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HIGH TEMPERATURE DRYING OF BEECH WITH CONTENT OF TENSION WOOD

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Abstract

The presented article is focused on comparison of tension and normal wood of beech (Fagus sylvatica L.) in a high-temperature drying process. Samples of 26 mm thickness were selected from sapwood zone with different angle of growth rings. The article evaluated properties of tension and normal wood before and after drying process. Properties which are monitored were moisture, moisture gradients, covering tests, colour changes and longitudinal warping. Tension wood and dominant cause of these defects is often attributed to the excessive axial shrinkage of reaction wood, which is driven by the shrinkage of the G-layer in tension wood. This scrutinised microscopic sign has many influences for other properties of tension wood in the technological processes.

Key words: *tension wood, normal wood, longitudinal warping, moisture gradient, high-temperature drying*

INTRODUCTION

Beech wood (*Fagus sylvatica* L.) is the most common wood species in Slovak republic. (ZELENÁ SPRÁVA 2015). Beech is wood with a high frequency of defects (red heartwood, reaction wood, splits, moulds), which affect its quality significantly. However, based on the citated work of authors KÚDELA and ČUNDERLÍK (2012) are findings 14 – 21 % ratio of reaction wood in beech logs. Tension wood affects the technologic properties of wooden materials since it has different physical, anatomical, and chemical characteristics in comparison with normal wood. Tension wood is thought of as an important wood defect because it causes negative alterations in solid wood quality and limits industrial utilization of wood. The different drying behaviour of tension wood in beech wood is removed. In fact, the difference in the drying rate curves of reaction and opposite wood gradually reduces when drying progresses to the bound water domain. The analysis of both mass diffusivity and density in beech tends to prove that the diffusion of bound water is relatively easy in tension wood. This is perfectly consistent with the structure of the G-layer (TARMIAN *et al.* 2009, TARMIAN *et al*. 2011, SHAVERDI *et al*. 2012 and TARMIAN *et al.* 2012). (DAVIS *et al.* 2002). SIAU (1984) demonstrated that difference in drying rate of tension and normal wood depends on moisture content. Specimen drying is more intensive in wood with moisture content above fiber saturation point. Water evaporation intensity is comparable with normal wood (approximately same like in normal wood).

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EXPERIMENTAL

MATERIALS

Beech wood (*Fagus sylvatica* L.) was used for experimental measurements. Samples were chosen from two beech logs with diameter 40 cm and length 5 m. Beech logs were selected from forests of Technical University in Zvolen. The selections of logs were qualified without visible defects like red heartwood, which can be affecting measurements. One of factors, to evaluate content of the reaction wood in logs is shiny appearance. When using this method we must brush surface of disks (8 cm) and then tension wood on the surface of lumber is more visible after drying process with temperature103±2 °C to 12 hours. This is also criterion for tension wood detection and then the content of reaction wood in lumber. Shine appearance is indicator (Fig. 1) of tension wood on the transverse plane. On the base of this zone we prepare cutting scheme of samples from logs. Test specimens of normal and tension wood with a thickness of approximately 26mm, width of 180 mm, and length 650 mm.

Fig. 1 a.) Eccentric pith, b.) Shiny appearance of tension wood

METHODS

Experimental measurements has chosen two-stage mode of drying process. The temperature of dry bulb was maintained at the value 100 °C the first phase of drying until the moisture content of the specimens did not fall below fiber saturation point. Temperature was increased to a maximum 120 °C after reducing the moisture content fall under the fiber saturation point. Average final moisture content was 8-10 %. The cooling of wood was a last section of the drying process. The drying rate was 3 ± 0. 3 $m.s^{-1}$. Specimens were dried by using special drying schedules in the HT laboratory dryer. The oven-dry method was used for the determination of moisture content. Weighing was performed with accuracy to the nearest 0.01 g. Drying to an absolute dry condition was performed in a laboratory kiln at 103 ± 2 °C. Moisture was calculated using Eq. 1.

$$w = \frac{m_w - m_0}{m_0}.100\ [\%] \tag{1}$$

where m_w *is the weight of the moist specimen [g] and* m_0 *is the weight of the absolutely dry specimen [g].*

Temperatures of test specimens were measured by thermocouples which were situated on the surface and middle layer as illustrated in the figure 2. Thermocouples were situated in reaction and normal wood.

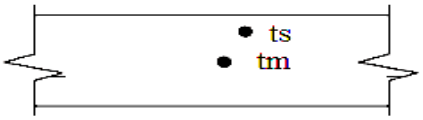

Fig. 2 The position of thermocouples

The size of the moisture gradient was calculated using the equation,

$$\Delta w = m_m - m_s \,[\%] \tag{2}$$

where m_m is the moisture of the middle layers [%] and m_s is the moisture of the surface layer [%].

Specimens for measure of covering with use by slicing test was prepare before and after drying process. Covering was measure through maximum space between two slices (Fig. 3).

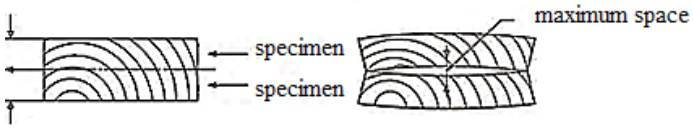

Fig. 3 Samples of measure covering – slicing test

Longitudinal warping was evaluated by maximum warping through length of the specimens (fig. 4).

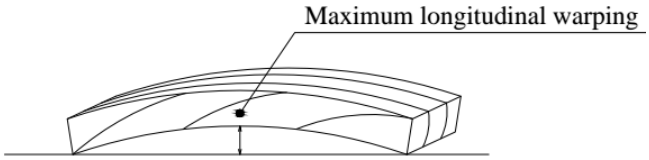

Fig. 4 Sample of measure longitudinal warping

RESULTS AND DISCUSION

Drying time is illustrated in figure 5. In sections 1 of the process, the temperature of the surrounding air was maintained at the boiling point of water 100 °C until the moisture content of the specimens did not fall below the fiber saturation point after 20 hours. Then, the temperature was increased to the maximum value of 120 °C. After achieving this phase of the final moisture content followed this operations final and cooling treatment and then drying process was completed after 28 hours. This temperature was maintained while final moisture content was of 8 %.

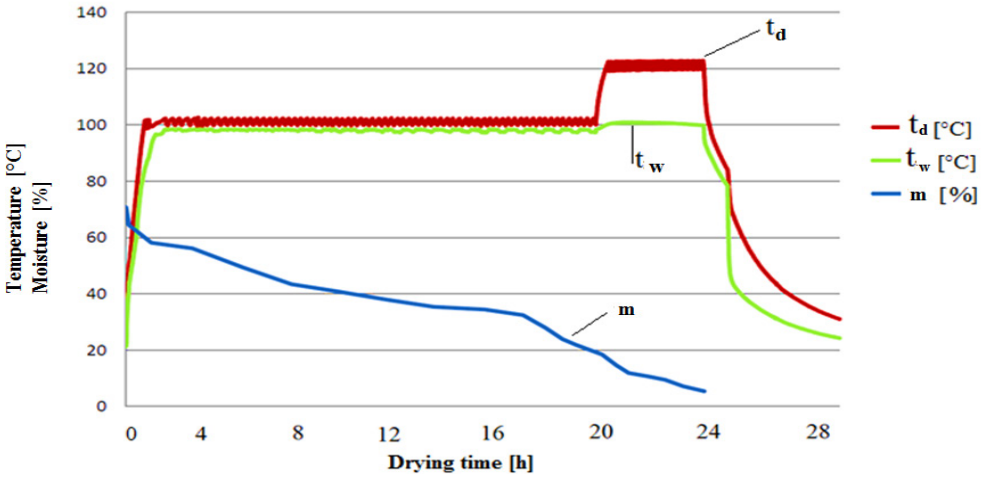

Fig. 5 High-temperature drying process

Figure 6 shows the temperature course of the sample surface and the middle layer. Course of temperature in the first phase was dried over fiber saturation point (FSP), which has achieved an average temperature of 97 ° C. After 18 hours temperature was increased to 120 °C is visible spread between the sensors in the specimen between tension and normal specimens. The tension samples showed a lower temperature than normal samples which may be due to different anatomical structures and thick cell walls too. Scrutinised final phase of treatment has not significant changes of temperature of thickness of the samples was straightened.

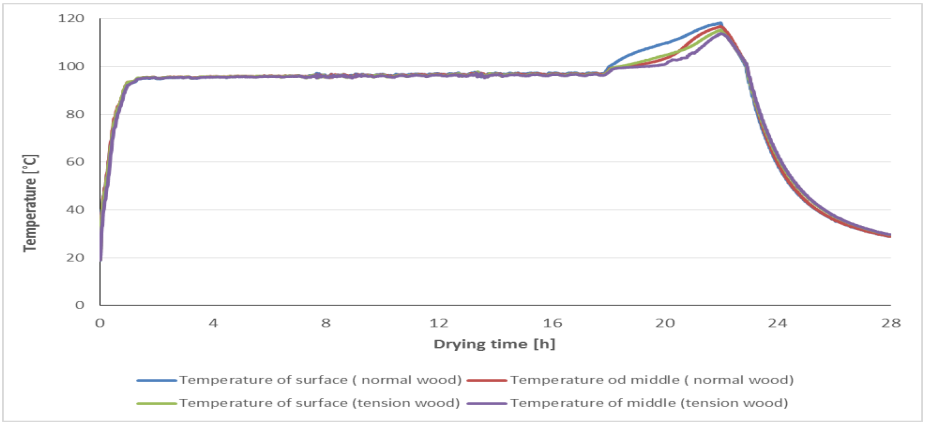

Fig. 6 Temperature course

The values of initial and final moisture and drying time are shown in table 1. Different initial moisture in the radial and tangential samples contains tension and normal wood could be caused by different structure of samples and sample position in a log too. The values of initial moisture are higher in the samples with content of tension wood, which is in agreement with the results of authors SIAU (1984) and DAVIS *et al.* (2002). Subsequently,

we can say that the drying of samples with tension and normal wood content were balanced and did not affect variability of initial moisture.

Tab. 1 the values of moisture and drying time reaction and normal samples

Test specimens		Moisture [%]		Time [h]
		Before drying	After drying	
Radial	tension	74.49	4.78	28
	normal	61.01	5.01	
Tangential	tension	76.88	4.85	
	normal	73.2	4.76	

The results here tend to prove that bound water diffusion is relatively easy in G – layer of tension wood. One first explanation could be chemical composition of this layer, which consists mostly of cellulose. Another possible explanation would involve the nanostructure of the G – layer, which contains mesopores producing an easy way for bound water migration CHANG *et al.* (2009). Scrutinised, of final moisture content confirmed our results that the variability of initial moisture content does not affect the final moisture even when using high temperature drying process. Our observations of the covering with use res-test method (Tab. 2) findings values before and after drying process showed the first grade. The final assessment of the tension and normal wood were not significant difference and the samples were graded in identical quality. The changes between samples with different angle of the growth rings have occurred in tangential samples were graded in two degree of quality, which can be to some affected by the anatomical structure and fact that tangential direction has higher shrinkage. The results are in good agreement with the thesis ČUNDERLÍK *et al.* (1992), which is dedicated that tension wood in a transverse direction substantially does not deform.

Tab. 2 The values of the covering (slicing test)

Test specimens		Slicing test [mm]			
		Before drying		After drying	
		Max. space	Quality	Max. space	Quality
Radial	tension	0.48	1. degree	0.81	1. degree
	normal	0.81	1. degree	0.88	1. degree
Tangential	tension	0.64	1. degree	1.42	2. degree
	normal	1.19	2. degree	1.1	2. degree

The values of longitudinal warping before and after drying process are shown in table 3. The values of longitudinal warping between tension and normal wood are less significant. The different values of longitudinal warping which were measured in tension wood before and after drying were significantly higher than in normal wood.

Tab. 3 The values of the longitudinal warping

Test specimens		Longitudinal warping [mm]	
		Before drying	After drying
Radial	tension	1.14	6.87
	normal	0.66	2.95
Tangential	tension	1.78	4.54
	normal	0.65	2.34

This fact can be explained by the value of shrinkage, that the tension wood has greater values in longitudinal direction. As well as arrangement of the tension wood in timber through thickness is significant factor too. The analysis of the physical properties confirmed that the main cause of deformation with content of tension wood has 6 times higher longitudinal shrinkage than normal wood (ČUNDERLÍK *et al.* 1992). This different angle of microfibrils in structure of the secondary cell wall is regarded like a significant factor between tension and normal wood.

CONCLUSIONS

Tension wood is a dominant cause of these defects it is often attributed to the excessive axial shrinkage of reaction wood, which is driven by the shrinkage of the G-layer in tension wood. This scrutinised microscopic sign has many influences for other properties of tension wood in the technological processes. On the basis of experimental measurements, we can conclude that the drying of tension and normal wood were less significant differences. Variability of initial moisture of tension wood was not significant and therefore has no significant impact on the final drying time. The tension samples showed a lower temperature than normal samples which may be due to different anatomical structures and thick cell walls too. The value of tension wood measured by covering and cross warping has not significant influence. The different values of tension wood were measured in longitudinal warping where higher values can be conclude by higher shrinkage in longitudinal direction. As well as arrangement of the tension wood in timber through thickness and length are significant factor too. Finally it can be conclude that influence of higher temperature with 120 ° C, has not significant factor.

ACKNOWLEDGEMENTS
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