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IMPREGNABILITY OF EUROPEAN BEECH FALSE HEARTWOOD AFTER MICROWAVE TREATMENT

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Abstract:

The purpose of this study was to experimentally evaluate the microwave radiation effect on weight percentage gain (WPG). The species European beech (Fagus sylvatica L.) was selected and testing samples from false heartwood with dimensions of 20×20×30mm^3 were used. The microwave treatment was carried out on laboratory device at a frequency of 2.45 GHz. Afterwards the oil impregnation in transverse directions was performed. Results were compared with the reference samples (untreated). The samples exposed at 20s intervals (20s treatment, 30s relaxation and 20s treatment) shows improvement of impregnability (WPG 33.84%), which is with agreement of authors hypothesis. The WPG at 30s intervals of exposure (30s treatment, 30s relaxation and 30s treatment) decreased to 26.59%. Based on results, the future work dealing with time influence of exposure in microwave treatment is needed.

Key words: *Impregnability; European Beech; False Heartwood; Microwave Modification, Fagus sylvatica L.*

INTRODUCTION

Beech is the most spread broadleaf species in forests of the Czech Republic. Its wood is a traditional material for wood-processing industry, although potential of use is not fully utilized. One of the most significant disadvantage is that it forms false heartwood, which is in the practise seen as a flaw reducing the quality of material entering the production process and thus also its utilization (Pouchanič 2011).

The formation of false heartwood in the beech is determined by two main factors: presence of ripe wood and air entering the wood structure. An absence of one of them prevents false heartwood from forming. A wound of the stem or a branch is a primary cause of air entering the tree stem. Oxygen contained in the air causes oxidation of soluble hydrocarbons and starch in living or partially dead parenchyma cells, while brown coloured polyphenolic compounds arise and enter the neighbouring tissues colouring them (Koch *et al*. 2001). At the same time, tyloses grow from parenchyma cells through pits between parenchyma cells and vessels and block them (Račko and Čunderlík 2010). The beech false heart wood is characterized by low durability and impregnability, which are important wood properties for exterior use. Species with low durability are usually improved by impregnation (Liu Hong-Hai *et al*. 2005). However, the anatomical structure of few species is due presence of several compounds in the cell walls characterized by low permeability (Torgovnikov *et al*. 2009). Vinden *et al*. (2000) mentioned that pine heart wood is almost unimpregnable. Similar results were obtained by Walker *et al*. (1993), which states that the heartwood cells are darker coloured because they contain extractable substances. These substances penetrate through the cell wall and lumen which leads to lower permeability of heart wood than sapwood. Microwave treatment leads to increase of permeability of heart wood and improve impregnability of substances into the wood structure (Vinden *et al*. 2000). Bao and Lu (1992) published study, where testing samples with average moisture content 24.5% were treated by using 5.7kW and 9kW of microwave energy. The experiments were done in two stages (20 or 30s intervals). Between stages was 25-30s lag for relaxation of material. Afterwards, the samples were impregnated. The higher WPG was observed in the samples treated by using 5kW in first stage and 9kW in second stage. It is believed that by using lower power during first stage occurs gradual plasticization of resin. In the next stage (with higher power) is the resin by steam and water forced out of the wood.

Aim of this paper was to find out the influence of microwave treatment on impregnability of false beech heartwood. The increase of permeability as well as impregnability by microwave radiation should be confirmed.

MATERIAL AND METHOD

Preparation of samples

The testing samples with dimensions 20×20×30mm^3 (R×T×L) taken from a section of beech *(Fagus sylvatica* L.*)* containing false heartwood were used. The section was without any indication of fungi or insect damage. The specimens did not contain defects, such as cracks, knots, pith, fibre deflection, or reaction wood. Before microwave treatment the samples were soaked in distilled water for 2 weeks. The material entering the process of modification contained 90% of moisture content on average.

Microwave treatment

The samples were treated in a laboratory microwave device at a frequency of 2.45GHz and output of 900W. The treatment process consisted of two intervals with a 30s pause in between for material relaxation (balancing of tension and decreasing of wood temperature). The experiment included two groups of treatment. The first group of samples was exposed to microwaves at 20s intervals (*20s treatment, 30s relaxation and 20s treatment*), the second group of samples was treated at 30s intervals (*30s treatment, 30s relaxation and 30s treatment*). To ensure homogeneity, the samples were treated separately.

Fig. 1
Microwave oven.

Coating of cross sections

The samples were after microwave treatment dried to 0% MC in an oven set at 103 ±2°C for 24 hours as mentioned in EN 13183-1:2002. To prevention that oil will be impregnated just from radial and tangential surfaces were cross section coated by urea-formaldehyde glue (purpose of the experiment was to find impregnability of microwave treated wood just from transverse directions). Kiln at 70°C was used to curing of glue.

Impregnation

Impregnation was carried out on laboratory vacuum–pressure impregnation device JHP1-0072 (Fig. 2). Initial moisture content of testing samples was 0%. Impregnation was performed by using impregnating oil Naturol (combination of hemp, soybean and linseed oil), which is suitable for wood protected against weather conditions. Impregnation was done in vacuum, by using pressure 10kPa for 120min.

Fig. 2
Vacuum – pressure impregnation equipment: JHP 1-0072.

Uptake of substance

Uptake of substance (oil) was calculated using the WPG (weight percentage gain) according to the formula:

$$WPG = \frac{m_m - m_n}{m_n} \cdot 100\ [\%] \quad (1)$$

WPG – weight percent gain [%]
m_m – weight of impregnated sample [g]
m_n – weight of unimpregnated sample [g]

RESULTS AND DISCUSSION

Changes in impregnability of microwave treated beech false heartwood were observed. Tab. 1 shows the calculated WPG (weight percentage gain) for all testing groups. The WPG of samples exposed at 20s intervals show an increase of impregnability in comparison with reference group. The average WPG was 29.37% for the reference group and 33.84 for treated group. The lower penetration uptake in comparison with references occurred in testing samples which were treated at 30s intervals. The average WPG of this treated group was 26.59%. Increase of weight percentage gain for samples treated at 20s intervals can be explained by generating steam in structure of wood. Internal steam pressure had effect on the pit membranes in cell walls, tyloses in vessels, and the weak ray cells, which leads to rupture wood pathways. This had a positive effect on the wood permeability and impregnability. It is believed that during microwave treatment the heartwood extractives (terpenes, phenolic compounds etc.) are plasticizied in addition to lignin plasticization. Those extractives could be by using longer microwave exposure forced from cell walls to lumens and intercellular spaces. Due that occurs lower permeability as well as impregnability.

Table 1

Results of weight percent gain (WPG)

Sample groups	Average [%]
Reference	29.37
20s intervals	33.84
30s intervals	26.59

As can be seen in graph (Fig. 3), because of high variability of output data the mentioned differences between treated groups (reference, 20/20s and 30/30s) are not statistically significant. Authors of paper expected increase of impregnability of treated wood; this hypothesis was in short treated group confirmed. Decrease of wood impregnability by using longer exposure (as can be seen in 30/30s group) will be intensively studied in next steps of research. The microscopic images could be useful to prove or disprove authors' theory about the leaching of heartwood extractives to lumens and intercellular spaces as a reason to decrease of WPG.

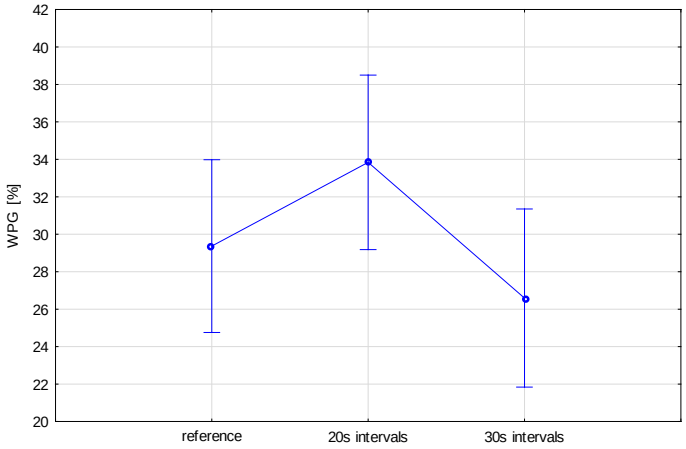
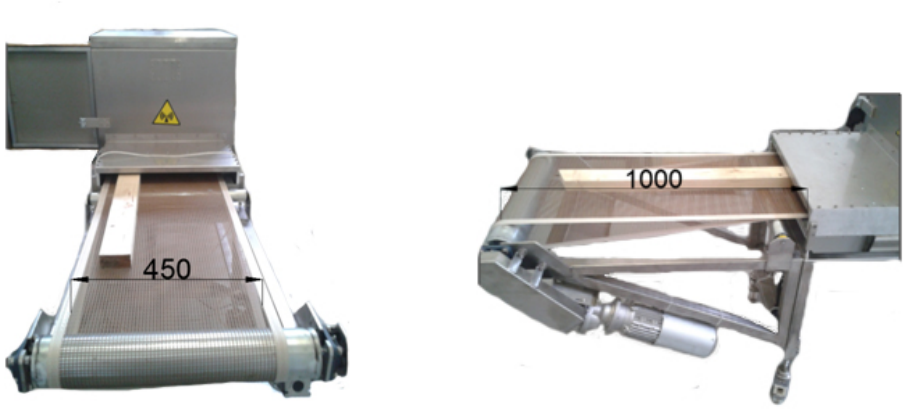


Fig. 3
Weight percent gain of different sample groups.

New microwave equipment

This study fallows the research of microwave treatment as a potentially useful method to improve the physical, construction and technological properties of wood. Based on recent activities in this topic, was on Department of Wood Science established a group dealing with the microwave modification. In co-operation with Romill company (CZ) was developed unique continuous microwave device (Fig. 4, 5) with power range from 0–7kW. In these days the testing experiments are in progress.



a **b**

Fig. 4
New MW equipment
a - front view; b - side view.

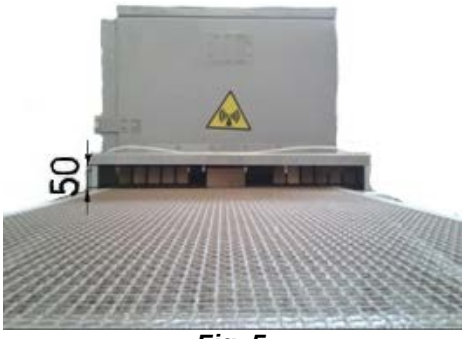


Fig. 5
New MW equipment – front detail.

CONCLUSION

The purpose of this study was to evaluate the influence of microwave treatment on impregnability of beech false heart wood. The microwave treatment was carried out on laboratory device at a frequency of 2.45GHz and output of 900W. The samples were divided to two groups and microwave treated at different time intervals of exposure (20s and 30s). Afterwards all samples were impregnated and the WPG test (weight percentage gain) was used to assess of impregnability. Reference group shows the average WPG 29.37%. The samples exposed at 20s intervals show the average WPG 33.84% which is with agreement of authors hypothesis, based on literature review (higher WPG after microwave treatment). The WPG of the samples exposed at 30s intervals decreased on average 26.59%. Based on these results the further experimental work needs to be done to study the effects of time exposure on impregnability of wood. Results provide a better understanding of microwave treatment, which probably contributes to a more controlled use of microwave treated wood in service conditions.

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