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The effect of periodic stressing and material thickness on the bending strength of native beech wood

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Abstract: *The effect of periodic stressing and material thickness on the bending strenght of native beech wood.* The article is concerned with examination of the chosen factors effects (thickness of the material, number of stressing cycles) on the bending strength „σ_p" of the native beech wood, during bending in the radial direction. For the purpose of establishing the examined parameter, the static three-point stress bending test was used. The examined properties were investigated on the test pieces of 4, 6, 10 and 18 mm thickness, which were not periodically stressed and the results were compared to the results acquired from the test pieces which were periodically stressed. The results show that the examined factor thickness of the material has a statistically significant (95% interval of reliability) effect on the values of bending strength. The effect of the number of stress cycles rendered on the verge of statistical significance. The interaction of the factors material thickness*number of cycles rendered as statistically insignificant. The results found constitute a base for further practical utilization of wood in the process of manufacture.

Keywords: periodical stressing, bending strength, native beech wood, process of manufacture.

INTRODUCTION

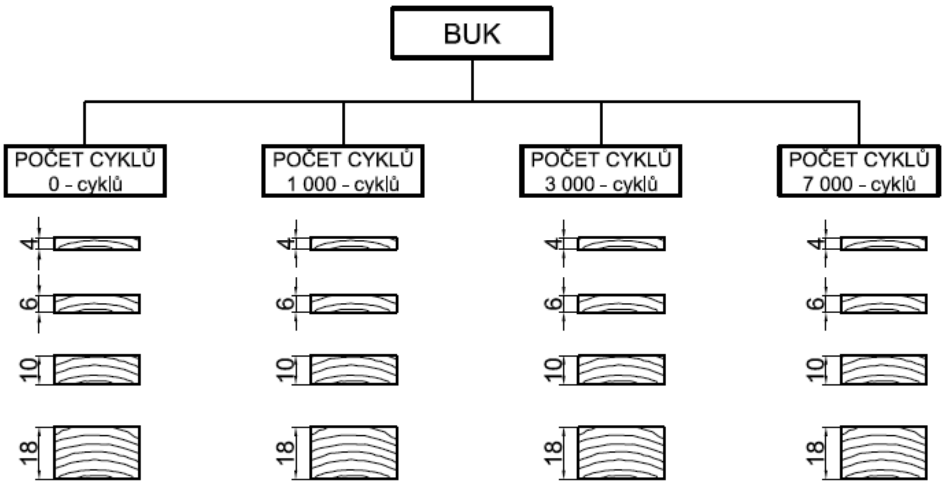
Wood is a traditional and perspective material of natural origin. Thanks to its positive natural properties, wood has a versatile utilization in various branches of economy (building industry, furniture industry and similar).

In this context, wood is an integral part of manufacturing process in wood-processing industry, which is characterized by repertory of activities the intent of which is modification of shape, dimensions, composition and quality of input materials and semi products into finished products (Zemiar and Fekiač 2014). General function of the manufacture system is a transformation of the materials and semi products into a product of desired parameters. Therefore a rigorously assessed transformation of the input corporeal quantities into the output corporeal quantities takes place in the manufacture system. The process of transformation takes place based on the input energy and controls its input and feedback quantities, i.e., the controlling information (Gaff 2011, 2014).

The input material is one of the crucial agents effecting the manufacture process, in the course of which the material alters its quantitative and qualitative properties. Significant role is played by the properties of the input raw material wood, which ultimately affect the quality of the final output products. Either native raw material wood or modified wood can be input in the manufacture process; in some cases the modification takes place directly in the manufacture process (Kurjatko et al. 2010). By the modification of the wood properties by mechanical, thermal, chemical modification or by their combinations we can obtain materials of desired properties for their subsequent utilization in further technological and industrial utilization (Gaff and Gáborík 2014). This shows that we will be able to determine and influence to some extent the properties of the final product by knowledge of properties of the wood as an input raw material of the manufacture process. The radial bending perpendicular to the fibers is the most frequently examined feature for the furniture elements loaded during their use. This is because this feature is the most useful in practice for beams and balks, as well as for lamella elements, which are used in difference types of furniture pieces (Gaff and Gáborík 2014).

METHODS

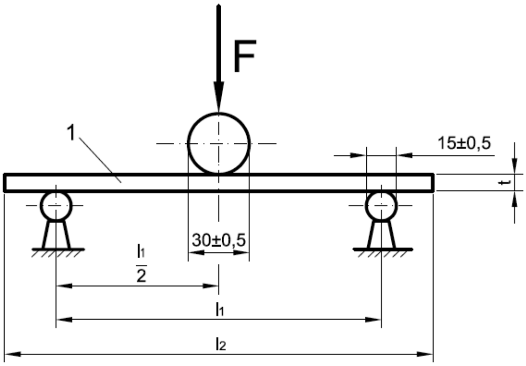
Test pieces of beech (*Fagus sylvatica* L.) wood pulp were used for the experimental tests. The essence of this article was experimental determination of effect of periodical stressing of native beech wood of various thickness on bending strength „σ_p“ at bending perpendicular to the fibers in radial direction. Determining the observed property of the examined test pieces took place before and after the periodical stressing of the pieces. Individual sets of test pieces were periodically stressed for 0, 1000, 3000 and 7000 cycles. The periodical stressing took place in a special cyclic machine, principle of which consists in periodical bending of the test pieces by uniaxial stressing. The stressing was executed at 90% proportional limit during the periodical stressing of the test pieces, which was determined by preliminary experimental measurement during stressing of the test pieces by static bending. For the purpose of determining the effect of the thickness of the material, tests took place on test pieces of thickness of 4, 6, 10 and 18 mm. Humidity of the test pieces were 8%. By reason of precluding the effect of material thickness, the distance of the supports was set as $l_1=20*t$ during the bending (picture 2). Exact division of the individual sets of test pieces is listed in the picture 1.



Picture 1 The categorization of the sets of test pieces

Methods of determining the bending strength

The determination of the bending strength was executed according to norm ČSN EN 310 (1995) on a special machine instrument during a bend-stressing the test piece in its center. This norm is concerned with determining the module of bending flexibility and strength. The test pieces had dimensions of *w*=30 mm x *t*=4, 6, 10 and 18 mm x *l*=600 mm. Scheme of the three-point bending is depicted in the picture 2.



Picture 2 The method of test pieces and the appliance for the bending test arrangement (ČSN EN 310 (1995))
1 – test piece, F—stressing, t – test piece thickness, $l_1=20\times t$, $l_2=l_1\pm 50$

The rate of stressing was set in a manner in which the maximal stress was achieved in (60±30) seconds. The measured values along with the corresponding stress were recorded with ±1% accuracy of a measured value.

The bending strength at the three-point bend was calculated in accordance with the norm ČSN EN 310 (1995) following a formula (1):

$$\sigma_p = \frac{3 * F_{\max} * l_1}{2 * b * t^2}, \text{ [MPa]} \qquad (1)$$

Where:

σ_p – bending strength limit	[MPa]
F_{max} – is a force recorded at the breaking point of a test piece	[N]
l_1 – a distance between the supports during testing	[mm]
b – the width of the test piece	[mm]
t – the thickness of the test piece	[mm]

Measured results of the bending strength were recalculated for the 12% humidity according to the equation number (2) (ČSN EN 310 1995):

$$\sigma_{12} = \sigma_w [1 + \alpha (w - 12)], \text{ [MPa]} \qquad (2)$$

Where:

σ_w – bending strength of wood at a humidity at the time of testing	[MPa]
σ_{12} – bending strength of wood at 12 % humidity	[MPa]
w – the humidity of a test piece at the time of testing	[%]
α – correctional humidity coefficient, which is 0,04 for all of the wood pulps	[-]

RESULTS AND DISCUSION

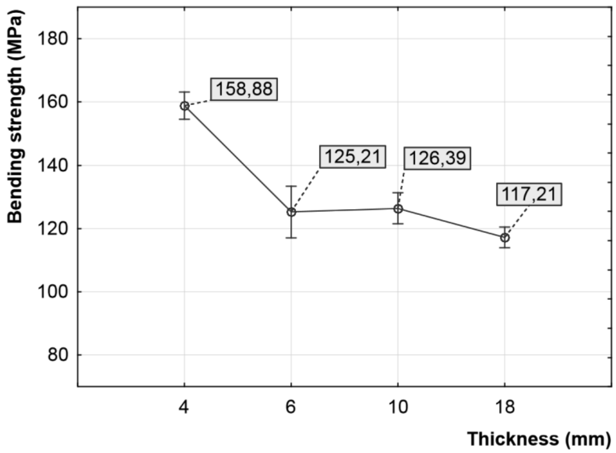
For the evaluation of the measured values, the method of multifactorial analysis of variance. In the table number 1, the results of the analysis of variance are listed, evaluating the effects of the material thickness, number of cycles and their significant interactions on the values of bending strength of the native beech wood. Based on the values of significance level „P“, it can be concluded, that the factor of material thickness can be considered as a statistically significantly agential (picture 3). The observed factor, the number of cycles of stressing, proved itself as a factor agential on the verge of statistical significance (picture 4).

From the results of a two-factorial interaction based on a significance level „P“ (table 1) it accrues, that the interaction of number of cycles and material thickness effects can be considered as a statistically insignificant factor.

Table 1 Basic table of the two-factorial analysis of variance, evaluating the effects of the individual factors on the change in bending strength of the native beech wood

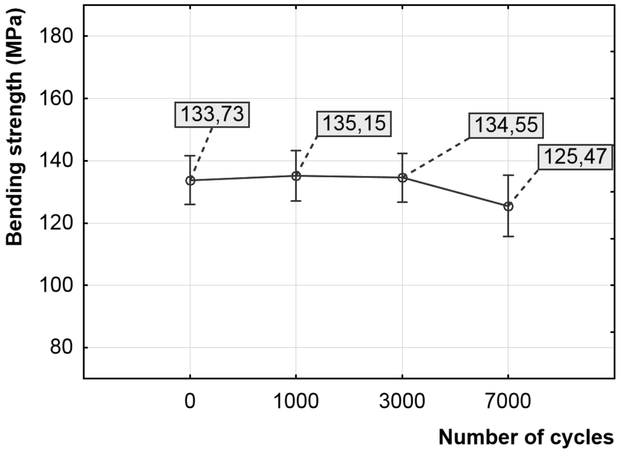
Observed factor	Summary of squares	Independence levels	Variance	Fischer's F-test	Significance level P
Abs. element	1817816	1	1817816	10636.65	0.000001
Thickness	28041	3	9347	54.69	0.000001
Number of cycles	1474	3	491	2.87	0.040552
Thickness*Number of cycles	1740	9	193	1.13	0.349307
Error	15381	90	171		

From the graph (picture 3) it accrues, that with the increase in the material thickness in 4 to 6 mm and 10 to 18 mm intervals, the values of bending strength of the native beech wood decrease statistically significantly. The statistically most significant difference was evident during the thickness increase of the 4 to 6 mm interval. The increase of material thickness in the interval of 6 to mm had no statistically significant effect on the values of bending strength. The decrease of the bending strength with increasing material thickness is a consequence of change of a cross-section module at bending.



Picture 3 Graph of the 95% reliability intervals illustrating the effect of material thickness on the values of the average bending strength of the native beech wood

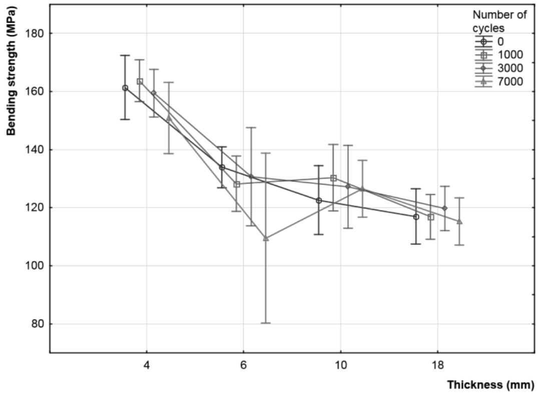
The effect of the stress cycles proved of statistically middle significance (picture 4), where the significant decrease can be observed only with the set of test pieces, which were stressed by the number of 7000 cycles. The increasing number of cycles in the interval of 0-3000 proved as a statistically insignificant.



Picture 4 Graph of the 95% reliability intervals illustrating the effect of the number of cycles on the values of the average bending strength of the native beech wood

Based on the analysis of variance evaluating the effect of interactions of material thickness and the number of stressing cycles on the values of bending strength (table 1), it can be concluded that the interaction of both of the observed factors has no statistically significant effect (picture 5, picture 6).

In the graphs (picture 5, picture 6), depicting the effect of number of stress cycles and material thickness interaction on the bending strength of the native beech wood, we can observe, that the mentioned effect occurred as a consequence of a significant effect of a different material thickness.



Picture 5 Graph of the 95% reliability intervals illustrating the effect of material thickness and number of cycles interaction on the values of the average bending strength of the native beech wood

CONCLUSION

Based on the aforementioned results, we can summarize the following conclusions:

- The number of cycles proved to be a factor agential at the verge of statistical significance on a values of bending strength. Although, during the cyclic stressing at 7000 cycles, a slight decrease in bending strength was recorded.
- The significant effect of the material thickness has shown. As a result of increase in material thickness in the 4 to 6 mm interval, the values of strength of native beech wood decrease significantly,
- the interaction of material thickness and number of stressing cycles factors was not shown as a statistically significant.
- In the future studies, we recommend to focus on the effects of the higher number of cycles - 7000 and more.

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Streszczenie: Wpływ obciążeń cyklicznych i grubości materiału na wytrzymałość na zginanie drewna buka. Praca dotycy wpływu wybranych czynników (grubość materiału, ilość cykli naprężeń) na wytrzymałość na zginanie „σ_p“ drewna buka podczas zginania w kierunku promieniowym. Używano zginania trzypunktowego, dla próbek o grubości 4, 6, 10 i 18 mm poddanych oraz niepoddanych obciążeniom cyklicznym. Badania wykazały statystycznie istotny wpływ grubości materiału na wytrzymałość, wpływ obciążeń cyklicznych był na granicy istotności. Wpływ obu czynników badanych na raz na wytrzymałość okazał się statystycznie nieistotny. Badania można wykorzystać w praktyce, przy zastosowaniu drewna litego w produkcji,.

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