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PHYSICO-MECHANICAL PROPERTIES OF THERMALLY MODIFIED BEECH WOOD AFFECTED BY ITS PRE-TREATMENT WITH POLYETHYLENE GLYCOL

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ABSTRACT

The European beech (*Fagus sylvatica* L.) wood – natural, as well as pre-treated with 20 wt.% water solution of polyethylene glycol (PEG 6000) – was thermally modified at the temperatures of 170, 190 or 210 °C for 1, 2, 3 or 4 hours. The selected properties of thermally modified beech wood, *i.e.* soaking, volume swelling, impact bending strength and Brinell hardness changed more intensively at using more severe thermal regimes from 170 °C / 1 h to 210 °C / 4 h. The presence of polar, white-waxy consistency of polyethylene glycol macromolecules in the thermally modified beech wood specimens had different effects on their properties. PEG 6000 participated in supressing the volume swelling and soaking in water of the thermally modified beech wood specimens, and also inhibited a decrease of their impact bending strength. On the contrary, polar PEG 6000 macromolecules together with thermal loads participated in decreasing the Brinell hardness.

Key words: beech wood, polyethylene glycol, thermal modification, swelling, soaking impact bending strength, hardness.

INTRODUCTION

Thermal modification of hardwoods and softwoods performed at high temperatures usually from 160 °C to 260 °C, is a physico-chemical process connected with changes in their structural characteristics and selected properties (REINPRECHT and VIDHOLDOVÁ 2011, SANDBERG *et al.* 2017, VIDHOLDOVÁ *et al.* 2019). Thermowood commercial products, such as ThermoWood, PlatoWood, RectifiedWood, OHT-Wood, and others, have a better dimensional stability and durability – mainly higher resistance against wood destroying fungi and insects (LUNGULEASA *et al.* 2018, TAŞDELEN *et al.* 2019). Modulus of elasticity in bending of thermally modified woods is obviously unchanged, however, their bending strength and other strength properties are decreased usually from 5% to 20% (KAČÍKOVÁ *et al.* 2013, ANDOR and LAGAŇA 2018, WANG *et al.* 2018).

Due to thermal modification processes firstly their molecular structure associated primarily with the hemicelluloses degradation, creation of hemicelluloses-lignin linkages, and extinction of some hydroxyl groups in various wood species is changed (TJEERDSMA *et al.* 1998, SRINIVAS and PANDEY 2012, CAI *et al.* 2018). A range of changes in the molecular structure and partly also in the anatomical structure (e.g. composition and thickness of the individual cell wall layers) and geometry structure (e.g. volume and cracks) of thermally modified woods, connected with following changes in their physical, mechanical and biological properties, is related: (a) to the type of used heating medium, *e.g.* air, nitrogen, steam, plant oil, wax, or other; (b) to the thermal modification technology, *e.g.*, regulation of the temperature, pressure, and time; (c) to the tree species used and its initial moisture content (TJEERDSMNA *et al.* 1998, HILL 2006, YILDIZ *et al.* 2006, ESTEVES and PEREIRA 2009, KOCAEFE *et al.* 2015, REINPRECHT 2016).

European beech (*Fagus sylvatica* L.) is one of the most used commercial hardwood species in Central Europe – as its logging is great and its workability and impregnability is well (KÚDELA and ČUNDERLÍK 2012). However, beech wood has also some disadvantages – as a great volume swelling or shrinkage (KLEMENT *et al.* 2019), and a lower resistance to fungi and insects (REINPRECHT 2016).

Polyethylene glycols are polar macromolecules. At a room temperature they are liquids (*e.g.*, from PEG 300 to PEG 1000) or solid substances with a waxy consistency (*e.g.*, from PEG 1500 to PEG 10000). In practice, various PEG types, containing smaller and also higher polyethylene glycol macromolecules, are successfully used for a dimensional stabilization of archaeological waterlogged wooden artefacts (HOCKER *et al.* 2012, MAJKA *et al.* 2018). However, polar PEGs usually decrease strength properties of wood, because the wood treated with them has permanently swollen cell walls and the strengthening effect of hydrogen bonds inside the cell walls consisting from polysaccharide and lignin molecules is suppressed (ALMKVIST *et al.* 2016).

The aim of this work was based on an assumption, that combining a primary technology of wood pre-treatment with polar polyethylene glycol macromolecules with a followed technology of wood exposition to high temperatures could effectively improve selected properties of the thermally modified wood.

MATERIALS AND METHODS

Wood

High quality specimens of European beech (*Fagus sylvatica* L.) heart-wood, *i.e.* without rot, insect gallery, growth defects, tension wood and red-false wood, were prepared from the sawn timber naturally seasoned to a moisture content of 13.5% ± 2%. Three dimensional types of specimens (longitudinal × tangential × radial) were used in the experiment – type (a) 25 mm × 25 mm × 5 mm in testing the Brinell hardness; type (b) 5 mm × 50 mm × 25 mm in testing the soaking and swelling; and type (c) 120 mm × 10 mm × 10 mm in testing the impact bending strength. The top and bottom surfaces of specimens of the type (a) and type (b) were milled.

The beech wood specimens were dried at 103 ± 1 °C to the oven-dry state in the kiln Memmert UNB 100 (Memmert, Schwabach, Germany), subsequently cooled in desiccators to a temperature of 20 ± 2 °C and weighed with an accuracy of 0.001 g.

Pre-treatment of wood with polyethylene glycol

Pre-treatment of the beech wood specimens was performed in stainless steel containers by immersion technology with 20 wt.% water solution of polyethylene glycol PEG 6000 (HiMedia, Ltd., Mumbia, India). Water solution of PEG 6000 had a dynamic viscosity of 21.8×10^{-3} Pa·s at 20 °C. Pre-treatment process at atmospheric pressure and at a temperature of 100 °C lasted 3 hours.

The weight percent gain (WPG) of PEG 6000 by beech wood specimens was determined after their 4-week conditioning in a moist-air ($\varphi = 95\%$; $t = 20$ °C; xylene = anti-mold component) and following drying to the oven-dry state, using Eq. 1:

$$WPG_{PEG} = \frac{m_{0-Pretreated} - m_0}{m_0} \times 100\ [\%] \tag{1}$$

where: $m_{0\text{-Pretreated}}$ – mass of the oven-dried specimen containing PEG 6000 [g], m_0 – mass of the oven-dried original specimen [g].

Thermal modification of wood

The natural as well as with PEG 6000 pre-treated beech wood specimens were thermally modified in the kiln Memmert UNB 100 (Memmert, Schwabach, Germany) at the temperatures of 170, 190 or 210 °C for 1, 2, 3 or 4 hours.

Thermally modified beech wood specimens were cooled in desiccators to a temperature of 20 ± 2 °C, then their weights with an accuracy of 0.001 g and dimensions with an accuracy of 0.01 mm were determined, and repeatedly were transferred to desiccators.

Specimens used for testing the impact bending strength and hardness were air-conditioned for 14 days at the temperature of 20 ± 2 °C and a relative air humidity of 60 ± 5%. Oven-dry specimens with 0% moisture content were used in soaking and swelling tests.

Soaking and swelling

The soaking test according to the Standard STN 49 0104 was performed, using Eq. 2, in order to determine the ability of the reference and modified beech wood specimens (5 mm × 50 mm × 25 mm) to absorb distilled water (S_i),:

$$S_i = \frac{m_i - m_0}{m_0} \times 100\ [\%] \tag{2}$$

where: m_i – weight of the moist specimen at the defined time of soaking [g], m_0 – weight of the oven-dried specimen [g].

At the same time, volume swelling of wood (β_{Vi}) was evaluated, using Eq. 3:

$$\beta_{Vi} = \frac{V_i - V_0}{V_0} \times 100\ [\%] \tag{3}$$

where: V_i – volume of the moist specimen at the defined time of soaking [mm^3], V_0 – volume of the oven-dried specimen [mm^3].

Impact bending strength

Impact bending strength of specimens in tangential direction (I) was determined according to the Standard ISO 3348, using Eq. 4:

$$I = \frac{W}{b \times H}\ [J.cm^{-2}] \tag{4}$$

where: W – work done for cutting the specimen [J], b, h – specimen cross section dimensions [cm].

Brinell hardness

Brinell hardness of specimens in radial direction (H_B) was evaluated according to the Standard EN 1534, using a steel ball with a diameter of 11.284 mm impressed into the wood surface with a force of 500 N. It was calculated by Eq. 5:

$$H_B = \frac{F}{S} = \frac{2 \times F}{\pi \times D \times (D - \sqrt{D^2 - d^2})}\ [MPa] \tag{5}$$

where: F – force on the ball [N], D – ball diameter [mm], d – diameter of the impressed area [mm].

RESULTS AND DISCUSSION

Weight percent gain (WPG)

The WPG values of polyethylene glycol PEG 6000 by beech wood specimens ranged from 5.49% to 8.26% depending on wood dimensions (Fig. 1).

Specimens having a relatively high portion of axial surfaces, *i.e.* of type (a) 25 mm × 25 mm × 5 mm (L × T × R) and type (b) 5 mm × 50 mm × 25 mm (L × T × R), had greater WPG values in comparison with specimens of type (c) 120 mm × 10 mm × 10 mm (L × T × R) having the smallest portion of axial surfaces.

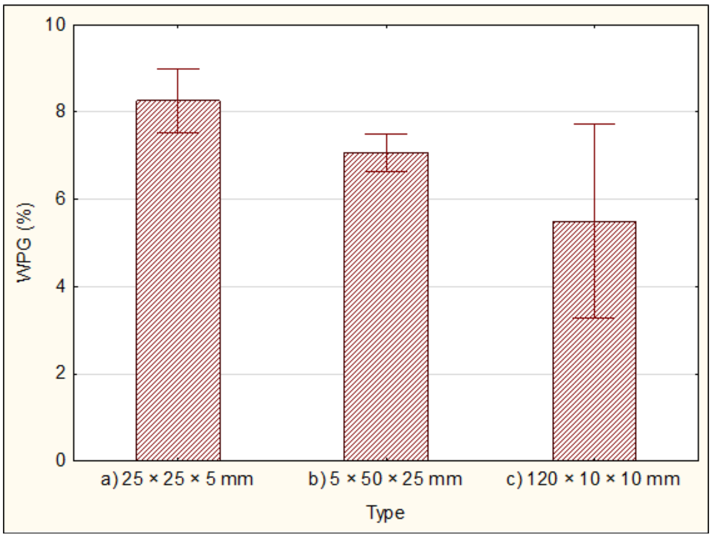
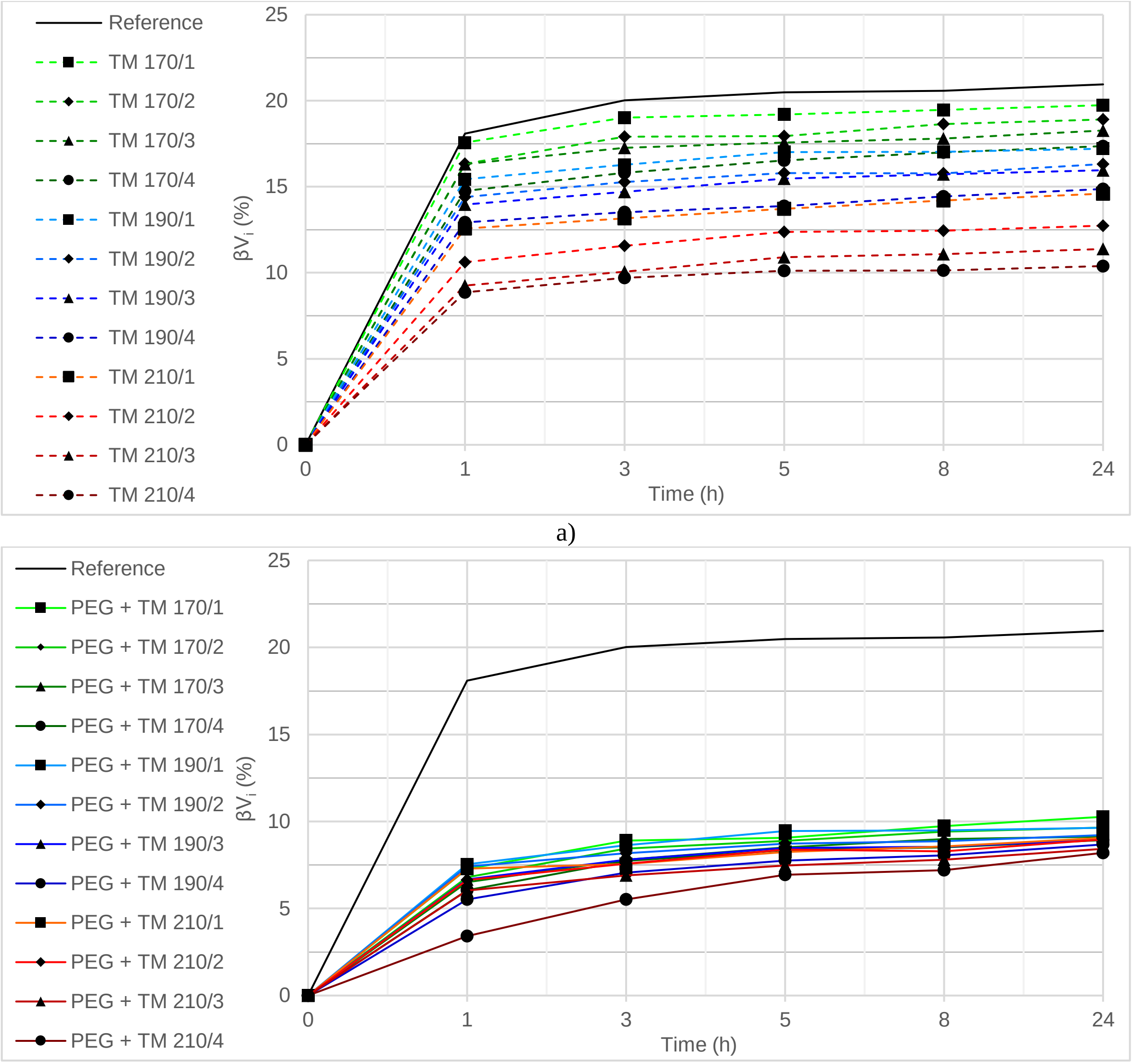


Fig. 1 WPG of PEG 6000 by beech wood specimens of types (a), (b) and (c).

Swelling and soaking

At the more severe thermal loads of beech wood specimens, *i.e.* from 170 °C / 1 h to 210 °C / 4 h, more apparent decrease in the kinetics of their volume swelling and soaking determined from 1 to 24 hours (Figs. 2 and 3), and also after 24 and 336 hours (Tabs. 1 and 2) occured. For example, after modification of beech wood specimens at a temperature of 210 °C for 4 h, the volume swelling determined after 24 hours decreased approximately about 50% (absolute decrease from 20.95% to 10.39%) and the soaking approximately about 25% (absolute decrease from 60.97% to 45.73%).

As already mentioned, in wood heated at high temperatures the hemicelluloses are depolymerized preferentially and the number of hydroxyl groups responsible for wood hygroscopicity is prominently decreased. LUNGULEASA *et al.* (2018), for beech plywood thermally treated at 200 °C for 3 h determined a reduction in the water absorption and thickness swelling about 70% and 60%, respectively. REINPRECHT and REPÁK (2019) found that as a result of beech wood paraffin-thermal modifications performed at 190 or 210 °C for 1, 2, 3 or 4 hours, there markedly decreased its soaking in water (in all cases by more than 30%) and volume swelling (from 26.8% to 62.9%). Similarly, REINPRECHT and VIDHOLDOVÁ (2008) found out that the soaking and swelling of beech and spruce woods were reduced due to thermal modification processes performed by the oil heat treatment (OHT) technology with rapeseed oil – maximally reduced in the case of the highest temperature of 220 °C acting for the longest time of 6 h.

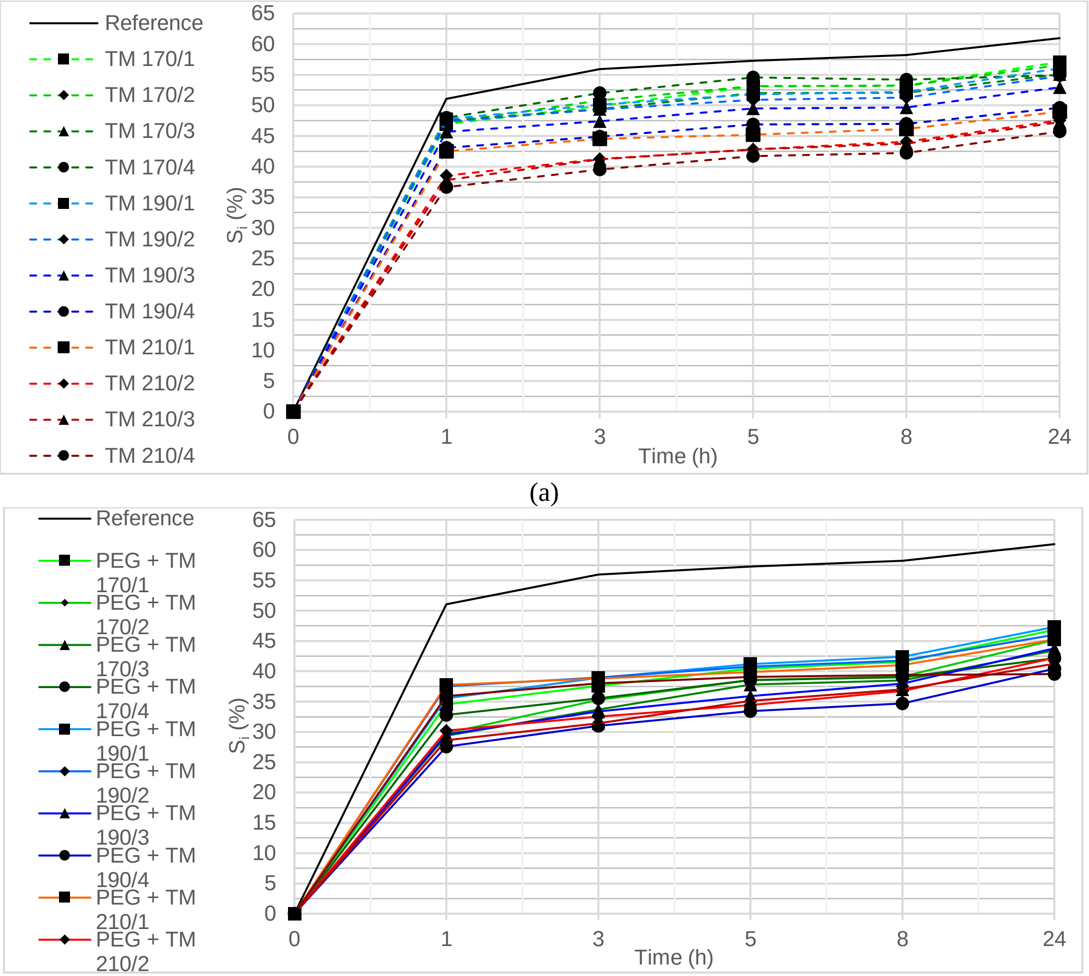


a)

(b)

Fig. 2 Volume swelling kinetics of the reference and thermally modified beech wood specimens – Not pre-treated = TM (a); Pre-treated with PEG 6000 = PEG + TM (b).

The polar polyethylene glycols (PEGs) are hydrophilic substances. PEG macromolecules can be in the pre-treated woods located not only in the cell lumens, but also in the cell walls depending: (a) on the dimensions of PEG macromolecules and also of new substances created from them at high temperatures; (b) on the additional conditionings of pre-treated woods in air-humid environment. Generally, PEGs with smaller macromolecules can better penetrate to the cell walls (Reinprecht 1995). The polymerization degree and 3D-size of PEG macromolecules can be decreased for example due to their thermal oxidative degradations already at temperatures below 100 °C, *e.g.*, in connection with a production of low molecular weight esters (Han *et al.* 1996). With a pro-longed impregnation/pre-treatment time and also with a pro-longed conditioning time, there better conditions for diffusion processes of PEG macromolecules (and also substances created from them at high temperatures) into micro-pores of the water-swollen cell walls of wood can occur. This fact shall apply for dimensional stabilization of archaeological wooden artefacts, when in the cell walls and cell lumens of wood are small vaporizable water molecules replaced with greater non-evaporable PEG macromolecules, and thus conserved wood is a permanently swollen. Hocker *et al.* (2012), Majka *et al.* (2018) and several other researchers studied moisture properties of wood containing polyethylene glycols in dependence on the different polymerization degree of PEG macromolecules, and on their different concentration in water, ethanol or other organic solvent. BRODA (2018) treated archaeological waterlogged oak wood with PEGs 400 and 4000 water solutions. The results of liquid water absorbability experiment clearly showed approximately about 50% decreased uptake of water by specimens treated with PEGs in comparison with untreated ones.



(a)

(b)

Fig. 3 Soaking kinetics of the reference and thermally modified beech wood specimens – Not pre-treated = TM (a); Pre-treated with PEG 6000 = PEG + TM (b).

The PEG 6000 ($\mathrm{HO\text{-}/CH_2\text{-}CH_2\text{-}O/_n\text{-}H}$) with molecular weight of 5000–7000 consists from relatively long linear macromolecules, which have polymerisation degree “n” from 130 to 140. Transport of the polar PEG 6000 from the lumens into the cell walls of wood is limited by dimension of its macromolecules and by dimension of the micro-pores in water swollen cell walls. In this experiment, the transport of PEG 6000 into the cells walls of beech wood specimens was, by our opinion, influenced and limited: (a) during the pre-treatment/impregnation process performed at 100 °C, *i.e.*, by a lower penetration possibility of greater PEG macromolecules and also from them at a temperature of 100 °C potentially created esters and other polar substances, in comparison to a good penetration possibility of small water molecules, so in a situation when the wood structure behaves like chromatography column (REINPRECHT and HUDEC 1995, REINPRECHT 1995); (b) during the air-humid conditioning of pre-treated wood specimens, *i.e.*, the diffusion possibility of PEG macromolecules (and eventually also substances created from PEG 6000 at thermal loads) from the cell lumens into the cell walls of wood primary saturated and swollen with small water molecules.

In accordance with the above mentioned facts, indeed the starting dimensions of the thermally modified beech wood specimens containing PEG 6000 were greater before the soaking and swelling tests comparing to the not pre-treated specimens. Subsequently, the volume swelling of the thermally modified beech wood should be and also was smaller for specimens pre-treated with PEG 6000 (Fig. 2, Tab. 1). Due to the presence of PEG 6000 in the thermally modified beech wood specimens, also more or less important decrease in their soaking in water occurred. This knowledge can be explained by a lower portion of empty pores and micro-pores in wood specimens containing PEG 6000 (Fig. 3, Tab. 2).

Tab. 1 Volume swelling of the reference and thermally modified beech wood specimens – Not pre-treated and Pre-treated with PEG 6000.

Thermal Modification	**Volume Swelling - β_{Vi} (%)**			
	24 h		**336 h**	
	Not pre-treated	**Pre-treated with PEG 6000**	**Not pre-treated**	**Pre-treated with PEG 6000**
Reference	20.95 (1.04)		21.25 (1.28)	
170 °C / 1 h	19.74 (0.56) c	10.27 (0.28) a	19.99 (0.67) d	10.37 (0.83) a
170 °C / 2 h	18.91 (0.48) a	9.65 (0.37) a	19.10 (0.48) b	9.74 (0.55) a
170 °C / 3 h	18.27 (0.20) a	9.13 (0.42) a	18.88 (0.20) b	9.42 (0.56) a
170 °C / 4 h	17.36 (0.76) a	8.93 (0.32) a	17.82 (1.00) a	9.40 (0.99) a
190 °C / 1 h	17.21 (0.21) a	9.64 (0.23) a	17.35 (0.66) a	9.72 (0.89) a
190 °C / 2 h	16.32 (0.52) a	9.22 (0.44) a	17.24 (0.81) a	9.52 (0.51) a
190 °C / 3 h	15.96 (0.38) a	8.96 (0.34) a	16.68 (0.30) a	9.17 (0.43) a
190 °C / 4 h	14.87 (0.39) a	8.68 (0.35) a	14.93 (0.54) a	8.75 (0.68) a
210 °C / 1 h	14.60 (0.64) a	9.06 (0.39) a	14.65 (0.32) a	9.10 (0.27) a
210 °C / 2 h	12.74 (0.13) a	8.97 (0.16) a	13.34 (0.37) a	9.01 (0.57) a
210 °C / 3 h	11.38 (0.56) a	8.43 (0.28) a	12.11 (0.57) a	8.51 (0.54) a
210 °C / 4 h	10.39 (0.13) a	8.20 (0.80) a	11.11 (0.65) a	8.32 (0.33) a

Note: Mean values are from four replicates. Standard deviations are in parantheses. The Duncan test, with significance levels a = 99.9%, b = 99%, c = 95% and d < 95%, was performed in relation to reference specimens.

Tab. 2 Soaking of the reference and thermally modified beech wood specimens – Not pre-treated and Pre-treated with PEG 6000.

Thermal Modification	**Soaking - S_i (%)**			
	24 h		**336 h**	
	Not pre-treated	**Pre-treated with PEG 6000**	**Not pre-treated**	**Pre-treated with PEG 6000**
Reference	60.97 (0.49)		90.65 (4.09)	
170 °C / 1 h	57.07 (2.18) c	46.84 (3.08) a	81.93 (4.10) b	64.52 (3.36) a
170 °C / 2 h	56.57 (1.28) c	45.17 (1.41) a	81.71 (5.36) b	63.84 (2.16) a
170 °C / 3 h	55.09 (1.07) b	43.45 (2.25) a	80.66 (2.37) b	61.84 (3.96) a
170 °C / 4 h	54.94 (1.80) a	42.15 (1.07) a	78.45 (4.06) a	57.30 (0.95) a
190 °C / 1 h	56.04 (1.04) b	47.31 (3.12) a	81.27 (1.80) b	62.09 (1.87) a
190 °C / 2 h	54.77 (2.84) a	46.02 (1.08) a	81.15 (3.11) b	61.41 (4.06) a
190 °C / 3 h	52.95 (1.53) a	43.79 (2.24) a	77.74 (5.25) a	60.92 (1.90) a
190 °C / 4 h	49.60 (1.69) a	40.42 (2.48) a	67.27 (1.90) a	56.78 (3.10) a
210 °C / 1 h	48.96 (1.27) a	45.25 (0.73) a	66.32 (1.54) a	61.80 (2.08) a
210 °C / 2 h	47.56 (1.63) a	42.21 (2.19) a	65.93 (3.93) a	61.24 (2.84) a
210 °C / 3 h	47.26 (2.50) a	41.25 (3.39) a	65.79 (1.16) a	59.78 (2.30) a
210 °C / 4 h	45.73 (1.26) a	39.54 (0.96) a	60.33 (0.53) a	55.13 (2.53) a

Note: Mean values are from four replicates. Standard deviations are in parantheses. The Duncan test, with significance levels a = 99.9%, b = 99%, c = 95% and d < 95%, was performed in relation to reference specimens.

Luo *et al.* (2012) found out that water absorption and thickness swelling of flour-wood polypropylene composites decreased with increased concentration of PEG 1000 in the wood substance. Treatment of wood with 30% water solution of polyethylene glycol reduced the 24 h water uptake and thickness swelling of this type of composite by 34.4% and 64.6 %, respectively. A following heat treatments of this type of composite with content of PEG provided an extra reduction in the thickness swelling (additional absolute decrease about 12.1–28.6%). Obtained results showed, similarly with our experiment, that the PEG pre-treatment and the following thermal modification can better improve the dimensional stability of wood composites as the alone thermal modification.

Impact bending strength and Brinell hardness

The impact bending strength of the thermally modified beech wood decreased in the range from 14.36% to 71.11% (absolute decrease from 5.92 J·cm^{-2} to 5.07 J·cm^{-2} until 1.71 J·cm^{-2}) – proportionally to an increase in the temperature and time of thermal modification (Tab. 3). It is especially caused by a significant thermal degradation of hemicelluloses situated between cellulose microfibrils in cell walls of wood and also due to organic acids resulting from the hemicellulose decomposition catalyzing the cleavage of lignin–polysaccharide matrix of wood (Zaman *et al.* 2000).

Similar results obtained Reinprecht and Repák (2019) for beech wood thermally modified in a paraffin melt at 190 or 210 °C from 1 to 4 hours when its impact bending strength decreased proportionally to increase in the temperature and time in the range from 17.84% to 48.33%. By Reinprecht (1992), the impact bending strength of poplar wood treated at a temperature of 210 °C for 3 h decreased as well as evidently about 61%. A strong decrease of the impact bending strength at several degradation processes, mainly of hardwoods containing 2–2.5 times more of pentosans in comparison to coniferous woods (Fengel and Wegener 2003), is owing to decomposition of pentosans and loss of their elastic-mechanical function in cell walls.

Tab. 3 Impact bending strength and Brinell hardness of the reference and thermally modified beech wood specimens – Not pre-treated and Pre-treated with PEG 6000.

Thermal Modification	**Impact bending strength** ***I*** **(J.cm^{-2})**		**Brinell hardness** ***H_B*** **(MPa)**	
	Not pre-treated	**Pre-treated with PEG 6000**	**Not pre-treated**	**Pre-treated with PEG 6000**
Reference	5.92 (0.97)		38.71 (3.40)	
170 °C / 1 h	5.07 (0.85) c	5.37 (0.58) d	37.75 (3.86) d	28.47 (1.96) a
170 °C / 2 h	4.73 (0.55) a	5.26 (0.21) c	35.07 (2.68) d	26.22 (3.67) a
170 °C / 3 h	4.63 (0.23) a	5.23 (0.48) c	35.02 (4.24) d	25.96 (4.88) a
170 °C / 4 h	4.55 (0.18) a	5.17 (0.32) c	34.63 (3.51) d	24.85 (1.96) a
190 °C / 1 h	4.05 (0.30) a	5.18 (0.32) c	36.11 (4.97) d	25.39 (2.31) a
190 °C / 2 h	3.76 (0.35) a	5.01 (0.42) c	35.02 (4.29) d	22.60 (2.33) a
190 °C / 3 h	3.51 (0.33) a	4.72 (0.56) a	33.61 (4.87) d	23.16 (3.81) a
190 °C / 4 h	3.38 (0.45) a	4.57 (0.26) a	30.72 (3.99) b	22.06 (3.84) a
210 °C / 1 h	2.83 (0.23) a	3.50 (0.22) a	27.85 (4.33) a	22.81 (2.73) a
210 °C / 2 h	2.33 (0.99) a	3.37 (0.17) a	27.00 (1.97) a	22.14 (3.43) a
210 °C / 3 h	2.12 (0.18) a	3.23 (0.30) a	24.75 (2.43) a	21.25 (3.51) a
210 °C / 4 h	1.71 (0.31) a	2.89 (0.49) a	22.68 (2.08) a	20.03 (2.55) a

Note: Mean values are from six replicates. Standard deviations are in parantheses. The Duncan test, with significance levels a = 99.9%, b = 99%, c = 95% and d < 95%, was performed in relation to reference specimens.

On the contrary, the presence of PEG 6000 in the thermally modified beech wood partly slowed down decrease of the impact bending strength, when its decrease ranged only from 9.29% to 51.18% (absolute decrease from 5.92 J·cm^{-2} to 5.37 J·cm^{-2} until 2.89 J·cm^{-2})

(Tab. 3). This finding can be explained by a protection effect of the polyethylene glycol macromolecules against the oxygen transport inside the cell walls of thermally exposed wood, in a connection with supressing the oxidation depolymerisation reactions in the lignin-polysaccharide matrix of wood (HILL 2006, REINPRECHT and VIDHOLDOVÁ 2011).

The Brinell hardness of the thermally modified beech wood decreased in the range from 2.48% to 41.41% (absolute decrease from 38.71 MPa to 37.75 MPa until 22.68 MPa), proportionally with the pro-longed time and increased temperature, especially at the highest temperature of 210 °C (Tab. 3). However, it should be stressed, that hardness of all thermally modified beech wood specimens containing PEG 6000 decreased more apparently, it means in presence of polar polyethylene glycol waxy-consistency macromolecules the hardness of thermally modified beech wood decreased in a greater margin from 26.45% to 48.26% (absolute decrease from 38.71 MPa to 28.47 MPa until 20.03 MPa).

Results of our experiment can be compared to results obtained by LUNGULEASA *et al.* (2018) who searched reduced Brinell hardness of beech plywood thermally modified at the temperatures of 160, 180 and 200 °C for 1, 2 and 3 hours. The Brinell hardness decreased about 16% at 180 °C for 3 h, or maximally about 40.6% at 200 °C for 3 h. On the contrary, the Brinell hardness slightly increased for specimens thermally modified at 160 °C. REINPRECHT and VIDHOLDOVÁ (2008) also determined a decrease in the Brinell hardness of beech wood by 1.5% to 33% when this wood species was modified in rapeseed oil at the temperatures of 180 or 220 °C for 3 or 6 hours. BORŮVKA *et al.* (2018) determined different changes in the Brinell hardness of thermally modified beech and birch woods at a temperature of 210 °C for 3 hours – hardness for beech wood decreased by 37%, bur for birch wood it increased by 9%.

CONCLUSIONS

- Beech wood had changed selected physical and mechanical properties, *i.e.*, soaking, volume swelling, impact bending strength and Brinell hardness due to thermal modifications performed at the temperatures of 170, 190 or 210 °C for 1, 2, 3 or 4 hours. These properties changed more intensively using more severe thermal regimes from 170 °C / 1 h to 210 °C / 4 h.
- The presence of polar and waxy-consistency polyethylene glycol macromolecules “PEG 6000” in beech wood before its thermal loads differently affected its final physical and mechanical properties:
    - PEG 6000 significantly reduced the volume swelling in water of the thermally modified beech wood specimens, and their soaking kinetics apparently decreased as well.
    - PEG 6000 slowed down decrease in the impact bending strength of beech wood caused due to high temperatures at its thermal modifications.
    - On the contrary, PEG 6000 participated in a more evident decrease in the Brinell hardness of the thermally modified beech wood.

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