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EFFECT OF PRESS DRYING ON DIMENSION STABILITY AND DENSITY OF BEECH WOOD

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Abstract

Timber is traditionally dried in kilns by processes that often take several days or weeks to complete. At present, it is possible to apply several methods of rapid drying of timber, including, for example, press drying. This research is based on the use of this process. Drying was performed using the heating plates with a temperature of 160 °C. Three pressures were compared in the research 1.0 MPa, 1.4 MPa, and 1.8 MPa. The density of the samples remarkably increased during press drying. The pressure of the heating plates had a substantial effect. The difference in the average density between the pressure of 1.0 MPa and 1.8 MPa was more than 92 kg.m^{-3}. A larger increase in density was discovered for radial samples (ranging between +95.31 to+110.85). The difference in the change of sample thickness was larger in the case of the tangential samples. For both groups of samples (radial, tangential) and all pressures, the samples dried by the contact method were more stable during swelling than the samples dried by the convection method.

Key words: press drying; beech wood; density, dimension stability, pressure

INTRODUCTION

The timber is traditionally dried in kilns by processes often taking several weeks. According to the research [1] should press drying understood as a method of rapidly removing water from the wood. The process of press drying can be defined as the application of heat to the opposite surfaces of timber by heating plates to remove moisture from the timber. Temperatures for press drying range from 130 up to 190 °C. During drying, the heat is transferred, mainly by conduction [2]. However, this rapid removal of water and the high-temperature cause modification in the wood such as darkening of natural colour in the case of some tree species. Press drying offers many advantages such as keeping the wood flat during drying, short time of drying, etc. Based on the research [3] the sawing pattern did not affect the drying time to a large extent. Following the paper showing [4] that a 10-minute difference can occur between a quarter-sawn board and flatsawn. The author of [5] mentioned in his work that drying time for beech wood was only 2 hours from 80% to 3% of moisture content (MC). In addition, contact drying can affect the dimensional stability or density of dried samples, as evidenced by several studies [6,7]. According to work [6] was performed on 24 mm-thick specimens from three species of coniferous wood

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(pitch pine, larch, and white pine) where press dried under two-platen pressures of 0.17 and 0.34 MPa to obtain drying information regarding drying rate, thickness shrinkage, and drying defects. The influence of platen pressure on drying fare in the range of moisture content (30 to 10%) increased for pitch pine and larch but reduced for white pine at higher pressure. Thickness shrinkage was increased at the higher pressure, and estimated thickness shrinkage at final MC of 10 percent became unrealistically greater for specimens containing higher final moisture content under the influence of compressive strain. Comparable observations [7] were researched density profiles by hot-press drying. Specimens were oven-dried temperatures at 115, 135, 160, 185, and 205°C, respectively. The thickness of the sample was dimensions of 50 mm (longitudinal) by 50 mm (tangential). Drying was under way placed between two plates with a pressure of 3.5 MPa applied in the radial direction. Hot-press drying created an M-shaped curve of density: high density at the two surface regions that gradually decrease toward the core region. During hot-press drying, wood became plastic and could undergo large deformation under the combined effect of moisture, high temperature and mechanical compression. As the drying process progressed, heat and water evaporation gradually moved inwards and resulted in the densification of the core layer. Consequently, surface regions in the timber were compressed more than core regions and a density profile is created. Surface regions had a density from 600 to 850 $kg.m^{-3}$ and the core regions had a density only ranging between 400-450 $kg.m^{-3}$.

Next observations [8] investigated the effect of heating platens temperature on the temperature and pressure inside poplar timber was investigated. Samples of poplar timber were with dimensions 400 × 120 × 25 mm (l × t × r). Results showed when the heating platens' temperature increase from 120 to 140 °C, the maximum values of temperature and pressure also increase by 14.5 and 26.2%, respectively. Moisture at the centre layer of poplar timber with MC above FSP was in a liquid state, i.e., unsaturated water under overpressure conditions in the hot-press drying process. Flashing occurred to the unsaturated water in poplar timber during the opening period of heating platens and resulted in the decrease in MC. This phenomenon was the main moisture transfer mode in the wood hot-press drying process with MC above FSP.

The objective of this research was to evaluate the effect of press drying process on the density and dimensional stability of beech wood with the use of different pressures.

MATERIAL AND METHODS

Beech wood (*Fagus sylvatica* L.) were used for the experimental measurements. The Sample were chosen from two beech logs with a diameter of 40 cm and the length of 300 cm. The forest located in the part called Môťová (475 m.a.s.l.) belonging to the University Forest Enterprise of the Technical University in Zvolen, Slovakia.

Radial and tangential samples were cut out (*longitudinal and cross section sawing)* from the log, according to sawing patterns (Fig. 1). Dimensions of drying samples were 120×800×30 mm (w × l × t).

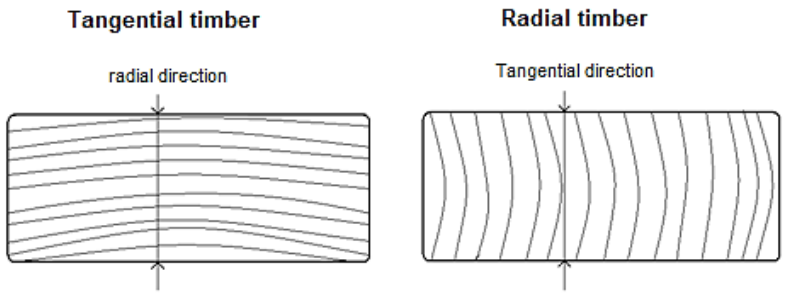

Fig. 1 Radial and tangential samples used in contact drying

The process of press drying was conducted in hydraulic single storied press type CBJ 500 - 5 (TOS RAKOVNIK). Temperature of the heating plates was 160 °C. Used were three specific plate pressures of 1.0, 1.4 and 1.8 MPa. The group of samples were dried until the temperature measured in the centre of the sample reached the temperature of the pressing plate (t_p = 5°C). The press drying in the was completed at that time. One filling always consisted of samples from one radial and one tangential log (R and T).

The regime of contact drying was consisting of three phases (I - III.). Samples were dried at a constant temperature (II.) after gradual rise in temperature (I.) to 160 °C. The cooling phase was (III.) after reaching the desired temperature in the centre of the samples. The last phase was air conditioning at 20 °C.

Convection hot air drying in the Memmert HCP laboratory dryer was used to compare the changes in the monitored properties of the sample groups. The standard drying regime according to ON 490651 for the given wood species, thickness, and initial moisture were used. The samples were also cut to determine initial moisture content and density as well (Fig. 4). Initial MC and final MC of wood was determined using the gravimetric method according to STN EN 49 0103. The moisture content was calculated using Eq. 1,

$$MC = \frac{m_w - m_0}{m_0} \cdot 100\ (\%) \tag{1}$$

Where: mw is the weight of the wet sample (g) and m0 is the weight of the absolutely dry sample (g)

Density in oven-dried state was measured before and after drying. The measurement was performed under laboratory conditions. The density (ρ_0) of wood at 0% moisture content was measured according to STN EN 49 0108. The oven-dried density was calculated using Eq. 2,

$$\rho_0 = \frac{m_0}{V_0}\ (\mathrm{kg.m^{-3}}) \tag{2}$$

Where: m_0 is the weight of oven-dried moisture samples (kg) and V_0 is the volume of oven-dried moisture samples (m^{-3}).

Thickness and width of the samples were measured before and after every contact drying with an accuracy of 0.01 mm. The samples were placed in an air-conditioning chamber at a temperature of 20 °C and a relative humidity of 60% after contact drying. Similarly, samples after convection drying were measured and conditioned. The dimensions of the samples were measured again after conditioning (Fig. 2).

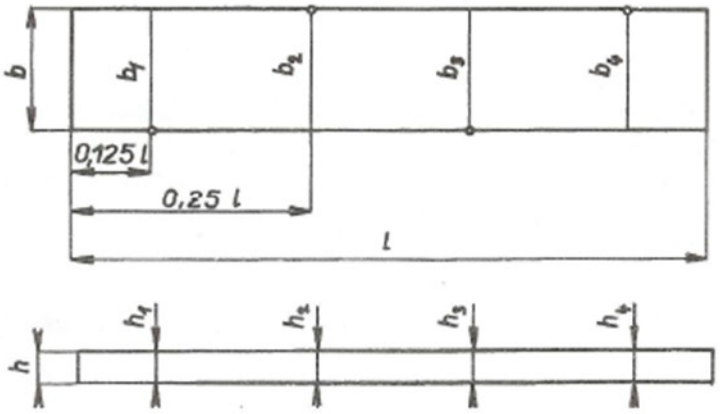

Fig. 2 Scheme of measuring the thickness and width of samples

All samples were still conditioned to an equilibrium moisture content of ≈20% and then the thicknesses and widths of the samples were measured (Fig. 4 and 5). From these values, the stabilizing effect of contact drying on the width using the anti-drying factor was evaluated:

$$F_b = \frac{b_{KV} - b_{KT}}{b_{KV}} \cdot 100 \qquad (\%) \tag{3}$$

Where: b_{KV} swelling of wood in width, dried by convection, transferred from one state of moisture balance to another (%),

b_{KT} - swelling of wood in width, determined by the contact method, transferred from one wood state of moisture balance to another (%).

Effect of contact drying on thickness:

$$F_h = \frac{h_{KV} - h_{KT}}{h_{KV}} \cdot 100 \qquad (\%) \tag{4}$$

Where: h_{KV} Swelling of wood in thickness, dried by convection, transferred from one state of moisture balance to another (%),

h_{KT} - Swelling of wood in thickness, dried by the contact, method transferred from one state of moisture balance to another (%).

RESULTS AND DISCUSSION

Table 1 shows the measured average values of the initial and final humidity of individual groups of samples and the total time of contact drying. The average values of the density of the samples in the dry state before and after drying and the increase in the average density of the samples due to contact drying are also shown here.

Tab. 1 Initial and final moisture of the samples, drying time, and density of the samples

Type of samples	Pressure of plates (MPa)	MC (%)		Drying time (min)	Density ρ_0 (kg.m^{-3})		
		Initial	Final		Before drying	After drying	Change of density (kg.m^{-3})
Radial	**1.0**	77.48	3.95	80	675.61	770.92	+95.31
	1.4	80.27	6.08	80	684.16	785.15	+100.99
	1.8	69.5	5.52	90	675.62	786.47	+110.85
Tangential	**1.0**	71.87	5.78	100	669.93	722.07	+52.14
	1.4	54.14	5.37	110	663.08	752.35	+89.27
	1.8	55.54	4.87	90	666.95	774.85	+107.90

It can be seen from the measured data that the initial moisture content of the samples was from 54.14 to 80.27% and the final moisture content was from 3.95 to 6.08%. Drying time was shorter for radial samples, while plate pressure had no effect on drying time, nor was the effect of sample type significant. As a result of contact drying, the density of the samples increased by an average of 92 kg.m^{-3}, while the influence of plate pressure on the density value was confirmed. A larger increase in density was discovered for radial samples (ranging between +95.31 to +110.85 kg.m^{-3}). This difference was caused by the direction of the plate pressure. In the case of radial samples, the direction of the pressure was tangential, the densification, and thus the increase in density was greater. For tangential samples was an increase ranging from +52.14 to +107.90 kg.m^{-3}. Similarly, observations [7] were researched density profiles by hot-press drying at temperatures of 115, 135, 160, 185, and 205°C, respectively, and a pressure of 3.5 Mpa which was applied in the radial direction. Results showed that drying for these conditions creates an M-shaped curve of density: high density at the two surface regions that gradually decreased toward the core region. Surface regions had a density from 600 to 850 kg.m^{-3} and the core regions had a density only ranging between 400-450 kg.m^{-3} The next study [6] similarly discovered that contact drying can affect the density of dried samples.

The change in the dimensions of the samples depending on the drying time is shown in Figures 3, 4 and 5.

The impact of plate pressure during contact drying was more remarkable for tangential samples, where a thickness change of 6.75% was measured at a pressure of 1.0 Mpa and a 23.3% change in thickness at a pressure of 1.8 Mpa (Fig. 4). In the case of radial samples, the impact of plate pressure was almost insignificant and the differences in the change in the thickness of the samples, at individual pressures, were less than 1.0% (Fig. 3). The differences in the change of the thickness of the samples were caused by the fact that the direction of the pressure is in the tangential direction for the radial samples and in the radial direction for the tangential samples. The values of the change in the width of the samples are significantly smaller than the change in thickness (less than 3%). The effect of pressure on the change in width was confirmed for both radial and tangential samples (Fig. 5). However, the effect of plate pressure is opposite to the change in thickness. As the pressure

of the plates increased, the change in the width of the samples was smaller. Greater values of the change in width were observed when evaluating the change in this dimension after conditioning the samples to a humidity of 12%. Research [6] was performed on 24 mm-thick specimens using three species of coniferous wood (pitch pine, larch, and white pine) where press dried under two-platen pressures of 0.17 and 0.34 Mpa. The initial moisture content of samples was from 30 to 89%. Results confirmed that thickness shrinkage was caused by increased at the higher pressure.

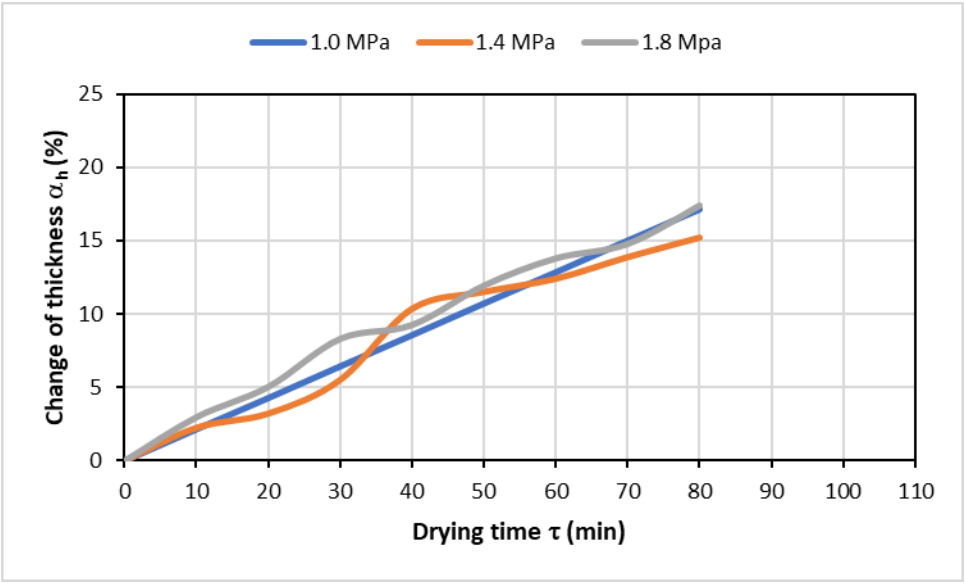

Fig. 3 Thickness change at different contact drying pressures – radial samples

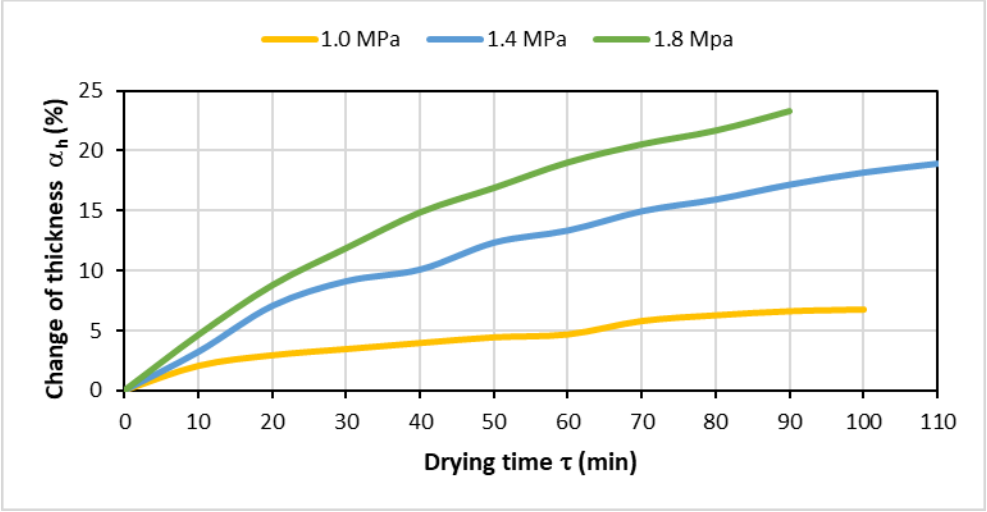

Fig. 4 Thickness change at different contact drying pressures – tangential samples

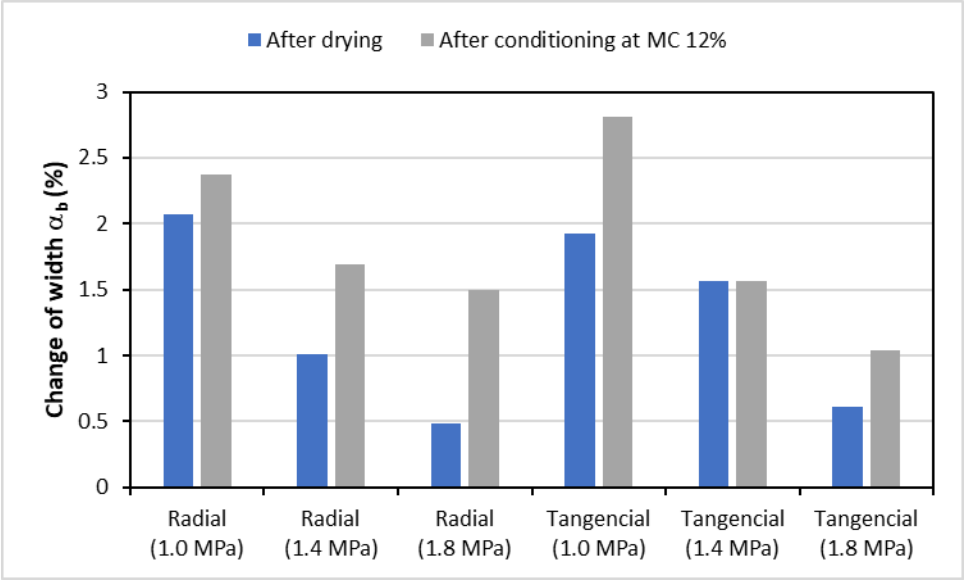

Fig. 5 Width change at different contact drying pressures and samples

Based on the measured changes in the dimensions of the group of samples during contact and convection drying, the values of the anti-drying factor were calculated (tab. 2 and 3).

Tab. 2 Dimensional change during contact and convection drying and anti-drying factor: radial samples

Measurements	Press drying						Convection drying	
	Pressure 1.0 Mpa		Pressure 1.4 Mpa		Pressure 1.8 Mpa			
	Thickness	Width	Thickness	Width	Thickness	Width	Thickness	Width
Before drying (mm)	30.19	110.39	31.10	111.37	30.19	110.66	30.91	110.45
After drying (mm)	25.03	108.10	26.45	110.25	24.83	110.12	28.24	107.61
After air conditioning MC=12% (mm)	25.82	107.77	26.65	109.49	25.09	109.00	27.37	105.59
After air conditioning MC=20% (mm)	28.09	109.56	29.32	111.59	27.74	111.21	28.42	109.42
The difference before and after drying (%)	17.09	2.07	14.95	1.01	17.75	0.49	8.64	2.57
Difference after air conditioning from 12% to 20% (%)	8.08	1.63	9.12	1.88	9.54	1.99	3.70	3.50
Factor F_h / F_b (%)	**-118.3784**	**53.4286**	**-146.4865**	**46.2857**	**-157.8378**	**43.1429**	**-**	**-**

Tab. 3 Dimensional change during contact and convection drying and anti-drying factor: tangential samples

Measurements	Press drying						Convection drying	
	Pressure 1.0 Mpa		Pressure 1.4 Mpa		Pressure 1.8 Mpa			
	Thickness	Width	Thickness	Width	Thickness	Width	Thickness	Width
Before drying (mm)	30.3	110.68	30.41	110.65	29.97	110.51	30.61	110.55
After drying (mm)	26.96	108.55	25.03	108.92	23.47	109.84	29.38	106.25
After air conditioning MC=12% (mm)	27	107.57	24.95	108.92	23.19	109.36	28.59	105.03
After air conditioning MC=20% (mm)	28.77	108.78	26.63	110.30	24.88	110.95	29.69	110.09
The difference before and after drying (%)	11.02	1.92	17.69	1.56	21.69	0.61	4.02	3.89
Difference after air conditioning from 12% to 20% (%)	6.14	1.11	6.32	1.25	6.81	1.43	3.7	4.6
Factor F_h / F_b (%)	**-65.95**	**75.87**	**-70.81**	**72.83**	**-84.05**	**68.91**	-	-

The anti-drying factor F inform the stabilizing effect of contact drying compared to convection drying. The results of F_b mean that for both groups of samples and all pressures. The samples dried by the contact method are more dimension stable in swelling than the samples dried by the convection method. For thickness swelling. The calculated F_h values were negative.

This means that the thickness swelling of the samples during contact drying was greater by the indicated F_h values at all pressures compared to convection drying. The bigger difference was at the radial samples.

CONCLUSION

The aim of the work was to determine the effect of contact drying on the change in thickness and width of the samples. well as the overall dimensional stability and change in density due to the different pressure used during contact drying. Samples with a thickness of 30 mm with radial and tangential course of annual rings were used for drying. Drying was carried out at a temperature of heating plates of 160 °C and a pressure of 1.0 MPa. 1.4 MPa and 1.8 MPa. The results were compared with classic hot air drying.

The following conclusions can be drawn from the measured data:

- Contact drying is very intensive, and a low final moisture was achieved in a short drying time.
- Radial samples dried faster than tangential ones. while plate pressure did not have a significant effect on drying time. during contact drying. the density of the samples increased significantly. the pressure of the plates had a significant effect on the density increase.
- In radial samples. the density increased by an average of 102 $kg.m^{-3}$ and in tangential samples by 83 $kg.m^{-3}$.
- The average thickness change for radial samples was 16.6%. while plate pressure had no significant effect. In the case of tangential samples. the influence of plate pressure was significant and the change in the thickness of the samples was in the interval from 7 to 23%.
- The change in width of the samples during contact drying was almost the same for radial and tangential samples. with the largest values at the lowest plate pressures.

- For both groups of samples (radial. tangential) and all pressures. the samples dried by the contact method were more stable during swelling than the samples dried by the convection method.
- Thickness swelling of the samples during contact drying was greater compared to convection drying. The bigger difference was with the radial samples.

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