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Effect of structure of laminated wood on bending strength after cyclic loading

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Abstract: *Effect of structure of laminated wood on bending strength after cyclic loading.* Laminated wood is particularly suitable for the production of seating and bedding furniture, for its suitable properties. The work is focused on the changes of the bending properties of laminated wood from beech and poplar veneers after its dynamic loading by cyclic bending. As we increase the number of cycles, we notice a decrease in flexural strength, a slight increase in flexural modulus, and a decrease in the number of cycles. Also the increase in the minimum bending radius as well as the flexural coefficient.

Keywords: laminated wood, beech, poplar, cyclic bending, bending strength, modulus of elasticity

INTRODUCTION

The incentive for the development and production of wood-based construction materials was to obtain material with better properties than solid wood. This area also includes the development and production of veneer-based laminates. One representative of these materials is laminated wood used in a wide range of products. For its good mechanical and aesthetic properties, veneer-based laminated wood, is widely used in furniture production (Fekiač 2016, Fekiač and Gáborík 2016, Gáborík and Vilhanová 2016, Dudas and Vilhanová 2013, Langová et al. 2013). The basic component is veneer obtained by stripping or slicing, which is applied in natural form or is suitably modified (Bekhta et al. 2017, Zemiar and Fekiač 2014, Zemiar et al. 2014). Modification improves the technical or aesthetic properties of the veneers (Bekhta et al. 2012, Fekiač et al. 2015, Fekiač et al. 2016, Langová and Joščák 2014, Slabejová and Šmidriaková 2014, Slabejová et al. 2017).

Laminated wood can be made by layering and gluing a variety of thin wood lamellas together. The lamellas are either of one type wood or of several types of wood, with the orientation of the wood fibres in the longitudinal direction (Figure 1) (Aydin et al. 2004, Eckelman 1993, Zemiar *et al*. 2009).

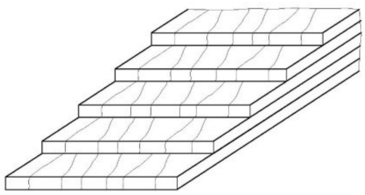


Figure 1. The longitudinal direction of the wood fibres in the layers of laminated wood (Joščák et al. 2014).

Laminating is considered as a technology that greatly enhances the woody raw material while also allowing to change wood properties (Zemiar and Kotrady 1999, Gáborík and Dudas 2008, Gaff and Gáborík 2014, Eckelman 1993).

According to the use in the manufacture of furniture, different requirements are imposed on wood materials. In specific cases, in addition to strength properties is also places emphasis on the elasticity, durability and shape. This is especially about specific pieces of bed and seating furniture. The task of these parts is to ensure adequate and time-stable user comfort (Zemiar et al. 2009). Different technical and aesthetic requirements are met by a suitable combination of lamellar wood layers and possibly by shaping of wood. Laminated wood is characterized by very good mechanical properties and dimensional stability (Svoboda et al. 2015). In three-layered aspen laminated wood, an increase in mechanical properties was achieved by 9 ÷ 23% compared to solid wood (Gáborík et al. 2011).

The beech wood (*Fagus sylvatica L*) is the most widespread wood in Slovakia with a share of about 32% (www.forestportal.sk, 2014). The most commonly used material in furniture production is beech wood (Zemiar et al. 2000).

Similarly, it is possible to change the aesthetic appearance, where the inner layers are from less striking woods and on the surface are veneers of exotic woods (Gáborík 2012). In our work we focused on lamellar wood made of veneer of beech and poplar veneer, which allowed a certain reduction in weight, compared to lamellar wood made only of beech veneer.

In addition to suitable wood, the properties of the laminated wood are also affected by the adhesive used. Urea formaldehyde (UF), phenol-formaldehyde (PF), melamine-formaldehyde (MF) and polyvinyl acetate (PVAc) adhesives are used. From point of view a healthy environment, PVAc adhesives are gradually being applied in wood products (Gáborík 2013, Gáborík et al. 2016, Svoboda et al. 2015, Šmidriaková et al. 2015, Joščák at al. 2015).

From the viewpoint of the user, besides the strength and aesthetics properties of the bed and seating furniture, is interesting also durability, i.e. life-time of the furniture as a whole or some of its components. That is why we have focused on monitoring the bending properties of laminated wood after its cyclic loading, which we can consider as a suitable representative of durability. Bending properties were investigated on a laminated wood made from beech and poplar veneer in the rate of 3:2. The orientation of the fibres was in each layer in the direction of the longer dimension, the layers was glued by the PVAC adhesive. By comparing the observed properties before and after cyclic loading, we determined the effect of cyclic bending stress on changing its properties.

MATERIALS AND METODS

The basic material was the veneers made of beech wood (*Fagus sylvatica L.*) and poplar (*Populus tremula L.*); veneers have a thickness of 2 mm. The Technobond D3 polyvinyl acetate (PVAc) coated by 190g/m^2 was used. The pressing operation was performed in a single-stage press at a temperature of T = 20 ° C, a pressing pressure of 0.8 MPa and a pressing time of 25 min. This produced laminated wood was composed of 5 layers of veneers with a parallel direction of the wood fibres of each layer with alternating beech and poplar veneers (Figure 2).

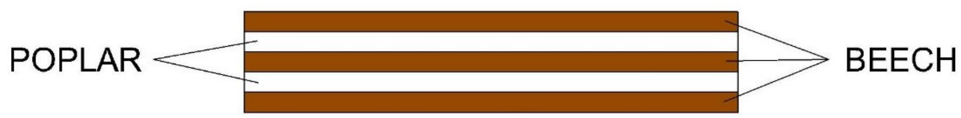


Figure 2. Layering of beech and poplar veneers of laminated wood.

The dimensions of pressed board was10 x 500 x 1300 mm. The plates were air-conditioned for 7 days. After the air conditioning, the test pieces were cut out. For the static three point bend test, the test pieces had a size of 10 x 40 x 250 mm. For the cyclic bending test, the test pieces had a size of 10 x 40 x 630 mm. The fibres were directed in the direction of the longer dimension of the test piece, 10 test bodies were used in each test. A static three-point bending test was performed according to the EN 310 (1993) (Figure 3). The cyclic load was performed on a cyclic bending machine with one-axis load in the elastic area (Figure 4).

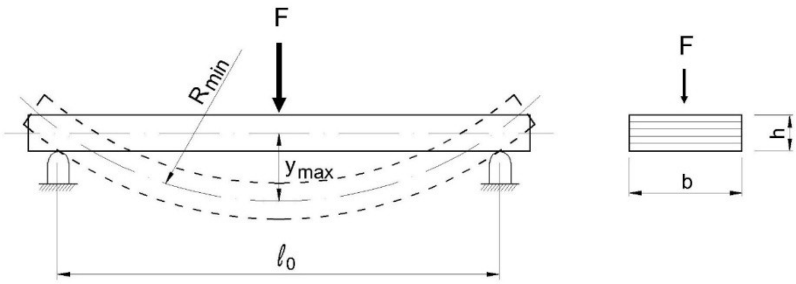


Figure 3. The three-point static bending test.

In the static bending test, we noticed the bending force and deflection (Figure 3). From the measured values we calculated the bending strength (*σ_{max}*) according to the equation (1), the modulus of elasticity (*E_{oh}*) according to the equation (2), the minimum bending radius (R_{min}) according to the equation (3) and the coefficient of flexibility (k_{oh}) according to the equation (4):

Bending strength σ_{max}:

$$\sigma_{max} = \frac{3 \cdot F_{max} \cdot l_o}{2 \cdot b \cdot h^2} \quad \text{[MPa]} \quad (1)$$

where: F_{max} – force at failure of specimen [N],
l_0 – distance between supports; $l_o = 20 \, . \, h$ [mm],
b – width of specimen [mm],
h – thickness of specimen [mm].

Modulus of elasticity E_{oh}:

$$E_{oh} = \frac{(F_{40} - F_{10}) \cdot l_0^3}{4 \cdot b \cdot h^3 \cdot (y_{40} - y_{10})} \quad \text{[MPa]} \quad (2)$$

where: F_{40} – 40 % from maximal force [N],
F_{10} – 10 % from maximal force [N],
y_{40} – deflection corresponding to force F_{40} [mm],
y_{10} – deflection corresponding to force F_{10} [mm].

Minimum bending radius R_{min}:

$$R_{min} = \frac{l_0^2}{8 \cdot y_{max}} + \frac{y_{max}}{2} \quad \text{[mm]} \quad (3)$$

where: y_{max} – deflection corresponding to force F_{max} [mm],

Coefficient of flexibility k_{oh}:

$$k_{oh} = \frac{h}{R_{min}} \quad \text{[-]} \quad (4)$$

where: h – thickness of specimen [mm],
R_{min} – minimum bending radius [mm].

Technological property - bendability, we evaluate on the base minimum bending radius (R_{min}), coefficient of flexibility (k_{oh}) and additionally the unit coefficient of flexibility ($1/k_{oh}$). Unit bending coefficient expresses at what minimum bend radius it is possible to bend the unit thickness of the material.

For the calculation of the minimum bending radius (Rmin), there are different equations as stated by several authors in their works (Buglaj 1967, Gaff et al. 2016, Stevens and Turner 1970, Šulan et al. 1965, Zemiar et al. 1992). We chose the above equation because of the low thickness of our test specimens (h = 10 mm). For this thickness, the equation is satisfactory.

To the test cyclic bend loading has been selected 5000 and 10 000 cycles. These values correspond to the half time and total time of the test of durability for upholstery furniture according to EN 1725 (2001).

The cyclic load was performed at cycler device speed 22 cycles per minute. The bending on the cycling machine took place from zero to the maximum deflection. The maximum deflection was set so that the laminated wood would only be stressed in the elastic area. The deflection (Y_D) of the cycling device was determined by the conversion from the data found in the static bending test according to the relationship (5):

$$Y_D = \frac{l_D^2}{8 \cdot R_u} \quad [\text{mm}] \qquad (5)$$

where: l_D – axial spacing between the supports on the cycler equipment l_D = [489 mm],
R_u – bending radius on the proportionality limit, determined by the static bending test [mm],

We set the deflection (Y_D 90%) at the level 90% from the calculated Y_D value, on the cycling equipment. This was assured by the stress of the test bodies in the elastic area (Figure 4).

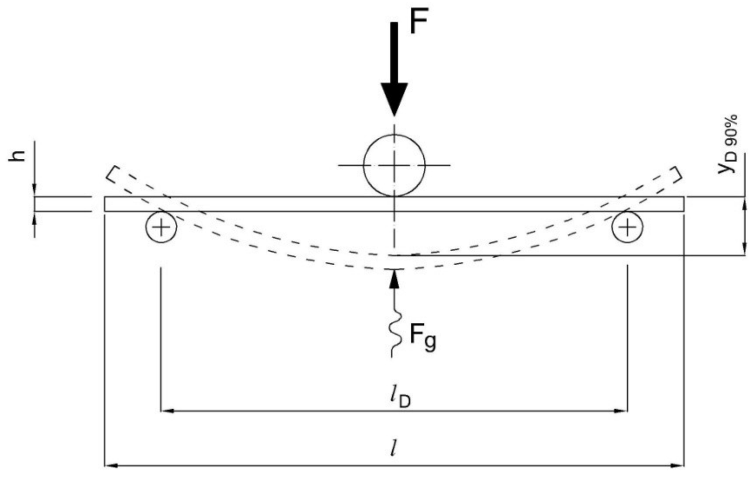


Figure 4. The principle of cyclic bending stress
F_g - elastic reaction of laminated wood, l - length of the test body.

After the cycling test, we have cut out test bodies for a static bending test. Based on the comparison of bending properties before and after cyclic bending, we evaluated the impact of cyclic stress on the change the investigated properties of beech laminated wood.

RESULTS

We monitored the impact of the number of cycles on the change of bending strength, modulus of elasticity, minimum bending radius and unit coefficient of flexibility. The observed and calculated values of the properties of laminated wood before and after the cyclic load (bending) were evaluated in the STATISTICA 12 program, through the box graphs and Duncan tests. Based on significance levels (p), the effect of significance cycles number on the observed properties was determined.

The analysis shows that, with the increasing number of cycles, the maximum bending strength (**σ_{max}**) of lamellae is decreasing (Table 1 and Figure 5a). Comparing the strength before cyclic loading (0 cycles) with a bending strength determined after cyclic loading with 5000 cycles, we found a 13% drop in bending strength and a 40% drop in strength after 10000 cycles (Table 1). The significance levels resulting from the Duncan test (Table 2) confirm that the observed decrease is significant.

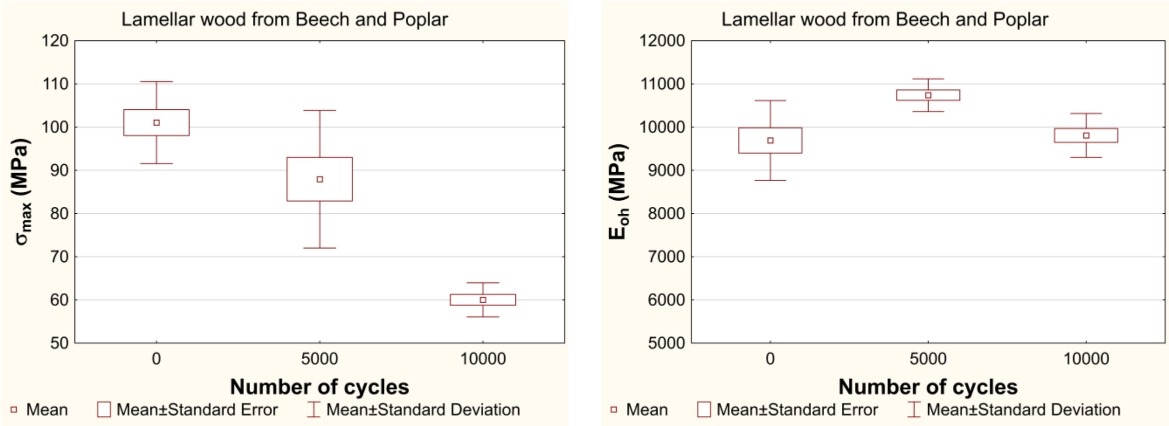
Table 1. Arithmetic averages and variation coefficients of bending strength, bending modulus of elasticity, minimum bending radius, and unit coefficient of flexibility.

Number of cycles	σ_{max}		E_{oh}		R_{min}		$1/k_{oh}$	
	$\bar{x}$ [MPa]	ν [%]	$\bar{x}$ [MPa]	ν [%]	$\bar{x}$ [mm]	ν [%]	$\bar{x}$ [-]	ν [%]
0	101,05	9,39	9691,76	9,53	456,34	8,90	46,67	9,54
5000	87,95	18,12	10739,87	3,52	427,98	12,44	41,58	7,15
10000	60,03	6,57	9806,85	5,19	480,97	5,01	48,28	8,00

Table 2. Duncan tests; a comparison of the effect of the number of bending cycles on bending strength (σ_{max}), bending modulus of elasticity (E_{oh}), minimum bending radius (R_{min}) and coefficient of f flexibility (1/koh) through levels of significance (p).

Number of cycles	Levels of significance - p											
	σ_{max}			E_{oh}			R_{min}			$1/k_{oh}$		
	0	5000	10000	0	5000	10000	0	5000	10000	0	5000	10000
0		0,013	0,000		0,002	0,694		0,135	0,191		0,006	0,354
5000	0,013		0,000	0,002		0,003	0,135		0,010	0,006		0,001
10000	0,000	0,000		0,694	0,003		0,191	0,010		0,354	0,001	

Comparing bending modulus of elasticity (E_{oh}) we found 10.8% increase over 5000 cycles and 1.19% increase over 10,000 cycles compared to the bending modulus of elasticity of samples before cycling (Table 1). In these cases, the Duncan test (Table 2) confirmed that after 5 000 cycles, this is a statistically significant change in bending modulus of elasticity and is not insignificant change after 10 000 cycles. The graphical representation of the bending modulus of elasticity shown Fig. 5b. The finding, that cyclic stress is unevenly reflected the change in flexural modulus reach in his works the authors Igaz et al. (2014), Gaff and Gaborik (2014) and Svoboda et al. (2015).



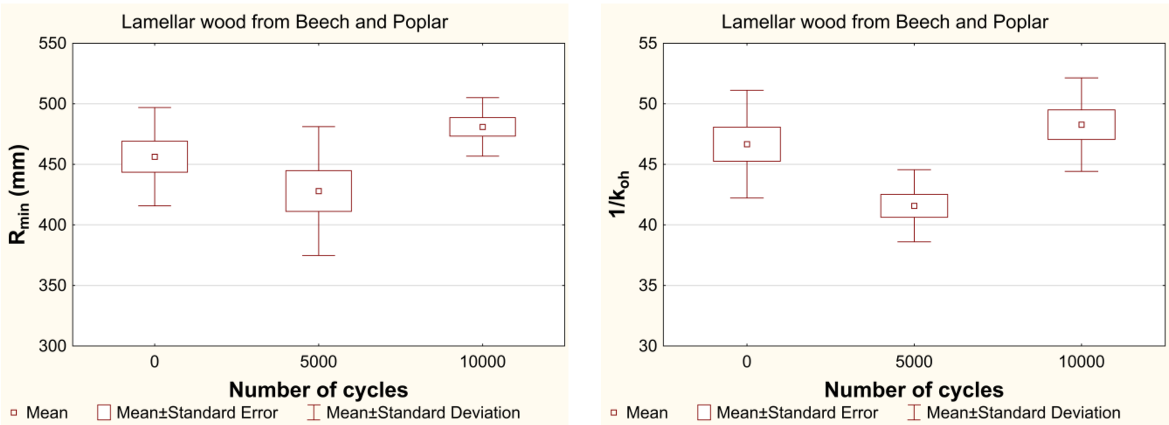
a) **b)**

Figure 5. The effect of the number of bending cycles on the change of a) bending strength, b) bending modulus of elasticity.

The influence of cyclic stress on the technological properties as bendability of laminated wood based on the change in the minimum bending radius (R_{min}) and the unit coefficient of flexibility ($1/k_{oh}$) was evaluated.

The minimum bending radius (R_{min}) of uncycled laminated wood was 456.34 mm (Table 1). After 5000 cycles, decrease about 6.2%, which was not shown to be significant p = 0.135 (Table 2) we recorded. Interestingly, the change in the minimum bending radius of 10000 cycles was recorded, where was increase about 5.4%. This change is also insignificant, but suggests that with the expected increase in the number of bending cycles, it is necessary to consider a greater minimum bending radius of laminated wood in the construction elements of furniture. The recorded changes in the minimum bending radius are shown in the graph in Fig. 6a.

Conversion of the minimum bending radius to the coefficient of flexibility and then to the unit coefficient of flexibility ($1/k_{oh}$), we have obtained the data from which we can compare the bending of the laminated wood before and after dynamic loading by cyclic bending. The graph showing the dependence of the unit coefficient flexibility on the number of cycles (Figure 6b) practically copies the graph with the evaluation of the minimum bending radius.



a) **b)**

Figure 6. The effect of the number of bending cycles on the change of a) the minimum bending radius, b) the unit coefficient of flexibility.

CONCLUSIONS

The main objective was to determined, how cyclic stresses affect to the bending properties of laminated wood. We created laminated wood by combination of beech and poplar veneer of the same thickness and bonded PVAc adhesive. Due to the possibilities of its application, especially in the production of seating and bed furniture, we assessed the impact of dynamic bending stresses on the change of bending strength, modulus of elasticity, minimum bend radius and coefficient of flexibility.

The evaluating of bending strength we found it to decrease with an increasing number of cycles up to 40% over 10,000 cycles.

Modulus with increasing number of cycles varied unevenly due to the increasing number of cycles. Is increased by 10.8% and by 1.19% in comparison with the uncycled laminated timber.

The change in the minimum bending radius per unit thickness - the unit coefficient of flexibility, affected significantly only 5000 bending cycles, when we noticed a 10.9% reduction in the bend radius of the laminated wood.

The cyclic loading of the beech-poplar laminated wood did not show any changes in the investigated properties unambiguously.

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REFERENCES

1. AYDIN İ., ÇOLAK S., ÇOLAKOĞLU G., SALIH E., 2004: A comparative study on some physical and mechanical properties of Laminated Veneer Lumber (LVL) produced from Beech (Fagus orientalis Lipsky) and Eucalyptus (Eucalyptus camaldulensis Dehn.) veneers. Holz als Roh- und Werkstoff. 62 (3), p. 218-220, DOI: 10.1007/s00107-004-0464-3.
2. BEKHTA P., NIEMZ P., SEDLIAČIK J., 2012: Effect of pre-pressing of veneer on the glueability and properties of veneer-based products. In European journal of wood and wood products. 2012, Vol. 70, No. 1-3, p. 99-106.
3. BEKHTA P., PROSZYK S., KRYSTOFIAK T., SEDLIAČIK J., NOVÁK I., MAMOŇOVÁ M., 2017: Effect of short-term thermomechanical densification on the structure and properties of wood veneers. In Wood material science & engineering. 2017, No. 1, p. 40-54, ISSN 1748-0272.
4. BUGLAJ B. M., 1967: Technologia stoľarno-mebeľnogo proizvodstva. In Lesnaja promyšlenosť, Moskva 1967, 345 p.
5. DUDAS J., VILHANOVÁ A., 2013: Sozdanije oblegčennoj fanery dľa konkretnych celej. In Annals of Warsaw University of Life Sciences. 2013, No. 82, p. 235-241, ISSN 1898-5912.
6. ECKELMAN C. A., 1993: Potential uses of laminated veneer lumber in urnitured. Forest Products Journal. 43 (4): p. 19-24.
7. EN 1725 2001: Domestic furniture. Beds and mattresses. Safety requirements and test methods. Brussels, Belgium: European Commttee for Standardization: 2001.
8. EN 310 1993: Wood-based panels – Determination of modulus of elasticity in bending and of bending strength. Brussels, Belgium: European Commttee for Standardization: 1993.
9. FEKIAČ J., 2016: Priestorové prvky v konštrukciách čalúneného nábytku - tvárnené dyhy. In Čalúnnické dni 2016: medzinárodný vedecko-odborný seminár. Zvolen: 2016, p. 44-49, ISBN 978-80-228-2906-9.

10. FEKIAČ J., GÁBORÍK J., 2016: Formability of radial and tangential beech veneers. In Annals of Warsaw University of Life Sciences. 2016, No. 94, p. 191-197, ISSN 1898-5912.
11. FEKIAČ J., GÁBORÍK J., ŠMIDRIAKOVÁ M., 2016: 3D formability of moistened and steamed veneers. In Acta Facultatis Xylologiae Zvolen, 2016, No. 2, p. 15-26. ISSN 1336-3824.
12. FEKIAČ J., ZEMIAR J., GAFF M., GÁBORÍK J., GAŠPARÍK M., MARUŠÁK R., 2015. 3D-moldability of veneers plasticized with water and ammonia. In BioResources. 2015. Vol. 10, No. 1, p. 866-876.
13. FORESTPORTAL.sk, 2014. Súhrnné informácie o stave lesov 2012, Zastúpenie drevín v lesoch SR, on line to: www.forestportal.sk.
14. GÁBORÍK J., 2012: Vybrané vlastnosti lamelového dreva na báze zhustených vrstiev. (Selected properties of laminated wood made of densified layers) In Chip and chipless woodworking processes 2012: the 8th international science conference, September 6-8, 2012, Technical University in Zvolen. Zvolen: Technická Univerzita vo Zvolene. 2012, p. 87-92, ISBN 978-80-228-2385-2
15. GÁBORÍK, J. 2013 Vplyv lepidla na vybrané vlastnosti lamelového dreva (Effect of adhesive on selected properties of laminated wood). In.: Pokroky vo výrobe a použití lepidiel v drevopriemysle = Adhesives in woodworking industry: XXI. sympózium, Zvolen, June 26-28, 2013: zborník referátov Zvolen: Technická univerzita vo Zvolene, 2013, p. 52-58, ISBN 978-80-228-2529-0.
16. GÁBORÍK J., DUDAS J., 2008: Thermo-mechanical Smoothing of Wood. In.: Annals of Warsaw University of Life Sciences –SGGW, Forestry and Wood Technology No. 65, Warszawa, 2008, p. 49 – 54, ISSN 1898-5912.
17. GÁBORÍK J., DUDAS J., KULÍK J., RAUČINA M., 2011: Properties of densified laminated aspen wood at bend loading. In.: Annals of Warsaw University of Life Sciences. Forestry and Wood Technology. - Warszawa: Warszaw University of Life Sciences Press, 2011, No. 74, p. 69-73, ISSN 1898-5912.
18. GÁBORÍK J., GAFF M., RUMAN D., ZÁBORSKÝ V., KAŠÍČKOVÁ V., SIKORA A., 2016. Adhesive as a Factor Affecting the Properties of Laminated Wood. In.: BioResources. Vol.11, No.4, p. 10565-10574, ISSN 1930-2126, DOI: 10.15376/biores.11.4.10565-10574
19. GÁBORÍK J., VILHANOVÁ A., 2016: Selected mechanical properties of lightened plywood. In Annals of Warsaw University of Life Sciences. 2016, p. 205-211, ISSN 1898-5912.
20. GAFF M., GÁBORÍK J., 2014: Effect of cyclic loading on the elasticity of beech solid and laminated wood / BioResources - Vol. 9, No. 3, p. 4288-4296, ISSN 1930-2126.
21. GAFF M., VOKATÝ V., BABIAK M., BAL B. C., 2016: Coefficient of wood bendability as a function of selected factors. In Construction and Building Materials 126: p. 632-640 DOI: 10.1016/j.conbuildmat.2016.09.085
22. IGAZ R., MACEK Š., ZEMIAR J., 2014: Vplyv jednosmerného cyklického zaťažovania ohybom na počiatočnú rýchlosť relaxácie bukových lamiel. In Acta Facultatis Xylologiae. Technical University in Zvolen, Faculty of Wood Science and Technology, 2014, 56 (2): p. 27-35, ISSN 1336-3824.
23. JOŠČÁK P., DUDAS J., GÁBORÍK J., GAFF M., LANGOVÁ N., NAVRÁTIL V., SLABEJOVÁ G., 2014: Konštrukcia nábytku z dreva a drevných materiálov. 1. vyd. Zvolen: Technická univerzita vo Zvolene, 2014. 366 p. ISBN 978-80-228-2646-4.
24. JOŠČÁK, P., LANGOVÁ, N., 2015: Influence of discontinuity the glue-line and selected technological factors on the shear strength of glued joints. In Annals of Warsaw University of Life Sciences. 2015. p. 161-167. ISSN 1898-5912.

25. LANGOVÁ N., JOŠČÁK P., 2014: Effect of mechanical modification of wood veneers on their planar formability. In Annals of Warsaw University of Life Sciences. 2014, No. 87, p. 142-147, ISSN 1898-5912.
26. LANGOVÁ N., JOŠČÁK P., MOŽUCHOVÁ M., TRENČANOVÁ Ľ., 2013: Analysis the effects bending load of veneers for purposes of planar moulding. In Annals of Warsaw University of Life Sciences. 2013, No. 83, p. 173-178, ISSN 1898-5912.
27. SLABEJOVÁ, G., ŠMIDRIAKOVÁ, M. 2014. Influence of modification of veneers on 3D - forming. In Annals of Warsaw University of Life Sciences. Forestry and Wood Technology. Warszawa: Warszaw University of Life Sciences Press, 2014, No. 85, p. 226-229, ISSN 1898-5912.
28. SLABEJOVÁ G., LANGOVÁ N., DEÁKOVÁ V., 2017: Influence of silicone resin modification on veneer tensile strength and deformation. Acta Facultatis Xylologiae Zvolen, 2017, 59 (1), p. 41-47, ISSN 1336-3824.
29. STEVENS W. T., Turner U., 1970: Wood Bending Handbook. London: Her Majesty´s Stationery Office, 109 p.
30. SVOBODA T., RUMAN D., GAFF M., GAŠPARÍK M., MIFTIEVA E., DUNDEK Ľ., 2015: Bending characteristics of multilayered soft and hardwood materials. Bioresouces 10(4), p. 8461-8473, DOI: 10.15376/biores.10.4.8461-8473.
31. ŠMIDRIAKOVÁ M., SEDLIAČIK J., VÉGH B., BEKHTA P., 2015: Aplikácia napenenej PVAC disperzie pri výrobe preglejovaných dosiek. In Acta Facultatis Xylologiae. Technical University in Zvolen, Faculty of Wood Science and Technology 2015. Roč. 57, No. 2, p. 109-115, ISSN 1336-3824.
32. ŠULÁN E., LIPTÁK J., HALABALA J., 1965: Technológia výroby nábytku. VŠLD – SNTL, Bratislava,1965, 210 p.
33. ZEMIAR J., KOTRADY M., 1999: Zhodnocovanie dreva technológiou tvarového lamelovania. 50 rokov vysokoškolského drevárskeho štúdia, TU vo Zvolene, 1999, p. 75-81.
34. ZEMIAR J., GÁBORÍK J., SOLÁR M., KOTRADY M., 2000: Tvárnenie dreva ohýbaním. 1. Vydanie. Zvolen : TU vo Zvolene. 2000, 69 p. ISBN 80-228-0930-6.
35. ZEMIAR J., GÁBORÍK J., MUZIKÁŘ Z., NAVRÁTIL V., RUŽINSKÁ E., ŠEBO N., 2009: Technológia výroby nábytku. 1. Vydanie. Zvolen: TU vo Zvolene. 2009, 287 p. ISBN 978-80-228-2064-6.
36. ZEMIAR J., FEKIAČ J., 2014: Skúšanie a hodnotenie 3D - tvárnosti dýh. In Acta Facultatis Xylologiae Zvolen: Technical University in Zvolen, Faculty of Wood Science and Technology, 2014, No. 1, p. 31-38, ISSN 1336-3824.
37. ZEMIAR J., FEKIAČ J., GÁBORÍK J., 2014: Strengthening of veneers for 3D-forming. In Annals of Warsaw University of Life Sciences. 2014, p. 297-303, ISSN 1898-5912.
38. ZEMIAR J., ŠOVČÍK J., GÁBORÍK J., 1992: Tvarovanie ohýbaním – analýza procesu a teoretické stanovenie stupňa ohýbatelnosti dreva. In Zborník MVK-92, Sekcia č. 5 – Technológia v spracovaní dreva, Technická Univerzita Zvolen, p. 284-292

Streszczenie: *Wpływ struktury klejonego drewna warstwowego na wytrzymałość na zginanie po obciążeniu cyklicznym*. Klejone drewno warstwowe, ze względu na swoje właściwości, nadaje się do produkcji mebli do siedzenia i spania. W ramach pracy przeprowadzono badania właściwości giętnych klejonego drewna warstwowego wytworzonego z fornirów bukowych i topolowych podczas jego cyklicznego obciążania dynamicznego. W miarę zwiększania liczby

cykli zginania odnotowano spadek wytrzymałości na zginanie oraz niewielki wzrost modułu sprężystości. Odnotowano również wzrost minimalnego promienia gięcia oraz współczynnika sztywności.

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