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Determining the effect of Fagus Silvatica densification on the deformation tension characteristics under pressure perpendicular to the radial direction fibers

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Abstract: *Determining the effect of Fagus Silvatica densification on the deformation tension characteristics under pressure perpendicular to the radial direction fibers.* The paper is oriented to determining the effect of densification (10% and 30%) of Fagus Silvatica wood-pulp on the evaluated characteristics, which are the deformation tension characteristics under pressure perpendicular to the radial direction fibers. Aim of the paper was to determine the behavior of densified (10%, 30%) and non-densified Fagus Silvatica up to the proportional limit for the purpose of creating materials of specific characteristics for given application intent. The resulting values of the tests were graphically processed and evaluated by the form of tables.

Keywords: densification, Fagus Silvatica, proportional limit

INTRODUCTION

As a consequence of improved properties and excellent mechanical properties of composite wood-based materials, the wood finds ever wider utilization as an ecological and renewable material. Thanks to composite materials, such as glued laminated beams (Sviták et al., 2014), it ascends among leading positions of utilization, ahead of other construction materials, which until now have shown better technical properties compared to untreated wood. We can assume, that its properties will improve up to some point of surface pressing, and after the violation of this limit, great differences in created deformations may occur, by which the structure and integrity of the wood begins to disrupt (Gaff, M., Zemiar, J., Koristová, E., 2010). By this reason we are trying to determine the limit up to which is possible to consider the densification as an enhancement to the examined wood characteristics.

The state, in which the wood achieves the highest level of plasticity, however, with the lignine – saccharide matrice compounds of the wood undamaged as much as possible, is convenient for the technology of molding (Gaff, M. , Zemiar J., 2008).

The process of surface densification by pressing generally takes place in three phases. Those are plasticization, actual pressing and conditioning (Gaff, M., Gáborík, J., 2009). The results of the authors' work (GAFF, M. , ZEMIAR J., 2006) showed that for the process of densification, the moisture higher than 12% is better than a lower one, and on that account we examined the effect of the mentioned factors at 12% moisture.

With wood-based materials, contrary to the actual wood, we can regulate the level of anisotropy, for example the size and orientation of the wood particles. This is a significant advantage of these materials, considering we can control their properties in individual areas according to demands on the final utilization. Non-negligible fact is also the option to utilize a raw material of lower quality for the production of high quality product.

In construction industry and lumber industry we encounter with increasing frequency material designs, properties of which have to be examined before they are actually created. An example of this could be floorings, on which specific demands are made. Flooring should be resistant to mechanical damage, which should be ensured by upper treading layer, and also flexible and resistant to dynamic stressing.

The level of densification was a basic factor during the observations. The observed parameter during the evaluation of strength under pressure perpendicular to the fibers was the proportional limit, as an indicator, which is measured with this characteristics.

WORK METHOD

Preparation of the test pieces

During the lumber production from logs, the circular cutting (Fig. 1a) was chosen for the purpose of tangential lumber. For the beech wood, only the lumber made out of sapwood was used. The lumber was laid by the mean of lintel bars and dried spontaneously in the lumber magazine down to the moisture of 16% (± 2%).

Dried lumber was shortened to desired rough dimensions (Fig. 1b), cleared – (Fig. 1c) and cut into concurrent cut pieces (Fig. 1d). For the purpose of achieving of two perpendicular planes, the surfaces of the material were leveled by a surface planer. Consequently, the cut pieces were treated by thicknesser (Fig. 1e). That is how the thickness before molding with allowance or already final thickness of the non-molded cut pieces was specified.

Individual cut pieces (densified and also non-densified) were shortened by the dimensioning saw to the desired dimensions of test pieces (Fig. 1f). The dimensions of pieces for the pressure test are 20 x 60 x 60 mm (Fig. 1g).

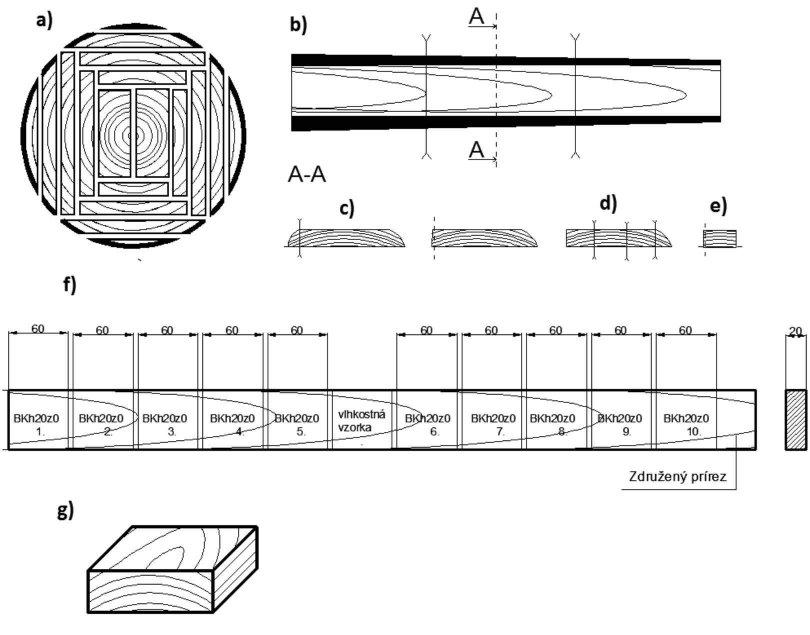

Fig. 1 Process of test pieces preparation

Densification of cut pieces

The samples were densified to the desired thickness by uniform molding of wood crosswise the fibers at 16% moisture using a hydraulic press. To achieve the final thickness of 20 mm, it was necessary to account for the allowance before molding. The molded samples were compressed by 10% and 30% of their thickness, whereby we have to account for the elastic deformation of the material. During the densification, cut pieces of 22 mm thickness, which were molded to 20 mm, i.e. by 10%, were used. The cut pieces of 26 mm thickness were molded to final 20 mm, i.e. by 30%. At higher levels of densification we reach higher wood density, but at the expense of damaged structure.

Density is assessed according to formula (1):

$$\rho = \frac{m}{V} \left[kg/m^3 \right] \quad (1)$$

Where: m – weight [kg],
V – volume in [m^3].

Conditioning

The test material was conditioned in an environment of relative air humidity of φ = (65 ± 5)% and of temperature of t = (20 ± 2) °C to a state of equilibrium. These conditions were assessed based on the Čullický diagram and match the 12% equilibrium moisture of wood, at which the test was executed.

Moisture assessment was executed by weighting method according to the norm ČSN 49 0103.

Tests on the tensile testing machine

The properties of the Fagus Silvatica material of 20 mm thickness were assessed (Fig. 2) (Table 3 ordinal number 1, 2, 3).

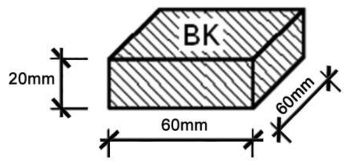

Fig. 2 Fagus Silvatica of 20 mm thickness

During the tests, 3 possible levels of densification were anlysed. For each set of test pieces, 10 samples were used, which constitute 30 samples overall.

Table 1 Compositions and combinations of materials

O.No.	Wood species	Thickness (h) in mm	Densification	Index
1	FS	20	0%	BKh20z0
2	FS	20	10%	BKh20z10
3	FS	20	30%	BKh20z30

Fig. 3 The ALMEMO measuring device and the FPZ 100/1 tensile testing machine

Method of assessing the strength under pressure perpendicular to the fibers

Strength under pressure perpendicular to the fibers was assessed on the conditioned samples with 12% moisture using the FPZ 100/1 tensile testing machine and the ALMEMO measuring device (Fig. 3).

Given deformation relationship in the "strength - deformation" diagram was achieved by testing (Fig. 4). The strength necessary for breaking and the corresponding values of proportional lengthening are input parameters at all times, based on which it is possible to evaluate the conclusions of these tests (Sviták, et al., 2013). The point of contact of the tangent on the curve was specified so that the tangent of the angle formed by the tangent and the load axis was 1,5 times higher than the tangent of the angle formed by the linear part of the curve and the load axis. The value of strength on the proportional limit (Fu) was deducted from the final diagram. Then we calculate the stress on the proportional limit according to the formula determined by the relationship (2).

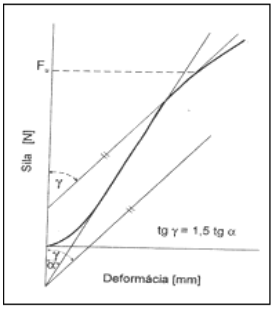

Fig. 4 "Strength - deformation" diagram for the pressure perpendicular to the fibers (DUBOVSKÝ, J. et al., 2001)

The test process

1. Width and length of the conditioned test piece in the axes of symmetry with accuracy of 0,1 mm using was assessed using a digital caliper.
2. The test piece was inserted into the tensile testing machine between the plates in a way in which force was applied in the radial direction (Fig. 5).

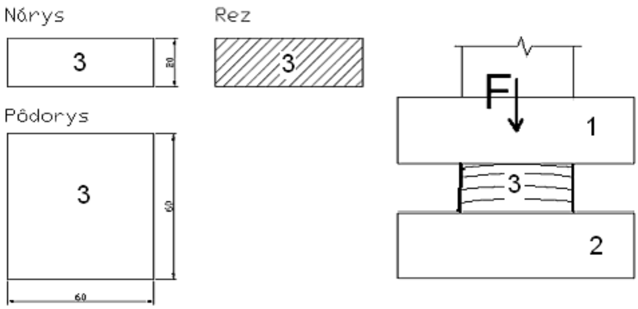

Fig. 5 Test piece for assessing the strength under pressure perpendicular to the fibers: 1 – pressure plate, 2 – fixed plate, 3 – test piece.

3. When using the testing machine without a recording device, the deformation was assessed using a numerical indicator with accuracy of 0,01 mm at the same intervals of load accession. The interval has to be at least 10 times smaller than the load corresponding to

the conventional fracture limit. It is allowed to use an interval of 200 N load accession for soft woods and 400 N for hard woods during the tests with pressure across fibers on the whole test piece. Similarly, 150 N and 300 N during tests with concentrated local pressure.

In our case, a testing machine with ALMEMO recording device was used, which scanned the material using measuring probes attached on the machine. ALMEMO device was connected to tensile testing machine and also to a computer, to which the measured data was transefered. The test piece was loaded at steady speed.

4. The test carried on until visible violation of the proportional limit, which was assessed by diagram or by numerical indicator.

Measured data was processed using Microsoft Excel application, the stress-deformation graph was created and from it the proportional limit was assessed. The proportional limit of pressure perpendicular to the fibers is assessed according to formula (2) (Požgaj. 1987):

$$\sigma_u = \frac{F_u}{S} \text{ [MPa]} \tag{2}$$

Where: σu – proportional limit,
Fu – force at proportional limit in N,
S – loaded area of test piece in mm2.

RESULTS AND DISCUSSION

Evaluation of proportional limit for substantial samples

It is possible to compare the illustration of tension on the proportional limit of all average values of substantial samples on the bar chart (Fig. 7). The value of proportional limit for Fagus Silvatica at 0% densification (non-densified) is 9,44 MPa. In the results listed in the chart we can see that by increasing the densification the proportional limit decreases.

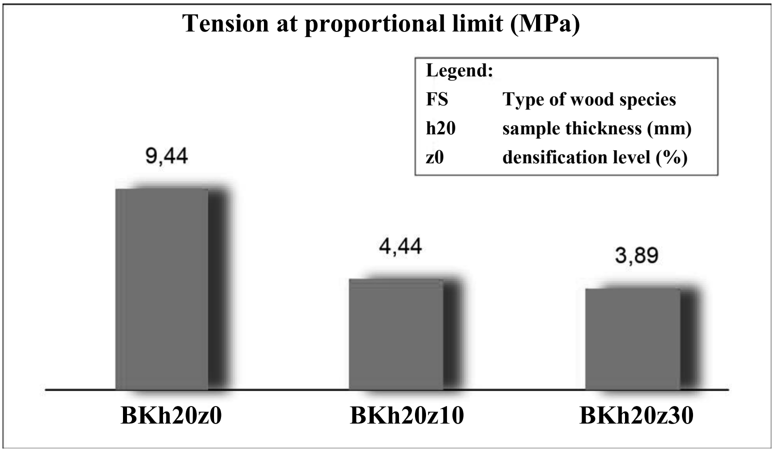

Fig. 6 Tension at proportional limit of substantial samples of Fagus Silvatica

Assessed average values of force at the proportional limit (Fu) of the substantial samples of Fagus Silvatica are depicted in chart (Fig. 8). Force achieved with non-densified sample of Fagus Silvatica is 34 MPa. With an increase in densification, we can observe a decrease in value of force achieved at the proportional limit.

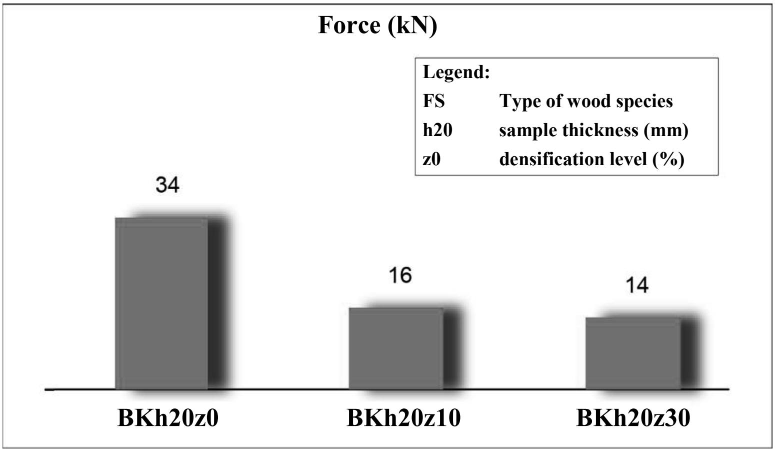

Fig. 7 Effect of force on substantial samples of Fagus Silvatica

It accrues from the measured average values of deformation at the proportional limit (mm) of the samples, that the elastic deformation achieved at non-densified sample of Fagus Silvatica is 0,8 mm. With the increase in densification, we can observe slight increase in deformation, which can also be seen in the chart (Fig. 9).

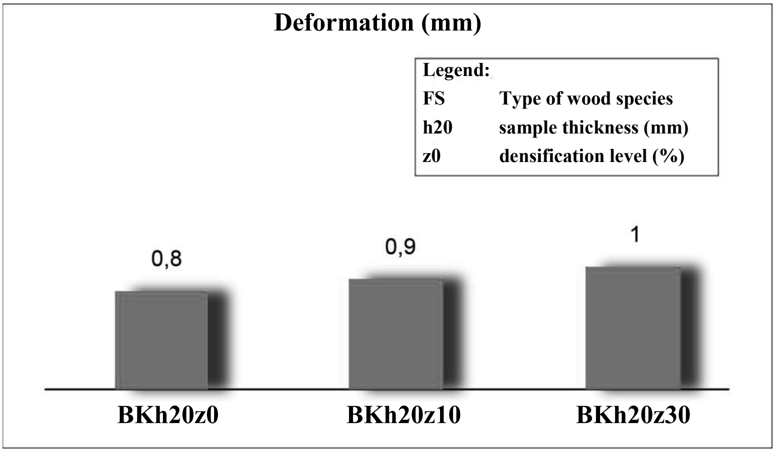

Fig. 8 Deformation of substantial samples of Fagus Silvatica

CONCLUSION

The capacity of wood to resist certain load – tension is one of the characteristics, which plays an important role in practice. Resistant and hard material, either solid or engineered, assumes the achievement of the highest possible proportional limit.

The options of optimal utilization of modified material properties were examined.

By executed measurements, we reached the conclusion that if the highest possible strength under pressure of material is to be achieved, the proportional limit has to as high as possible.

Based on the analyses, a lower strength under pressure was found for densified samples, expressed by the proportional limit. Therefore it accrues from the results of the paper, that we do not achieve higher strength under pressure perpendicular to the fibers in radial direction by densification.

Analyses did not prove better capacity for mechanical damage resistance of Populus tremula after the densification, densified Fagus Silvatica therefore is not ideal for use as a treading layer of flooring. The use of non-densified sample is the most advantageous for the use of Fagus Silvatica wood in flooring.

BIBLIOGRAPHY

1) BRUTOVSKÝ, T. 2013. Pružnostné vlastnosti lamelových materiálov na báze dreva a nedrevených komponentov. M.S. thesis, Technical University in Zvolen, Zvolen, Slovakia.
2) DUBOVSKÝ, J. – BABIAK, M. – ČUNDERLÍK, I. 2001. Textúra, štruktúra a úžitkové vlastnosti dreva. 3. vyd. Zvolen: Technická univerzita, 2001. 106 s. ISBN 80-228-1014-2.
3) GAFF, M. , ZEMIAR J., 2006: Analýza vplyvu vybraných faktorov na tvarové a rozmerové zmeny reliéfu a kvalitu jeho povrchu. In Trieskové a beztrieskové obrábanie dreva 2006 : V. medzinárodná vedecká konferencia : zborník prednášok. - Zvolen : Technická univerzita vo Zvolene, 2006. - ISBN 80-228-1674-4. - S. 119-128.
4) GAFF, M. , ZEMIAR J., 2008: Vplyv vlhkosti dreva a ohrevu lisovacieho nástroja na tvarovú stabilitu a kvalitu nerovnomerne zlisovanej plochy osikového dreva. In Trieskové a beztrieskové obrábanie dreva 2008 : VI. Medzinárodná vedecká konferencia, 11.-13. September 2008 Hotel Thermal, Štúrovo : zborník prednášok. - Zvolen : Technická univerzita vo Zvolene, 2008. - ISBN 978-80-228-1913-8. - S. 315-320.
5) GAFF, M., GÁBORÍK, J., 2009: Vlastnosti povrchu dreva modifikovaného reliéfovaním, Zvolen : Technická univerzita vo Zvolene, 2009. - 80 s. ISBN 978-80-228-2035-6
6) GAFF, M., ZEMIAR, J., KORISTOVÁ, E., 2010: Tvarová a rozmerová stabilita povrchu dreva modifikovaného lisovaním – reliéfovaním. Zvolen : Technická univerzita vo Zvolene, 2010. - 75 s. : 65 obr., 6 tab. - ISBN 978-80-228-2107-0
7) POŽGAJ, A. 1987. Metódy zisťovania mechanických vlastností dreva a drevných veľkoplošných kompozitných materiálov. Zvolen: Vysoká škola lesnícka a drevárska, 1987. 170 s.
8) SVITÁK, M., BARCÍK, Š., RYSPLER, J. Application of Carbon Fibers on Wood Beams. Acta Facultatis Xylologiae Zvolen. 2013. S. 5 - 13. 55 (2). ISSN: 1336-3824
9) SVITÁK, M., GAŠPARÍK, M., PENC, J. Heat resistance of glued finger joints in spruce wood constructions. Bioresources. 2014. S. 7529 – 7541. 9 (4). ISSN: 1930-2126.

Streszczenie: *Ocena wpływy zagęszczania drewna Fagus Silvatica na charakterystykę deformacji w pod obciążeniem w kierunku promieniowym.* Praca skupia się na określeniu wpływu zagęszczenia (10% i 30%) masy Fagus Silvatica na charakterystyki deformacji pod obciążeniem promieniowym.

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