Influence of drying technique and process conditions on the drying quality of beech wood (*Fagus silvatica* L.)

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ABSTRACT

Complex structure and specific feature of European beech wood (Fagus silvatica L.) have great influence on its specific drying characteristics, which are often negatively expressed as various drying defects. Therefore, four drying techniques, i.e. controlled air drying, normal temperature kiln drying, vacuum drying and drying with high frequency (HF) were compared to achieve the best technique. Quite the same quality, 32 mm thick beech wood samples were dried from green condition to the final moisture content of 10%. At successive time intervals during drying processes wood quality was evaluated regarding drying rate, time of drying, moisture content (MC) gradient, casehardening and occurrence of drying defects. Drying with the HF was the fastest, followed by vacuum drying and kiln drying. In air drying wood kept good quality, with the lowest MC gradient, however too high MC of wood was achieved. Low MC gradients were confirmed at vacuum and HF drying, where the latter was applicable only at MC below fiber saturation point (FSP). Good drying quality, concern casehardening and visual appearance was achieved at vacuum drying process, quite comparable to air drying. In this research the vacuum drying was assessed as the most preferential techniques for drying beech wood.

Key words: *air drying, kiln drying, vacuum drying, HF drying, drying rate, drying quality*

INTRODUCTION

Beech wood (*Fagus silvatica* L.) represents in Slovenian woodworking industry very important part, in a sense of quantity and quality as well as in a sense of value. Complex structure and specific feature of European beech wood have great influence on its specific drying characteristics, which are often negatively expressed as various drying defects, mostly depending on process conditions.

In dying practice a combination of different techniques has been applied to take advantage from them or air pre-drying to minimize the energy consumption, despite unpleasant oscillating climate conditions, has been used. For using more different drying techniques, especially for drying beech wood, we can find some reasons: c.f. annually we have usually two main cutting seasons with concentration of great amount of fresh logs and sawn wood; the drying capacity in the industry is limited; with exploitation of natural condition we get better energy effectiveness of drying. Generally, the aim of the drying process is to achieve the optimal quality in shortest drying time and with minimum energy consumption. According to achieve sufficient drying quality of dried wood for wood products with the best quality and with great added value we have to choose convenient drying techniques for each drying period.

In our examination we investigated drying kinetics and quality of wood dried with different techniques. With analyzing drying curve and rate of drying we would like to predict favorable drying techniques for wood for different end use. With the model it would be able to choose the best combination of drying techniques and to calculate the optimum MC at which change of drying techniques would bring the best results.

To attain the main goal of examination we analyzed and compared four drying techniques: air drying, normal temperature kiln drying, vacuum drying and drying with high frequency (HF). Drying processes were evaluated regarding drying rate, time of drying, moisture content, moisture content gradient, casehardening and occurrence of drying defects.

MATERIALS AND METHODS

For the experiment we used fresh beech wood boards with 78±12% average initial moisture content. High quality 32 mm thick boards were cut into four 60 cm long pieces with quite the same quality. All boards were also cut to the same with of 80 mm. We tried to get board with tangential orientation. We assured comparable material for further examination. In each drying process we controlled kinetics of drying and quality of wood on 13 samples with dimension 32 mm x 80 mm x 600 mm. Beech wood samples were dried from green condition to the final moisture content of 10%.

The accurate initial moisture content and moisture gradient were determinate by gravimetrical method (EN 13 183-1). During drying processes we followed the MC changes with eclectic resistance moisture meter (EN 13 183-2). At successive time intervals all samples were weighted and MC was calculated. At the same time smaller controlled samples were taking out to define précis MC, moisture content gradient and casehardening (Welling, 1993).

At the end of drying wood quality was evaluated regarding drying rate, time of drying, moisture content, moisture content gradient, casehardening and occurrence of drying defects.

Due to very variable climate condition we followed the air drying during spring and winter period. At the beginning of experiment the evaluation of MC, MC gradient and casehardening was done every 3 days and after two weeks of drying every 7 days. Air temperature and relative humidity were noted at the same time intervals.

For »conventional« drying experimental kiln dryer was used ($V = 1\ m^3$). Drying schedule was adapted due to experience and same specific characteristics of the kiln. Drying conditions in the kiln was controlled with dry and wet bulb temperature through regulation system Vea. Every two hours dry and wet bulb temperature, mass of wood, energy consumption, as well as MC on 6 places were registered.

Vacuum drying was simulated in small vacuum-pressure chamber. Climate condition in the chamber was regulated with pressure and temperature. The industrial drying schedule was adjusted to the possibilities of laboratory chamber. During drying process every 15 minutes the wood and chamber temperature, moisture content and pressure were collected with date acquisition system

We used the HF only for drying wood below FSP; before fresh wood was carefully dried in the controlled climate chamber to moisture content around FSP. HF generator had 4 stage regulations of power. The wood samples were evaluated at successive time intervals (25 min.) with measuring: mass, moisture content and temperature on the surface and in the centre of the samples.

RESULTS

Air drying

During air drying of beech wood we perceived and confirmed significant influence of season. The average drop of moisture content per day in spring time was 6,1 %, meanwhile in winter period the drying rate decreased to 2,2 %/day. So favorable drying was achieved in spring but the constant drying rate was relatively short (about 1 week). First period with constant rate was finished at 46 % average moisture content (Fig. 2A). But at less favorable winter period constant drying rate period lasted at least 3 weeks and finished at lower average moisture content (at about 36 %). In both seasons more than half of water was driven from wood during constant drying rate. As expected the drying rate was continued with exponential decreasing and was finished with achieving the equilibrium moisture content of environment.

The rate of air drying in spring as well as in winter time was good correlated with exponential mathematical model (Fig. 1).

$$\frac{\Delta u}{\Delta t} = \frac{a}{1 + e^{(-k(u-u_c))}}$$

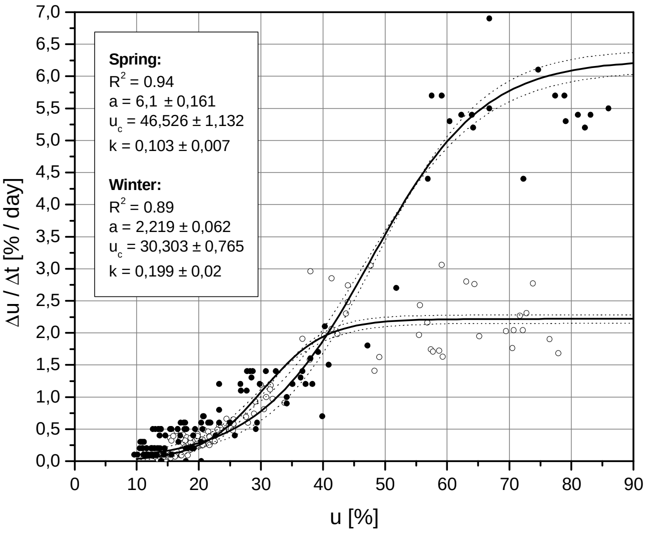


Fig. 1 Drying rate during air drying in spring and winter.

More favorable drying during spring months induced in wood grater moisture gradient. Relatively fast drying of surface caused that MC of surface fell below FSP and interrupted the effective flow of capillary water from the core of the wood. Slower drying induced smaller moisture gradient so there was very little danger for appearance of diffusion barrier on the wood surface.

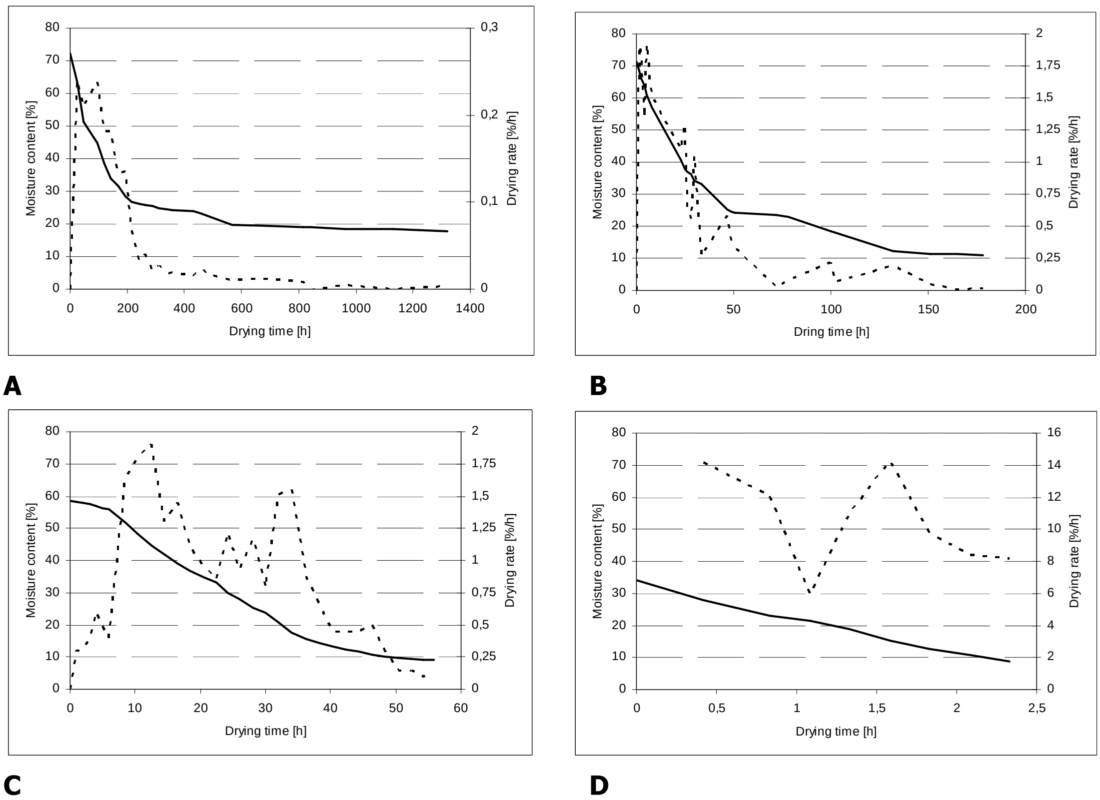


Fig. 2 Drying curves and drying rates for A/ air, B/ kiln, C/ vacuum and D/ HF drying.

Kiln drying

Overall drying time in the kiln drying was 178 hours (heating 8 h, drying 143 h, conditioning 27 h). At the beginning the drying was very intensive, but drying rate dropped very quickly and decreased exponentially to the final moisture content (Fig. 2B).

The beginning of drying induced very sharp moisture gradient (Fig. 3). Consequences were seen in generating drying stresses which could cause surface checking or casehardening at the end of drying (Fig. 4). Therefore, kiln drying hat to be fished with conditioning.

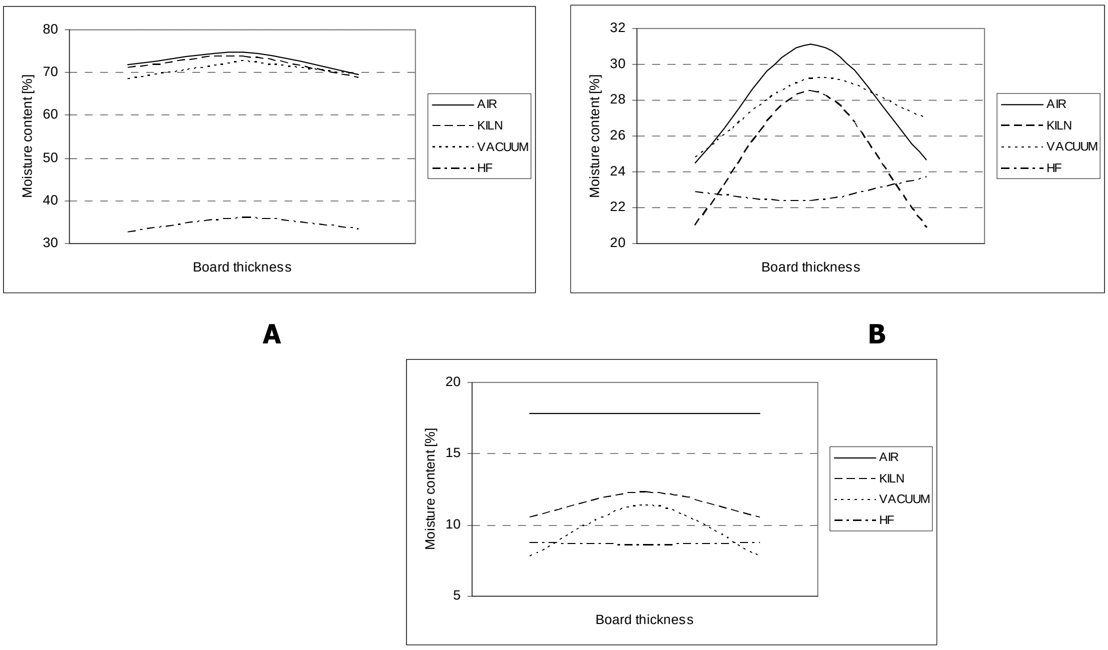
Vacuum drying

The complete time of continuing vacuum drying was very favorable (58 h). The drying rate during first period was not so high but last till MC dropped well below FSP (Fig. 2C). We concluded that quite all free water was eliminated through capillary flow. Also the decrease of diffusion flow was not significant as in other drying techniques (c.f. Ressel 1999).

The drying rate in vacuum was comparable with that achieved in kiln drying, but favorable conditions lasted in vacuum drying much longer with smaller moisture gradient (Fig. 3). Despite of small moisture gradient or potential the drying was relatively fast until 20 % average moisture content was reached. Because of small differences between MC on the surface and MC in the core, also drying stresses was not so distinctive (Fig. 4). The risk for split or wrap of wood was therefore very small.

HF drying

Before drying the wood in the dielectrics field of high frequency we hat to dry it to MC just about FSP, so we have no date about effectiveness of HF drying of green wood. HF drying below FSP was very effective and the rate of drying was 10 times higher than in others drying techniques (Fig. 2D). Before drying with HF the MC in the core was a little higher than at the surface. The temperature at the core of the wood increased faster than in the surface, therefore the condition for further drying was very favorable. As in other techniques also in HF, drying rates decreased exponentially with decreasing MC. Drying gradient was small but some casehardening occurred (Fig. 3 and Fig. 4) (c.f. Kobayashi et al, 1999).



C

Fig. 3 Moisture content gradients in three stages of drying 1 – initial state, 2 – around FSP and 3 – final state for air, kiln, vacuum and HF drying.

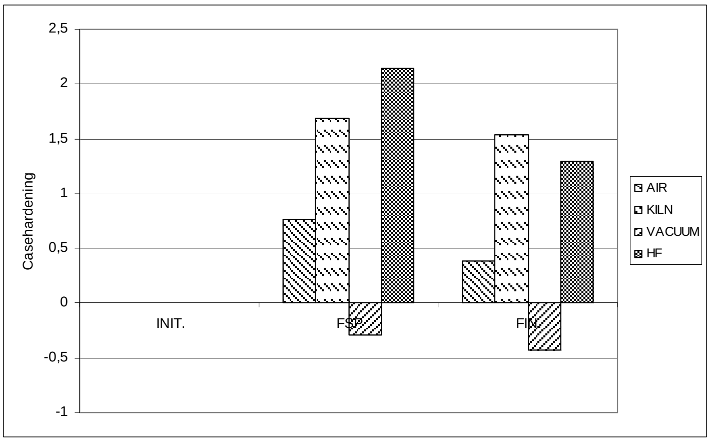


Fig. 4 State of casehardening in three stages of drying 1 – initial state, 2 – around FSP and 3 – final state for air, kiln, vacuum and HF drying.

Constant drying rate period was significant only for air drying (Fig. 5 and Fig. 6). In other drying techniques MC of surface dropt quickly below FSP and interrupted effective capillary flow of free water from the center of wood. In this period the air drying is also competitive if the climate conditions is favorable, for example in spring. Air drying below FSP was very slow and wasteful. In hygroscopic range much longer, than in other techniques lasted favorable drying conditions in vacuum drying. This is also the reason for smaller moisture gradient and very good quality of dried wood. Because of small capacity HF drying was not competitive with other drying technique.

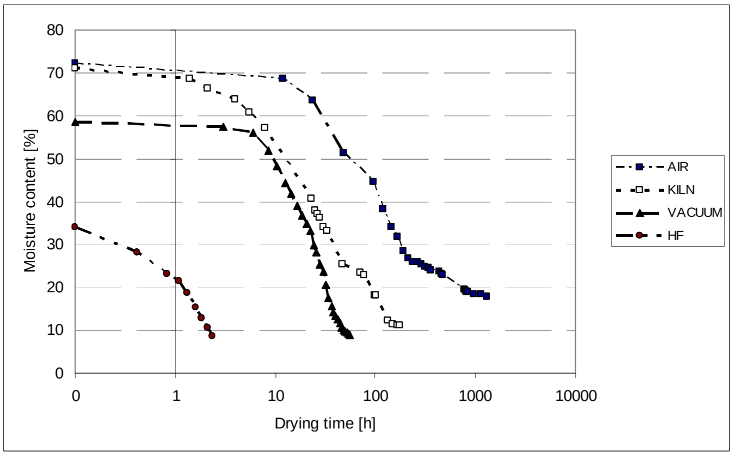


Fig. 5 Comparison of drying curves for air, kiln, vacuum and HF drying

We can conclude that in some cases we get the best results with combination of different drying techniques. For this reason we set up a model with which we are able to predict the best combination of drying techniques and to calculate the optimum MC at which change of drying techniques brings the best results. Because of great variability of wood some more date for verification is needed.

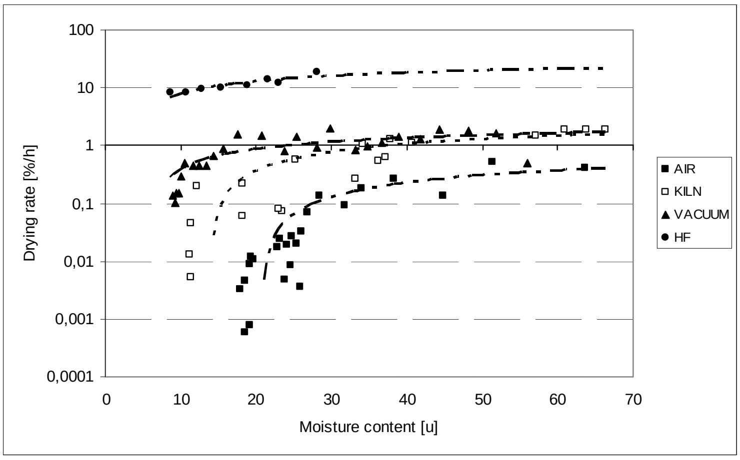


Fig. 6 Drying rate and their regression

In further investigation we will include in the model besides drying kinetics and drying quality also energy consumption and costs of drying, which is by the way very specific for each firm.

CONCLUDING REMARKS

Drying with the HF was the fastest, followed by vacuum drying and kiln drying, whereas expected duration of air drying was the longest.

In air drying wood kept good quality, with the lowest MC gradient, however drying to lower MC is too long.

Low MC gradients were confirmed at vacuum and HF drying, where the latter was applicable only at MC below fiber saturation point. Good drying quality, concern casehardening and visual appearance was achieved at vacuum drying process, quite comparable to air drying. In this research the vacuum drying was assessed as the most preferential techniques for drying beech wood.

With a mathematical model we are able to predict best combination of drying techniques and to calculate the optimum MC at which change of drying techniques brings the best results.

REFERENCES

Kobayashi Y. et al. 1999. High performance drying using combination of HF and hot air under atmospheric pressure. V: Wood Drying Research & Technology for sustainable Forestry beyond 2000. 6th International Wood Drying Conference, Stellenbosch, 25 th-28th January. 1999. Stellenbosch, University in Stellenbosch, Faculty of Forestry, Department of Wood Science: 18-21

Neumann R. et al.. 1992. Comparison of conventional and convective vacuum drying of beech. V: Understanding the Wood Drying Process: A synthesis of theory and practice. 3rd IUFRO international wood drying conference. Vienna: 222-226.

Ressel, J.B. State of the art for the vacuum drying in wood working industry. Edinburgh 1999. COST E 15.

Straže, A., Gorišek, Ž. 2007. CAE analysis and optimization of wood drying energy consumption with use of air pre-drying Les. 56. 142-147

Welling J. 1993. Spezifikation und Üuberprüufung der Trocknungsqualität vor Schnittholz. Holzbearbeitung 40 11, 56-62.