BRIEF REPORTS

Effect of Drying Force on Birch Wood Colour Change during High Temperature Drying

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Abstract

Sawn birch timber is traditionally dried very carefully at low temperatures in order to avoid discolouration of wood. To be able to increase the capacity of old kilns and enable the drying of birch in high temperature drying kilns, experiments of high temperature drying of birch were made. The main aim of the study was to investigate the intensity of discolouration of birch during high temperature drying and test the novel combination drying (hot air drying/high temperature drying).

The results have shown that sawn birch timber darkens in normal high temperature drying when drying force is kept low above FSP. Especially, reddish colour will appear in the planks. The results also have shown that this kind of discolouration can be decreased considerably by increasing the drying force during the first steps of the drying process. The results indicate that hot air/high-temperature-dried birch timber could be used particularly in gluelams and I-beams for the lower price categories. Further studies are needed on other mechanical and physical properties of birch wood dried by the hot air/high temperature method.

Key words: Drying force, hardwood, high temperature drying, wood colour

Introduction

High temperature drying (drying at dry bulb temperature over 100°C) is increasingly used for drying softwood timber due to its quickness and high energy efficiency. Compared to slower drying methods, some advantages in raw material properties, *e.g.* decrease in hygroscopicity, are also achieved (Edvardsen and Sandland 1999, Gard 1999, Sehlstedt-Persson 2000, Bekhta and Niemz 2003). Some trials with high temperature drying have also been made for birch timber (Sonninen 2001). In practice, however, the high-temperature-dried birch timber has been strongly discoloured differing clearly from the natural colour of birch wood. The specific reason for this commercially unacceptable discolouring is unclear. However, any birch-specified high temperature drying schedule has not been developed, but the schedules used are based on knowledge of high temperature drying of softwood timber.

The light colour of wood is highly valued for end-uses of wood products industries using birch timber (Luostarinen and Verkasalo 2000). However, discolouration of wood during drying is a typical defect for sawn birch timber, which occurs especially inside sawn timber in thicker dimensions. Discolouration occurs with all artificial drying methods and sometimes even with open air or room drying (Luostarinen *et al.* 2002). Discolouration is seen as a dark reddish colour, which appears uneven at different depths of the sawn board. The discolouration of birch wood is a result of chemical reactions, which can also be influenced by *e.g.* drying temperature and tempo and storage time (Mononen *et al.* 2002, 2004). Growing site and felling time also have an influence to the occurrence of discoloration. Evidently, the main reason for the variation of discolouration is the variation in initial moisture content, extractive composition and density which leads to variation in drying behaviour of wood (Möttönen 2005). In addition, due to the low temperature used during the first steps of the conventional drying process, there is a large variation of the drying conditions in the kiln between the drying processes.

Nowadays, a significant part of the sawn birch timber is dried artificially; with conventional kiln drying (heat and vent drying) being the most common method. Also vacuum drying is used especially when extra light-coloured birch wood is desired. In both of these drying methods the temperature range of 40-80°C is used. Due to the mild temperature and low equilibrium moisture content especially in the beginning of the drying process, the duration of drying birch timber varies between two and five weeks. The growing demands for the capacity of drying, new product possibilities for using sawn birch timber (*e.g.* as stained and lacquered) and the acceptance of lightly discoloured birch wood in lower segment products, has raised interest to dry birch timber also at higher temperatures. Overall, the dominant drying methods in use for birch timber are time consuming and have low energy efficiency. On the other hand, the vacuum drying and radio-frequency-vacuum drying, which are known to yield high quality, light-coloured wood have very high establishment and operating expenses. From the point of view of the wood products industries, additional research is required to optimise the drying quality as a function of drying costs. Additional research is needed also on other drying methods which are faster and perhaps more economical than the drying method commonly in use these days.

The objective of this study was to determine the intensity of discolouration during the normal high temperature drying and during a novel combined method of hot-air drying/high temperature drying, where the drying rate above the wood fibre saturation point is increased.

Materials and methods

The study was conducted on sawn timber of *Betula pendula* sawn by Koivusaha Solla Ltd., Ruokolahti, Finland. The trees for the sawing were harvested during the frost period from October 2002 to February 2003 from the district of southern Karelia, Finland.

Drying experiments were made in April 2003 at the Laboratory of Wood Technology at the Lappeenranta University of Technology. A pilot scale high temperature/heat treatment kiln with the maximum treatment temperature of 220°C and the total volume of 4 m^3 was used for the drying experiments. In this study, the temperature of 120°C was used at the highest, which is a typical temperature for the high temperature drying. Variable high temperature drying schedules were tested in order to study the occurrence of discolouration in birch (Table 1). The test dryings were made in two different ways:

1. Drying was made as normal high temperature drying boiling the water present in wood and using it for heat transfer to the wood by keeping the vents of the kiln closed.
2. Drying was made as a combined hot air/high temperature drying which was performed so that down to the approximated fiber saturation point (FSP) the kiln was run as a hot air dryer (vents open) and after the FSP (below the moisture content of 25%) as a high temperature dryer. This stage was reached on average after 8 hours of drying.

Table 1. Drying formula for the high temperature drying process

Time (h)	T_{dry} (°C)	T_{wet} (°C)
0	40	39
2	80	78
5	105	97
8	108	100
12	112	100
20	116	100
24	118	100
36	118	100
42	70	62
48	50	40

Material that was used in this study was green birch timber (average initial moisture content of wood 80%). The dimensions of the boards were 25 mm × 100 mm × 3000 mm (for both drying processes) and 32 mm × 100 mm × 3000 mm (for the combined drying process), which are common dimensions in gluelam production.

After drying, the boards were cut in thickness into thinner boards to be able to measure the possible discolouration in the core of the boards. Thereafter, the colour of wood was measured from the surface and middle parts of the planed boards. The colour was measured using a portable spectrophotometer (Minolta CM-2002) with d/8 geometry (diffuse illumination/8° viewing angle) and a measuring area of 8 mm in diameter. Measurements were made always from the freshly planed surface and avoiding knots and other defects. The spectrum of reflected light in the visible region (400-700 nm) was measured and transformed to the CIEL*a*b* colour scale using a 2° standard observer and D_{65} standard illuminant. In this colour scale L* axis represents changes in lightness from an L* value of 0 (black) to an L* value of 100 (white), +a* represents red, -a* represents green, +b* represents yellow and -b* represents blue (Hunt 1998). The difference in colour between woods from different treatments was determined as ΔE^*_{ab}, which represents the distance between two points in the CIEL*a*b* colour scale and is calculated as follows:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Results

Discolouration during the drying processes

During high temperature drying, the colour of wood darkened strongly and turned reddish and yellowish (Table 2). The change of colour was similar both in the core and near the surface of the boards.

During hot air/high temperature drying the change in wood colour was smaller than during high temperature drying (Table 2). The wood dried by the combination drying was significantly lighter coloured, and less red and yellow than the wood dried by the high temperature drying. The colour of wood dried by the hot air/high temperature drying differed between the variable board thicknesses. In 25 mm boards, which had the lightest colour, the colour changed during drying similarly in the core and in the surface layer of the boards. In 32 mm boards, the wood in the core discoloured more than the wood in the surface layer of the boards.

Colour differences

When comparing the difference in colour between the drying processes, the greatest difference was found in the surface layer of boards (Table 3a, 3b). However, ΔE^*_{ab} was high between the high temperature drying and combined drying with all board thicknesses both in the core and in the surface of the boards. The colour difference between the core and the surface of the boards was the highest in the combination drying with 32 mm boards (Table 3c). The colour difference between the core and the surface of the boards was equal in high temperature drying and combination drying when 25 mm boards were used.

Table 2. CIEL*a*b* colour values of dried boards in the board core and surface

Drying process(1) - board thickness	N(2)	Board core L*	Board core a*	Board core b*	Board surface L*	Board surface a*	Board surface b*
HT - 25 mm	22	73.7 (2.4)	7.6 (1.1)	19.1 (1.1)	73.5 (2.5)	7.6 (1.0)	19.5 (1.2)
HA/HT - 25 mm	50	77.9 (1.9)	5.3 (0.8)	16.7 (0.7)	78.2 (1.7)	5.1 (0.7)	16.5 (0.6)
HA/HT - 32 mm	50	76.2 (2.0)	6.6 (1.0)	16.8 (0.8)	77.2 (2.0)	6.1 (1.0)	16.5 (0.8)

Reference colour values of undried birch timber for the same material(3):

L*	a*	b*
87.8	1.0	16.4

(1)High temperature drying, HT; combined hot air/high temperature drying, HA/HT
(2)Number of measurements
(3)Colour values of undried timber are valid for both the core and the surface of boards

Table 3. Colour difference (ΔE^*_{ab}) between different dryings in the board core (a) and surface (b) and between the board core and surface in each dryings (c)

	Between the dryings in the surface of boards	ΔE^*_{ab}
a	HT, 25 mm – HA/HT, 25 mm	6.11
	HT, 25 mm – HA/HT, 32 mm	4.99
	HA/HT, 25 mm – HA/HT, 32 mm	1.41

	Between the dryings in the core of boards	ΔE^*_{ab}
b	HT, 25 mm – HA/HT, 25 mm	5.36
	HT, 25 mm – HA/HT , 32 mm	3.54
	HA/HT, 25 mm – HA/HT, 32 mm	2.14

	Between the core and the surface of boards in each dryings	ΔE^*_{ab}
c	HT - 25 mm	0.45
	HA/HT - 25 mm	0.41
	HA/HT - 32 mm	1.16

Discussion and conclusions

The results of this study have shown, that the discolouration of wood during high temperature drying of birch timber can effectively be reduced using the high drying force during the drying above FSP. The drying force is easily increased by using hot air drying during the early phase of drying process. As a result the moisture is evacuated rapidly from the kiln and the drying rate is increased.

The discolouration in the high-temperature-dried sawn timber was not totally avoided in this experiment. High temperature drying of birch timber cannot be recommended if very whitish birch is needed. However, based on the colour measurements, the level of discolouration was at best on the same level than in low temperature drying methods. The comparative study between the high temperature drying methods used in this study and the low temperature drying methods (conventional heat and vent drying and vacuum drying) should be made in the further studies.

The novel method, combination of hot-air drying and high temperature drying, gives a reasonable possibility to better the high temperature drying quality when considering the colour of the end product. Also the level of the discolouration can be controlled according to the needs that are set to the drying result. Therefore, by increasing the drying rate at the beginning of the process, discolouration of wood can be decreased. These results agree well with those presented by Stenudd (2002), who reported that the most important factor affecting the colour of birch is the time a local section of wood spends in the capillary phase during drying. However, the drying rate in the core of the boards decreases with increasing timber thickness. The use of high drying force may have a risk on other drying defects (deformation, case hardening, and surface checking), which should be studied in further research. Birch wood, however, is not very sensitive for this kind of defects.

In the future, it would be interesting to study the possibilities of this novel hot-air/high temperature drying –method also for the other light hardwoods (*e.g.* maple and beech) or even for softwoods in order to prove the suitability of the system for other tree species. Other facts considering drying quality (distortions, mechanical properties etc.) of birch in high temperature drying should also be studied as well the total economy of high temperature drying of birch wood compared to normal temperature kiln drying.

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ВЛИЯНИЕ СУШИЛЬНЫХ ВОЗДЕЙСТВИЙ НА ИЗМЕНЕНИЕ ЦВЕТА В ПРОЦЕССЕ ВЫСОКОТЕМПЕРАТУРНОЙ СУШКИ БЕРЕЗОВЫХ ПИЛОМАТЕРИАЛОВ

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Резюме

Березовые пиломатериалы обычно сушатся очень аккуратно, надлежащим образом, при низких температурах, во избежание изменения цвета древесины. С целью увеличения производительности старых сушилок и сделать возможной сушку березовых пиломатериалов в сушильных камерах высокотемпературной сушки, были проделаны опыты по высокотемпературной сушке березы. Главной целью работы было получение сведений о степени изменения цвета березы в процессе высокотемпературной сушки и исследование новой сушильной комбинации (сушка горячим воздухом/ высокотемпературная сушка).

Результаты показали, что березовые пиломатериалы темнеют при обычной высокотемпературной сушке, когда сушильное воздействие сохраняется на низком уровне выше предела насыщения клеточных стенок. Красноватый цвет появляется главным образом на обрезных пиломатериалах. Результаты также показали, что эта разновидность изменения цвета может быть значительно снижена увеличением сушильного воздействия во время первых ступеней сушильного процесса. Результаты показывают, что березовые пиломатериалы, высушенные методом сушки горячим воздухом/высокотемпературной сушки могут использоваться особенно при изготовлении клееной ламинированной древесины и брусьев для снижения ценовых категорий. Необходимы дальнейшие исследования других механических и физических свойств древесины березы, высушенной методом сушки горячим воздухом/высокотемпературной сушки.

Ключевые слова: Сушильное воздействие, древесина лиственных пород, высокотемпературная сушка, цвет древесины