Pre-sorting for density in drying batches of Norway spruce boards

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Abstract

One of the key processes for product performance, and the most energy consuming process in the production of solid timber, is the drying process, a process heavily influenced by the wood density. Normally no information of density in a timber drying batch is known today, apart from previous experience of the level of density for the timber of that particular mill. In this study the effect of dividing boards into a high and a low density drying batch was investigated.

66 boards of 50 x 150 mm^2 were collected randomly from the green sorting at a Norwegian sawmill. The boards were cut into 1200 mm long pieces and grouped in a high density group, low density group and a mixed density group. The batches were dried in a laboratory kiln with a constant dry bulb temperature of 70 °C and a decreasing wet bulb temperature. The drying schedule was designed with the help of simulation software and was adapted to the average density and average moisture content of each batch. Total drying times for the low, mixed and high density batch was 58 h, 63 h and 70 h respectively.

The downgrading due to checks showed no statistically significant difference between the density batches and the final moisture content was statistically equal. Only the level of case hardening was significantly lower for the low density batch. This density separation resulted in a net saving of 4 % in drying time at the test mill.

1 Introduction

One of the key processes for product performance, and the most energy consuming process in the production of solid timber, is the drying process. A pre-sorting of timber prior to drying should be performed after the drying rates of the timber, i.e. by moisture content and density (Avramidis et al. 2004). This will yield a more homogenous moisture content after drying, decreasing the amount of over-dried and under-dried boards. It also allows the use of more efficient drying schedules. According to Esping (1992) the drying time is doubled if the density is doubled when drying green 50 mm thick Scots pine boards down to 20 % MC in a constant climate with a temperature of 50 °C, RH of 60 % and air velocity of 1.3 m/s. Under the fiber saturation point (FSP) the drying time may quadruple if the density of a board is doubled (Esping 1992) given the same climate conditions as above. This increase in drying time due to increased density is stronger the higher the temperature in the kiln is (Esping 1992) when

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drying timber under the FSP. This makes density in the drying process increasingly relevant in modern sawmilling since the temperature in the kilns has been raised substantially the later years. The density influence on drying time is the main cause of spread in the moisture content within a drying batch (Esping 1992) since the density range is large between boards within a normal drying batch.

As Rozema and Schuijl (2005) shows, a pre-sorting of boards by an in-line moisture meter using the capacitance method is not sufficiently accurate, and will require a density measurement and possibly some kind of heartwood/sapwood separation as well. However, Elustondo and Oliveira (2009) found a reduction in drying time of 7 percent by dividing boards in three groups according to the measured MC in green boards with an in-line capacitance moisture meter.

Normally no information of density in a drying batch is known in a sawmill today, apart from previous experience of the level of density for the timber of that particular mill. This implies that the sawmills must let the highest density boards in a batch decide the drying schedule in a kiln, since they are most prone to develop checks, and need the longest time to obtain the target moisture content. This results in a drying schedule with too mild climate for most of the boards in a drying batch, and as such a great reduction in drying can be achieved by homogenization of the density in a drying batch. A division of boards in two groups of density level can be imagined as a homogenization that could be obtained in practice. The effect of such a homogenization will give reduced drying time, decreased spread in moisture content and possibly reduced occurrence of drying checks, distortion and case hardening. The challenge is to find accurate means of finding the density in each board and allocate it to different density groups. Most sawmills do not have density measurement systems for green boards installed, although technology is available, mainly through x-ray or weighing equipment. Such equipment do, however, need some kind of moisture content approximations either through measurements in-line or of quality control of drying batches. This will not make them possible to use early in the process either on logs or on green boards with high accuracy due to the high and varying moisture content in green timber.

A number of prediction models for basic density in Norway spruce exists, for example; for individual annual rings (Mäkinen et al. 2007), for 20 mm segments from the pith and outwards on several stem heights (Lindström 2000), for different cross-sections in stems (Ikonen et al. 2008; Wilhelmsson et al. 2002), for different logs (Duchesne et al. 1997) and for individual stems (Bergstedt and Olesen 2000). From such models a division into density classes could be implemented, the simplest system using the dimension of the boards as the prediction parameter. Another, or sometimes additional separation, will be to separate inner boards, i.e. boards adjacent to the pith from the boards further from the pith. The inner boards probably will have a lower density due to more juvenile wood which has a lower density than wood closer to the bark. Typically the first fifteen to twenty annual rings consist of juvenile wood. Such a differentiation is done in several mills when producing sound knot timber or heartwood timber. More advanced models for density separation could include forest data like site or tree variables, giving a higher prediction accuracy.

This study has been performed to investigate the benefits of knowing the density and reducing the density spread in drying batches. The study used data from timber collected in the running production at a Norwegian sawmill.

2 Materials and methods

66 boards of 50 x 150 mm^2 were collected randomly from the green sorting at a Norwegian sawmill. From each board three 1200 mm long samples were cut and both ends of the samples were sealed with silicone prior to drying. From the remaining piece of the boards, density and moisture content were measured. Moisture content and basic density were measured by the oven-dry method according to EN 13183-1, and volume determined by immersion of the samples in water according to Kučera (1992).

Based on the density measurements, the boards were grouped as high density or low density. One sample from each board was dried in a mixed batch where no division according to density was made. The two remaining samples from each board were then dried in either a high density batch or a low density batch. The distribution, mean, and standard deviation of the basic density in the batches are shown in Figure 1.

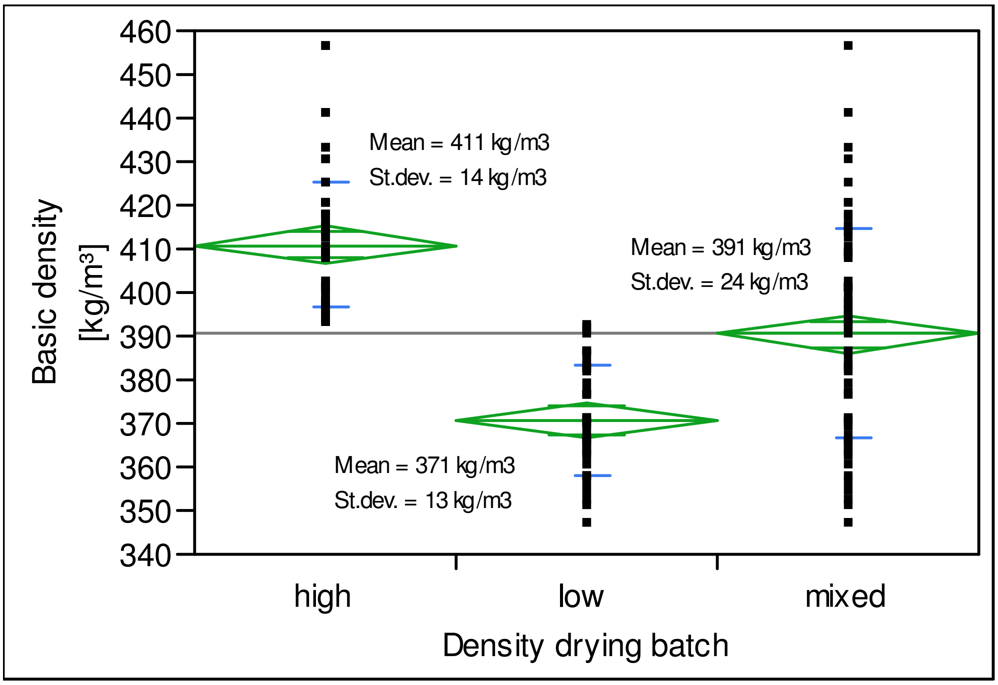

Figure 1: The distribution, mean and standard deviation of the basic density in the drying batches

The drying schedules were simulated in a drying simulation model called Torksim (Trätek 2001) and designed to have similar stress development both in regards to time point of maximum stress (relative to total drying time) and total stress load for the whole drying process. All schedules had a constant dry bulb temperature of 70 °C and a decreasing wet bulb temperature. The three different programs were developed to give a relative stress of 0.33 at approximately 50 % of the total drying time based on the initial moisture content and mean basic density in respective drying batches. A relative stress of 0.33 is the recommended limit according to the manual of Torksim (Trätek 2001). In addition, the drying schedules had a simulated case hardening level of 3.0, 3.1 and 3.1 for the low, mixed and high density batch respectively. This gave total drying times of 58 h, 63 h and 70 h for the low, mixed and high density batch respectively (see Figure 2).

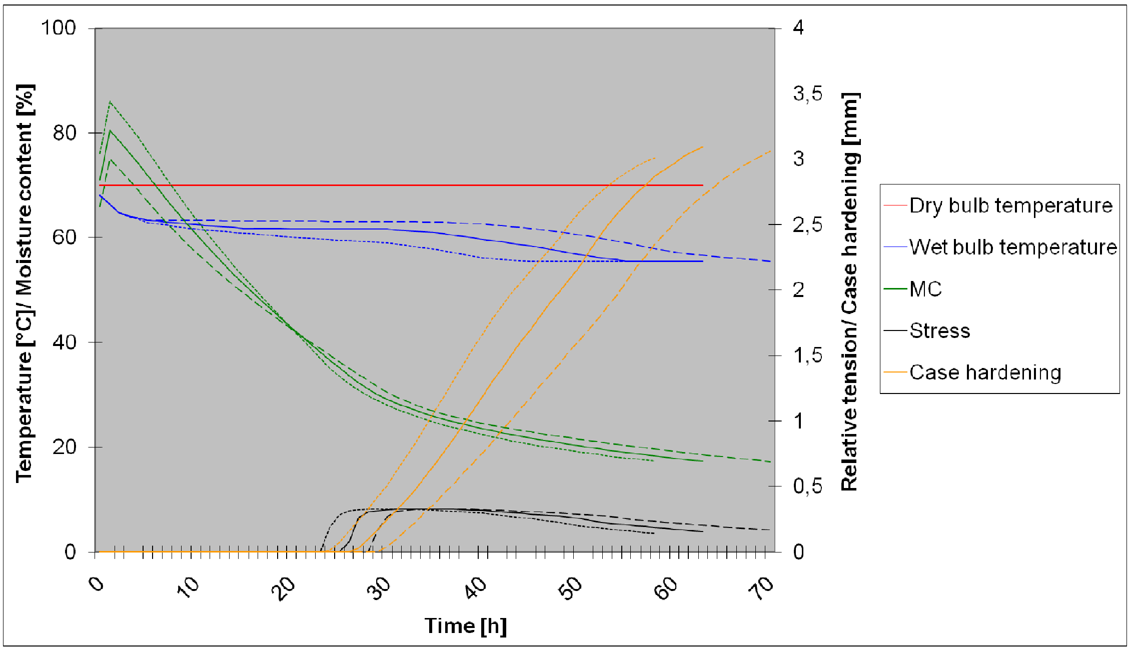

Figure 2: Drying schedule for the three drying batches with simulated development in moisture content, stress, and case hardening according to Torksim (Trätek 2001) (— mixed density batch, --- high density batch, ···low density batch)

After drying, total check length was measured on all boards. Overlapping checks gave some boards a total check length longer than 1200 mm. 2-3 cm thick slices were cut from the centre of each board. Moisture content and case hardening were measured on these slices. Moisture content was found according to the oven-dry method of EN 13183-1. Case hardening was found by trimming down the slice to a width of 100 mm and splitting the piece in two. After storage, in a 20 °C and 65 % climate for 24h, the gap between the two splitted pieces was measured as outlined in ENV 14464. All checks in each board were measured and assessed in terms of the down grading it would give according to the rules of Nordic Timber (Anonymous 1994).

3 Results

The results for the final moisture content, the measured gap and the downgrading due to checks are summarised for all the drying batches in table 1.

An analysis of variance showed no significant differences in MC between the batches in MC.

A higher tendency of checking was found in the high density batch, but a Chi Square test gave no statistically significant difference.

The gap in the low density batch was found to be smaller than in the other batches by a student-t test of variance with a level of significance of over 99 %.

A comparison of the drying quality for the high density boards in the mixed batch should be separated and compared to the quality in the whole mixed batch, the high density and the low density batch. A summary of this is shown in Table 1.

Table 1: Comparison of the drying quality between the batches and within the density groups of the mixed batch

Drying batch	Density group	Final MC [%]	Gap [mm]	Check downgrading [%]
High	High	16.8 (1.9)	2.1 (0.6)	A4: 8, B:5, C:11, D:4
Low	Low	16.3 (2.3)	1.7 (0.6)	A4: 5, B:3, C:6, D:3
Mix	Both	16.5 (1.7)	2.3 (0.7)	A4: 2, B:2, C:5, D:6
Mix	High	16.7 (1.3)	2.4 (0.6)	A4: 3, B:3, C:9, D:9
Mix	Low	16.2 (2.0)	2.2 (0.7)	A4: 0, B:0, C:0, D:3

As the results in Table 1 show, the only decrease in drying quality is the slightly increased casehardening in the high density boards in the mixed batch. This increase is, however, not statistically different from the low density boards of the mixed batch, and certainly not greater than that of the mixed batch in total. Also the decrease in case hardening in the low density boards will more than balance this, and confirms that the drying quality is not impaired by sorting boards in density batches before drying.

4 Discussion

The slightly higher occurrence of checking in the high density batch is somewhat surprising since this batch is dried with the gentlest drying schedule. This can be explained in two ways; either that the boards that develop checks have a strong individual tendency to check regardless of the drying process, or that the high density drying schedule was not gentle enough, implying that density perhaps is underestimated as a factor in the drying process.

If the density in all boards were known prior to drying, the sawmill could sort out the low density boards and dry them on the “low density schedule” as suggested here, and to use the “mixed density schedule” for the rest of the boards (the high density boards). One condition for such a choice is that the drying quality is maintained.

In practice the only difference in drying quality between the batches is a smaller level of case hardening in the batches of low density timber. This tendency of smaller case hardening in the low density batch implies that a shorter period of conditioning in timber meant for splitting in further processing could be imposed.

Based on this study, the net effect of this density separation in batches will be the decreased drying time of 5 h for the low density batches compared to the mixed batch. For the sawmill, this means a time save of 5 h for half of the drying batches, or 2.5 per batch in their total timber production. This constitutes a net saving in drying time of 4 % in the kiln drying of timber at this sawmill.

In a study of drying of hem-fir squares of 101 x101 mm^2 Zhang et al.(1996) found a decrease in drying time of 24, 22 and 15 % respectively for low density batches of hem-fir, all hemlock and all-fir batches compared to high density batches. Their separation was done similarly as in this study, but the difference in mean density was larger. 447 to 376 for hem-fir, 472 to 395 for all-hemlock and 386 to 325 for all-fir respectively. This could explain the larger saving in drying time in their study.

Time saving in kiln drying in itself is positive for a saw mill since the drying capacity often is the bottleneck in timber production. This allows a saw mill to increase the production capacity without kiln investments, and also in the long run decrease the volume of kilns making the need for capital invested in production equipment smaller.

The initial moisture content is also important for the drying time and quality as is shown by Elustondo and Oliveira (2009) and Sugimori et al. (2006), but did not affect the drying quality significantly in this study.

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