stands of high quality (stand 2 and stand 3) following data were obtained: 39.59-46.72% of class WA, 38.40-38.93% of class WB and 14.88-21.48% of class WC. In classification by DGLP technical specifications the share of lower classes (C and D) was increased by 10%: 40.50-43.66% of class WA, 28.52-35.74% of class WB, 13.99-20.43% of class WC and 6.61-10.55% of class WD. Incomparable worse results were obtain when raw material was classified according to European Standard. Only 2.42-3.60% of timber was of higher classes. Majority of timber, 78.88-82.59%, was classified in class C and rest of it, 13.81-18.70% in class D.

Introduction of "technical specifications", first of all limiting or even eliminating admission of rot, has not significant influence on classification results. Almost revolutionary change, consisting in almost eliminating higher classes, caused applying of European classification.

Most frequent reason behind class decrease of timber classified by European standard was higher requirements regarding buckles. Polish standard permits in class WA buckles with height up to 1 cm and in class WB even higher on half of circumference. Buckles are not permitted in classes A and B of ENV. It results in "moving" of significant amount of timber classified in classes WA and WB to classes C and D. The second reason for class decrease were requirements of European standards regarding permitted diameters of knots. PN permits knots in classes WC and WD. In ENV in class C only intergrown, sound knots are permitted. Permitted diameter for dead knots is 7 cm and 5 cm for unsound knots. In consequence certain amount of timber, classified by PN to class WC, "moved" to class D. Other characteristics mentioned in ENV have not significant influence on classification results.

Table 2. Comparison of significant requirements regarding pine round timber in Polish and European standards

Characteristics		PN (KJW)				ENV-2: 1998			
		A	B	C	D	A	B	C	D
Minimal length (m)		2,7	2,7	2,7	2,7	3,0	3,0	3,0	3,0.
Minimal nominal diameter, over bark (cm)		35,0	25,0	unlimited	unlimited				
Minimal top diameter, under bark (cm)		22,0	14,0	14,0	14,0				
Knots (cm)	Intergrown, sound.	not permitted	not permitted	permitted	permitted	not permitted	≤ 5	permitted	permitted
	Dead					not permitted	≤ 4	≤ 7	permitted
	Unsound					not permitted	not permitted	≤ 5	permitted
Buckles (mm)-		Knots with height up to 1 cm are not considered, higher knots: not permitted	permitted on ½ circumference	permitted	permitted	not permitted	not permitted	permitted	permitted
Smallest length of butt part without defects or with permitted defects		4 m	4 m	unlimited	unlimited				
One-side sweep (cm/m)		Permitting to produce a log 2.7 m long: 2cm/1m	3cm/1m	3cm/1m	8cm/1m	≤ 2	≤ 2	≤ 4	≤ 6
Shakes	Heart shakes < 35 cm(except dry shakes) ≥ 35cm					not permitted ≤ ¼ ø.	not permitted ≤ 1/3 ø.	≤ 1/2 śr.	permitted
	Ring shakes < 35cm ≥ 35cm					not permitted ≤ ¼ ø	not permitted ≤ ¼ ø	not permitted ≤ 1/3 ø	permitted
	Dry shakes	permitted with width up to 3mm	permitted	permitted	permitted	not permitted	not permitted	permitted	permitted
	End shake	Up to 1/5 ø	Up to 1/3 ø	permitted	permitted				
	End-side shake, deep and passing	not permitted	not permitted	not permitted	permitted				
Insect attack - < 3 mm (e.g.: *Trypodendron lineatum*) - ≥ 3 mm (e.g.: *Sirex, Cerambyciden*)		not permitted	not permitted	Permitted except *Trypodendron lineatum*	permitted	not permitted	not permitted	not permitted	permitted

Tabela 2. (contined).

Rot	Inner rot	up to 1/5 of end diameter	up to 1/3 of end diameter	up to 1/3 of end diameter	up to 1/2 of end diameter	not permitted	not permitted	not permitted	permitted
	Surface rot	not permitted	not permitted	on ¼ of circumference up to 1/5 ø.	permitted				
	Stem rot (fungus)	not permitted	permitted in 2 whorls, at distance from butt end no longer than 6 m	permitted in 3 whorls	permitted				
Foreign bodies		not permitted			permitted				
Stain	Blue stain	not permitted	permitted on cross-sections up to 1/8 of sapwood area	permitted	permitted	not permitted	not permitted	permitted[1]	permitted
	Brown stain	not permitted	not permitted	permitted on cross-sections up to 1/2 of sapwood area	permitted				
Spiral grain		up to 5cm/1m	permitted	permitted	permitted	≤ 3	≤ 7	unlimited	unlimited
Gall		permitted	permitted	permitted	permitted				
Resin pocket						not permitted	1 per section	permitted	permitted
Rate of growth (mm) - Scotch pine						≤ 4	≤ 6	unlimited	unlimited
Features of timber - Excentric pith (%) - Reaction wood (%) - Taper[2] (cm/m) < 35 cm ≥ 35 cm						10 not permitted unlimited unlimited	20 10 ≤ 1,5 ≤ 2	unlimited 30 unlimited unlimited	unlimited unlimited unlimited unlimited

[1] – Permitted in sapwood area only
[2] – Mid-diameter, under bark

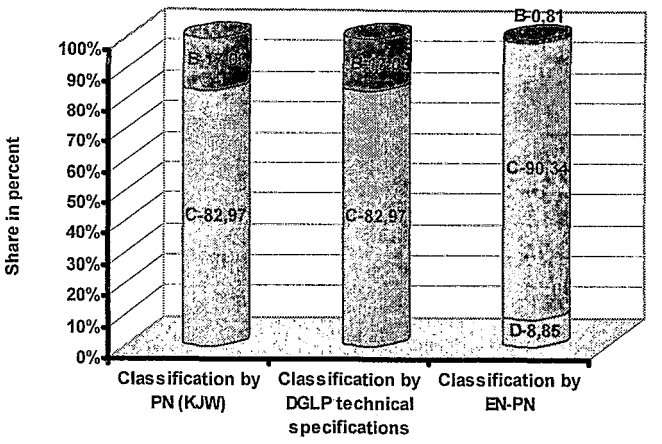


Fig. 1 - Percentage share of qualitative classes of pine timber. Stand No 1.

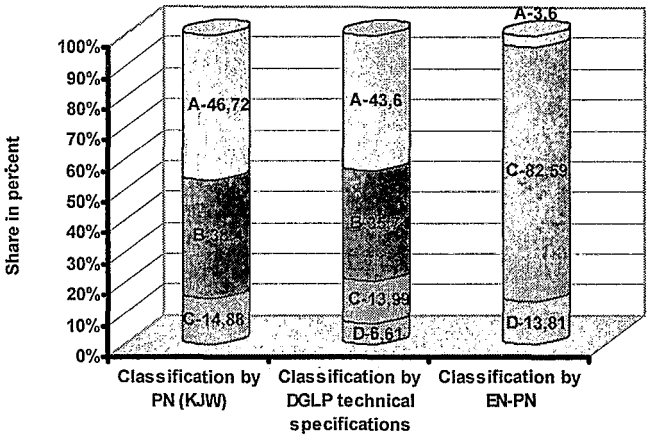


Fig. 2 - Percentage share of qualitative classes of pine timber. Stand No 2.

Versuchsmaterial

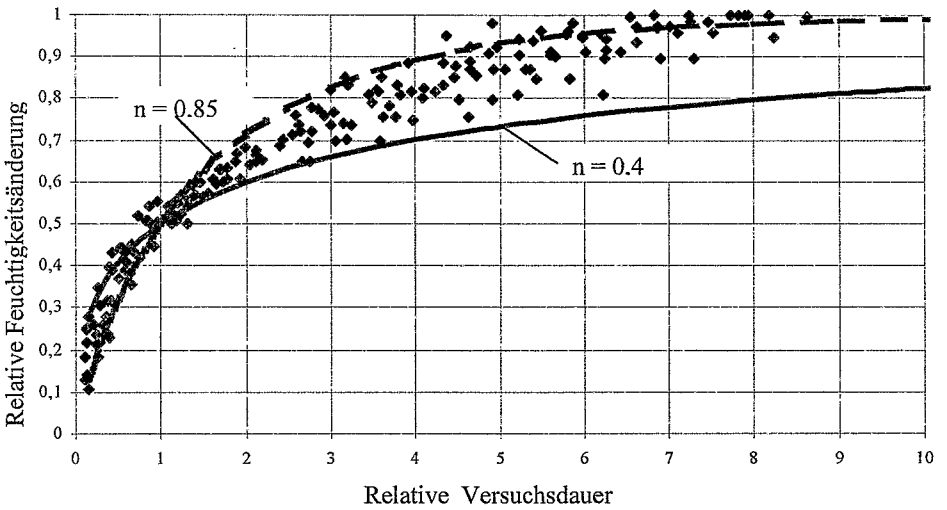
Für die Untersuchungen wurden, ebenso wie im Fall der Adsorptionsänderung der Feuchtigkeit, [Domański 2001] Eichenparkettbrettchen verwendet, die im normalen Produktionszyklus hergestellt worden waren. Von den im Warenlager mit einem der Gleichgewichtsfeuchte von Holz entsprechenden Klima (7-9%) gelagerten Brettchen wurden wahllos 10 Stück der Güteklasse I mit Abmessungen von 200x60x22 mm entnommen.
Untersuchungsmethodik

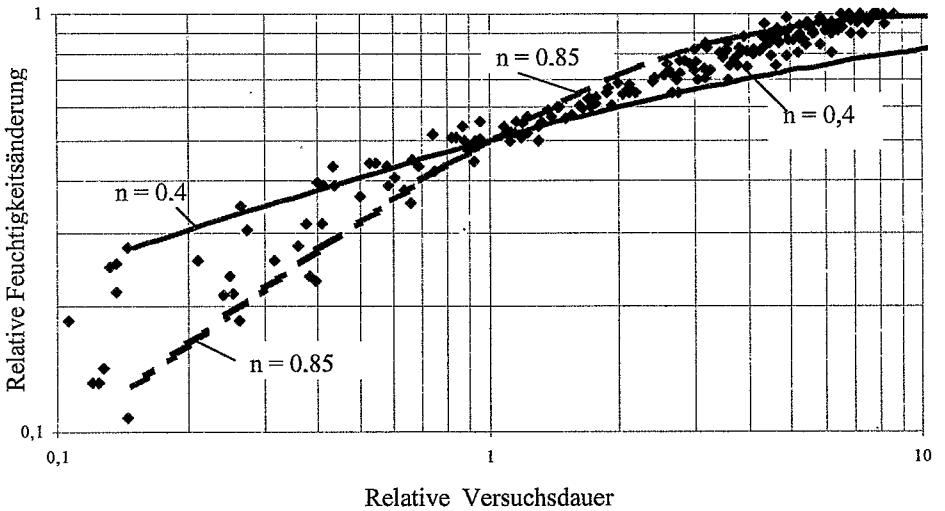
Nach dem Wiegen (Genauigkeit ± 0,1 g) wurden die Brettchen in einen Exsikkator mit gesättigter wässriger CH_3COOK-Lösung gegeben, der sich in einem Raum mit einer Temperatur von 21-26°C (durchschnittlich 24,7 ± 1,73°C) und einem Temperaturvariationskoeffizienten v= 9,78% befand. Bei dieser Temperatur betrug die relative Luftfeuchtigkeit im Exsikkator 18,8 ± 0,59°C. Diesem Klima entspricht die Gleichgewichstfeuchte des Holzes, die nach Krjetschetow [1980] 4,6% beträgt, d.h. ebenso viel, wie im Winter unter erträglichen Bedingungen in Wohnräumen [Domański, Matejak, 2000].
In regelmäßigen Zeitabständen wurden die Brettchen gewogen, eine zeitlang in Tagesabständen und nach Verringung der Masseabnahme alle zwei und vier Tage. Die Brettchen verblieben so lange im Exsikkator, bis sich nach 12 Tagen ihre Masse nicht mehr verändete. Anschließend wurde nach der Darrmethode die End- und Anfangsfeuchtigkeit der Brettchen bestimmt. Nachdem die als Gleichsgewichstfeuchte angenommene Anfangs- und Endfeuchtigkeit bekannt war, wurden die Halbwertzeiten $Z_{0,5}$ für die einzelnen Brettchen bestimmt. Als die Halbwertzeiten und die Zeiten, nach denen die Masse der Brettchen um 0,1 g ($\Delta u \approx 0{,}99\ \Delta_{max}$)
höher war als die Endmasse, bekannt waren, wurden die Werte der Koeffizienten n bestimmt.

Untersuchungsergebnisse und ihre Analyse

Die Anfangsfeuchte betrug zwischen 6,2 und 8,8%, die Durchschnittsfeuchte folglich 7,17% ± 0,68%, der Variationskoeffizient betrug 13,20%
Die Endfeuchte lag zwischen 4,9% und 5,8% , die Durchschnittsfeuchte betrug also 5,35% ± 0,22%, der Variationskoeffizient 5,80%.. Die nach der Regressionsgleichung berechneten Halbwertzeiten betrugen 6,9-8,3 Tage, im Durchschnitt also 7,52 ± 0,33 Tage bei einem Variationskoeffizienten von 6,04%.
Die Zeiten bis zum Erreichen der Gleichgewichstfeuchte betrugen 5-65 Tage, im Schnitt 58,6 ± 4,46 Tage bei einem Variationskoeffizienten von 10,65%, sie waren 6,6-9,0 mal länger als die Halbwertzeiten, durchschnittlich 7,8 mal.
Die Potenzexponenten betragen 0,50-0,83, im Schnitt 0,657 ± 0,071 bei einem Variationskoeffizienten von 15,19 %.
Die durchschnittliche Halbwertzeit bei der Desorptionsänderung der Feuchtigkeit von 7,52 Tagen ist um 2,32 Tage länger als die mittlere Halbwertzeit (5,20 Tage [Domański 2001]) bei der Adsorptionsänderung der Feuchtigkeit der untersuchten Parkettbrettchen. Die mittlere Zeit des Erreichens der Gleichgewichtsfeuchte bei der Desorptionsänderung der Feuchtigkeit von 58,6 Tagen ist um 5,7 Tage kürzer als die mittlere Zeit (64,3 Tage [Domański 2001]) bei der Adsorptionsänderung der Feuchtigkeit der untersuchten Parkettbrettchen.
Die erzielten Ergebnisse zeichnen sich durch einen größeren Variationskoeffizienten als bei der Adsorptionsänderung der Feuchtigkeit aus.
Die Abhängigkeit der relativen Feuchtigkeitsänderung von der relativen Versuchsdauer zeigen die Abbildungen 1 und 2.

Relative Feuchtigkeitsänderung : $\frac{u - u_A}{u_{GL} - u_A}$; relative Versuchsdauer $Z/Z_{0,5}$





Schlußfolgerungen

Aus der Analyse der Untersuchungsergebnisse der Geschwindigkeit der Feuchtigkeitsänderungen der Brettchen bei der Desorption und Adsorption können folgende Schlüsse gezogen werden.

1. Die mittlere Zeit des Erreichens der Gleichgewichtsfeuchte bei der Desorption ist etwa 9% kürzer als bei der Adsoption.
2. Die mittlere Halbwertzeit ist bei der Desorption etwa 45% länger als bei der Adsorption.
3. Die Parkettbrettchen können nach Unterbringung in einem Wohnraum im Winter (Desorption) bzw. im Sommer (Adsorption) bereits nach 5-8 Tagen ihre Feuchtigkeit um 1,5-3,5% ändern.

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Die Wirksamkeit der Brandschutzbehandlung von Holz mit dem Antipyrin „Ogniochron"

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Abstract: Im Artikel wurden die Untersuchungen über die Eigenschaften eines in Polen hergestellten Brandschutzmittels dargestellt.

Schlüsselwörter: Holz, Brandschutzmittel, Antipyrin,

Ziel der vorliegenden Arbeit war die Untersuchung der Wirksamkeit des Brandschutzmittels „Ogniochron" , eines Antipyrins auf der Basis von Ammoniumphosphaten und Ammoniumsulfaten mit Zugabe von Harnstoff und Borverbindungen. Es wirkt durch Wärmeentzug und Herabsetzung des Sauerstoff- und der Brenngasgehalts in der Brandzone. Abgesehen von der Brandschutzwirkung des Mittels schützt es das Holz auch vor Hauspilzen und Insekten.
Zur Untersuchung wurden Proben von 10x10x150 mm aus Kiefernsplintholz (Pinus silvestris L.) verwendet. Sie wurden parallel zum Jahrringverlauf geschnitten. Ihre Dichte betrug durchschnittlich 524 kg/m^3, die Holzproben hatten einen mittleren Frühholzanteil (ca. 60%) und einen mittleren Jahreszuwachs (2-5mm). Die Feuchtigkeit betrug 6,3%. Es wurden 10 Kontrollproben (nicht imprägniert) und 10 in der Antipyrinlösung (Konzentration 4%, 6% und 8%) getränkte Proben verwendet.
Vor dem Tränken wurde an den Proben eine Öffnung von ∅ 3 mm in 10 mm Entfernung vom Probenrand angebracht. Anschließend wurden die Proben geschliffen und mit einer Genauigkeit von 0,01 g gewogen.
Die Impragnation der Proben erfolgte nach dem Druck-Vakuum-Verfahren. Der Druck bei der Tränkung betrug 130 hPa (± 10 HpA), die Tränkungszeit 15 min. Diese Parameter gewährsleisteten eine vollständige Tränkung der Holzproben mit der Antipyrinlösung. Die Lösung hatte eine Antipyrinkonzentration von 4%, 6% und 8%. Nach dem Tränken wurden die Proben erneut mit einer Genauigkeit von 0,01 g gewogen.
Die Menge des vom Holz aufgenommenen Antipyrins P (in kg/m3), umgerechnet auf 1 m^3 betrug demnach

$$P = \frac{(m_2 - m_1) \cdot s}{100 \cdot V_P} \qquad \text{..... (1)}$$

m_1 –Probenmasse vor dem Tränken [kg]
m2 – Probenmasse nach dem Tränken [kg]
s – Konzentration der Antipyrinlösung [%]
Vp – Probenvolumen [m3]
100 – Konversionsfaktor

Nach der Feststellung des Imprägnationsgrades wurden alle Proben 4 Wochen lang im Labor saisoniert.
Die Apparatur zur Untersuchung der Brandschutzeigenschaften des Antipyrins (Abb. 1) [Lutomski 1986, Osipiuk 2001] bestand aus einem Rohr (1) von 50 mm Durchmesser und einer Länge von 165 mm. Dieses Rohr hängt an einem Rahmen (5) derart über einem Gasbrenner (2), daß der obere Rand des Gasbrenners sich in einer Entfernung von 15 mm vom Rohrende befindet. Die Probe (3) hängt so an einem Bolzen (4), daß ihr unteres Ende 5 mm aus dem Rohr herausragt. Die Flammenhöhe wurde auf 40 mm eingestellt. Das Gas strömte über einen Gaszähler (6) mit Druckstabilisator (7) zum Brenner.

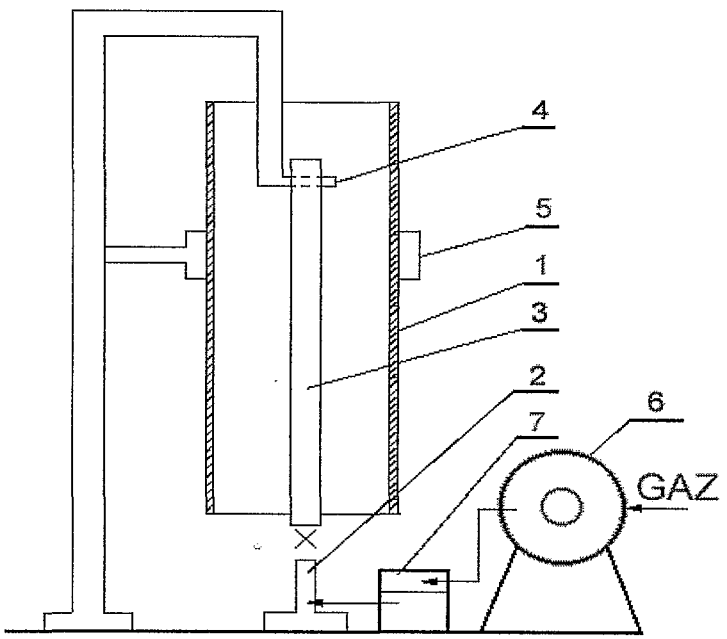


Abb. 1. Prüfanordnung zur Untersuchung der Wirksamkeit des Antipyrins (Erläuterungen im Text)

Nach der Lagerung vor der Untersuchung der Brandschutzwirkung des Imprägniermittels wurde jede Probe mit einer Genauigkeit von 0,01 g gewogen, um ihre Masse vor dem Verbrennen zu bestimmen. Anschließend wurde die Probe in der Prüfapparatur untergebracht und der Gasbrenner angezündet.
Die Einwirkungszeit der Flamme betrug 60 s. Nach Entfernung des Gasbrenners wurde die Zeit des selbständigen Brennens der Probe und die Zeit des Glimmens im Anschluß an das selbständige Brennen notiert. Nach Aufhören des Glimmens wurde die Probe aus dem Halter genommen und nach dem Erkalten gewogen.
Die Wirksamkeit des Brandschutzimprägnats wurde anhand des Masseverlusts der Proben beim Verbrennen festgestellt. Der Masseverlust wurde nach folgender Gleichung berechnet.

$$\Delta M = \frac{m_p - m_k}{m_p} \times 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

ΔM -Masseverlust der Probe [%]
m_p -Masse der Probe vor dem Verbrennen [g]
m_k -Masse der Probe nach dem Verbrennen [g]
Es wurde angenommen, daß das Antipyrin als wirksam gelten kann, wenn der Masseverlust der Probe 20% nicht übersteigt, das selbständige Brennen 30 s und das Glimmen der Probe nach dem Erlöschen der Flamme ebenfalls 30 s nicht übersteigt. Die Zeit des Brennens und des Glimmens sind Parameter, die die Wirksamkeit des Bransdschutzes des Holzes zusätzlich bestimmen.
Die Untersuchungsergebnisse der Antipyrinwirkung sind in Tab. 1 und in den Abb. 2 und 3 dargestellt.

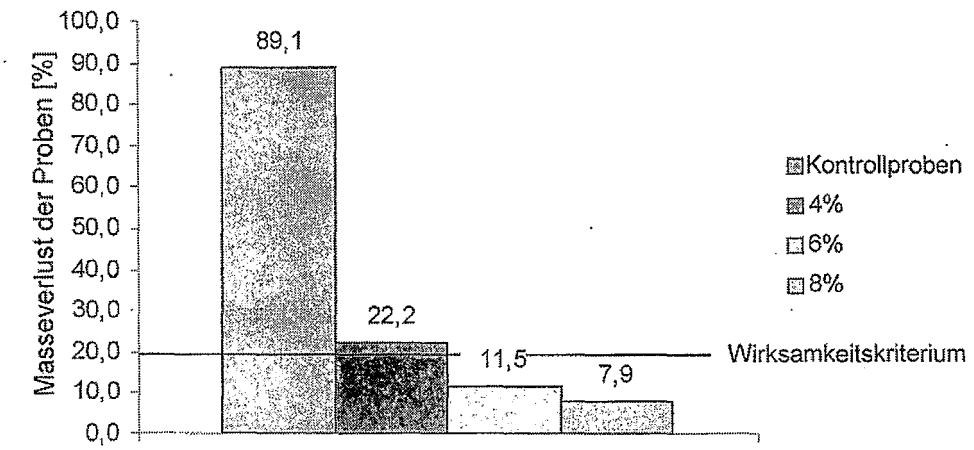


Abb. 2. Untersuchungsergebnisse der Wirksamkeit des mit der Antipyrinlösung „Ogniochron" getränkten Holzes.

Tab. 1. Untersuchungsergebnisse der Brandschutzwirkung des Antipyrins „Ogniochron „ bei Holz.

Antipyrin-konzentration [%]	Menge des aufgenommenen Antipyrins			Beurteilung des Brandschutzes			Zeit des selbständigen Brennens [s]	Zeit des Glimmens [s]	Wirksamkeits-kriterium
	[kg/m^3]	Standardab-weichung [kg/m^3]	Variations-koeffizient [%]	[%]	Standardab-weichung [kg/m^3]	Variations-koeffizient [%]			
Kontroll-proben	-	-	-	89,1	2,86	3	77	217	-
4	23,62	1,66	7	22,2	2,83	12	48	7	unwirksam
6	38,28	1,55	4	11,5	1,65	14	10	0	wirksam
8	52,66	1,96	4	7,9	1,1	13	2	0	wirksam

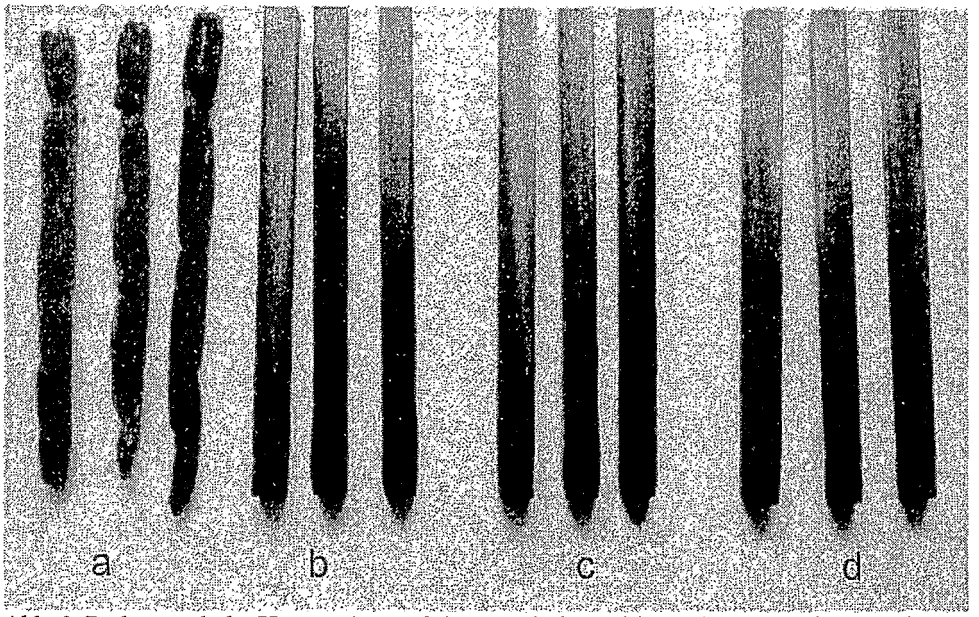


Abb. 3. Proben nach der Untersuchungs d der Brandschutzwirkung des Antipyrins „Ogniochron" (a- Kontrollproben, b- 4%, c- 6%, d – 8%)

Anhand der erfolgten Untersuchungen kann festgestellt werden:
Das untersuchte Antipyrin mit dem Handelsnamen „Ogniochron", das hauptsächlich aus Ammoniumphosphaten und Ammoniumsulfaten besteht, gewährleistet den wirksamen Brandschutz von Holz nach dessen Tränkung mit 38,3 kg/m^3 Antipyrin , d.h. nach der Imprägnierung des Holzes mit einer 6-prozentigen Antipyrinlösung.

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STRESZCZENIE

Praca poświęcona została badaniu skuteczności zabezpieczenia przeciwogniowego drewna solnym antypirenem „Ogniochron". Badania dokonane na drewnie sosnowym pozwoliły stwierdzić, że antypiren „Ogniochron" składający się głównie z fosforanów i siarczanów amonu skutecznie zabezpiecza przeciwogniowo drewno przy wprowadzeniu do niego 38,3 kg/m3 antypirenu, czyli przy nasyceniu drewna roztworem antypirenu o stężeniu 6%