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SAW-DRY-RIP QUALITY OF NORWAY SPRUCE SAWN TIMBER FROM FINNISH AND NORTH-WESTERN RUSSIAN LOGS FOR VALUE-ADDED END-PRODUCTS

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Abstract
*The paper presents the results from an experimental study on geographic and wood growth/maturation related variation in technical quality of centre-yield sawn timber of Norway spruce (Picea abies (L.) Karst) of three dimensions (38*100, 50*150, 63*200) after sawing, kiln drying (two steps) and ripping. The dimensions represented primary-processed materials for selected value-added further-processed products with special requirements for quality, including moisture content. Sawn timber quality was evaluated in three steps of saw-dry-rip process considering deformation and pith checking in individual pieces of sawn timber. The material consisted of 420 sawn pieces from three log regions in Finland (south-eastern, western, northern) and two log regions in north-western Russia (Republic of Karelia, Vologda). Significant differences in twist, bow and pith checking were shown in the different steps of processing between the geographic origins of the materials. Moderate increase in the deterioration was detected during the second drying phase. Ripping had even a positive effect regarding the occurrence of twist, bow and cup (not crook) and the apparent pith checking. Based on the results, recommendations were addressed on the technical suitability of logs and sawn timber to the selected value-added wood products, the geographic regions and processing steps in the focus.*

Key words: *picea abies; sawn timber; further processing; deformation; checking.*

INTRODUCTION

High-quality drying and pre-fabrication of sawn timber are essential for secondary manufacturing in joinery and furniture industries to meet the customer demands in the value chain of value-added wood products. Product quality is associated with wood processing and raw material both, and the origin of raw material, either roundwood or sawn timber, has a role here.

Norway spruce is the most common coniferous raw material in European wood product industries, and largely used in Nordic countries and Russia as well (FAOSTAT 2015). In the Nordic sawmills, domestic logs and imported logs, a great deal of those from Russia, are used both. Nordic and Russian sawmills supply timber to the same customer markets as well, including further processing industries. The important product groups cover indoor panels and mouldings, doors, staircases, flooring and furniture as well as outdoor cladding, window shutters, roof trusses, posts and beams, glulam products and log houses (e.g., Virtanen 2005). In all of them, stability and minimum deformation (warp) are required and checks or cracks are not allowed; the defects also decrease strength, stiffness and weather resistance (e.g., Woxblom 1999, Hoadley 2000). Warp was claimed to be the major disadvantage of timber as a building material, compared to steel, for example (Johansson et al. 1994). Warp and checking of timber are closely linked with drying, especially when drying to the MC of joinery and furniture grades, down to 6–13%, and ripping (e.g., Hoadley 2000, Rikala 2003).

Growth and maturation characteristics, including ring width and early wood - latewood relationships, juvenile wood – mature wood relationships, sapwood – heartwood relationships, growth stresses and strains, knots and spiral grain, and abnormal types of wood, such as reaction wood or wetwood, have been shown in many studies to affect the performance of Norway spruce in drying (Ward and Pong 1980, Danborg 1994, Forsberg 1999, Johansson et al. 1994, 2001, Perstorper et al. 1995, 2001, Boren 2001, Johansson and Kriger 2002, Saranpää 2002; see also Stevens and Johnston 1960, Simpson and Gerhardt 1984, Archer 1987) and ripping (Kärkkäinen 1995, Hoadley 2002, Rikala 2003). While wood growth and biotic deterioration of Norway spruce trees show considerably variations within Europe (Hudson 1967, Kärkkäinen 1985, Verkasalo and Leban 2002, Ranta-Maunus 2009; Stapel and Denzler 2010) and also within the boreal climatic region (Hakkila 1968, Bergstedt et al. 2001, Hautamäki et al. 2010), we can assume meaningful differences in drying and ripping behaviour of sawn timber as well. They may be important in sourcing logs and designing their sawing strategy, sorting and pricing logs and sawn timber and allocating sawn timber to the most suitable end-products in further processing. It is also useful to investigate sawing, different steps of drying and subsequent ripping as a process chain when aiming to high-quality customer products.

OBJECTIVES

The main objective of the present study was to assess the variation in the technical quality of centre-yield sawn timber of Norway spruce of three dimensions (38*100, 50*150, 63*200) after sawing, kiln drying (two steps) and ripping when aiming to selected value-added further-processed products, as regards the geographic origin of logs in boreal regions of Finland and north-western Russia and the related factors of wood growth and maturation. Sawn timber quality was evaluated in three steps of saw-dry-rip process based on the deformation (twist, bow, crook, cup) and pith checking in individual pieces of sawn timber, and considering the targeted moisture content. The relative significance of drying to the moisture content of the selected end-products and the subsequent ripping was discussed as well. Based on the results, recommendations were addressed on the technical suitability of logs and sawn timber to the selected value-added wood products, the geographic regions and processing steps in the focus:

MATERIALS AND METHODS

The study material consisted of a sample of Norway spruce sawn timber that was derived from a large material of a project where the appearance quality and strength of timber was studied when sourced from Finland or north-western Russia (Hautamäki et al. 2010). The material represented three log regions in Finland (eastern, western, northern) and two log regions in Russia, Republic of Karelia representing more southern and fertile growing conditions and Vologda representing continental and colder growing conditions (Fig. 1). The logs were sampled from three large sawmills, each located in one of the before-mentioned Finnish regions (Kitee, Kyröskoski, Kajaani). All logs were processed to sawn timber at an educational sawmill in Kotka using the Nordic cant sawing principle and applying there the setup of 2EXLOG (Virtanen 2005), and kiln-dried to a target MC of 20–24%. Detailed description of the sampling, processing and log characteristics is given by Hautamäki et al. (2010).

Fig. 1.
Approximate sampling areas in Finland and in Russia (W-F = western Finland, N-F = northern Finland, S-E F = eastern Finland) (Hautamäki et al. 2010)

For this study, we selected a sub-sample of center-yield sawn timber, covering all regions of the before-mentioned sampling. In the approach, we stressed value-added products by studying three dimensions of sawn timber that match to important end-products of spruce, as follows: 38*100 for interior panels (ripped); 50*150 for cladding (ripped), 63*200 for flooring boards or parquetry (ripped) or log-house beams or lamella logs (non-ripped). The dimensions represented the respective log diameter classes (over bark) as follows: 155–169mm, 205–274mm, 275–304mm. The material consisted of 420 pieces of sawn timber, 20 pieces per region and dimension, except 40 of them in the thickest dimension and in the region of the Republic of Karelia in the middle dimension. With this segregation we ensured the supply of both fast-grown and slowly-grown wood in the data.

We conducted the experiments at an industrial joinery mill, first kiln-drying in a steam-heated drying chamber and then ripping edgewise to 2-3 pieces. We studied the occurrence and severity of twist, cup, bow, crook, and pith checking in sawn pieces before and after drying, and after ripping. These features were measured according to the standard EN 1310 (1997) and the grading rules of European Drying Group (1994). In the study, the results on twist, bow and crook are expressed per two-meter length of sawn pieces.

Two separate sets of drying were carried out, one for the thick dimension (63*200) and another for the two other dimensions (38*100, 50*150), the durations of the drying processes being 169 and 96 hours, respectively (Table 1). The initial MC of sawn pieces was 21–22% for all dimensions. The final MC was 10% for the dimensions of 38*100 and 63*200, and 12% for the dimension of 50*150. We used one-way variance analysis in the statistical data analysis.

Table 1

Kiln-drying schedules used for different dimensions of sawn timber. T_d = dry bulb temperature, T_w = wet bulb temperature.

38 * 100 mm and 50 * 150 mm			
Stage	Time	T_d	T_w
0	10	46.0	44.0
1	58	54.0	45.0
2	106	62.0	48.0

63 * 200 mm			
Stage	Time	T_d	T_w
0	6	45.0	43.0
1	42	46.5	44.0
2	84	49.0	46.0
3	126	51.0	47.0
4	168	52.5	46.3
5	210	55.0	44.0

RESULTS AND DISCUSSION

Twist

Twist is considered the most severe type of deformation in sawn timber. In this study, the average twist before drying was higher in the Republic of Karelia than in other regions, 10.6 mm vs. 8.7 mm (Fig. 2) (F: 13.372, p: 0.000). The twist was the larger the larger the dimension of sawn piece. After drying, the twist was 6-10 mm on average. It decreased during drying in all regions except eastern Finland, where it was at this point the greatest (F: 2.871, p: 0.023). Before drying, the level of twist was similar or higher but even lower after drying compared with most previous studies on Norway spruce (e.g., Perstorper et al. 1995, Forsberg 1999, Johansson and Kliger 2002, Saranpää 2002). Overall decrease in twist was an opposite result, but at least partly attributable to the larger sawn timber dimensions in those studies. For example, Johansson et al. (2001) found the values of crook to double when drying from MC 15% to MC 7%. After drying, 11% of sawn pieces were discarded due to the overlarge twist, i.e., more than 14 mm (c.f. Rikala 2003: 17%). The percentage was the highest in eastern Finland and the lowest in northern Finland and Vologda.

Ripping decreased clearly the twist of sawn timber, especially in eastern Finland (Fig. 2). After ripping, the twist was only 5-7 mm on average, but in eastern Finland slightly higher than in other regions. Ripping did not reduce the twist at all with the smallest dimension, but a bit with the middle and clearly with the thickest dimension, and the pieces of the thickest dimension twisted the least (Fig. 3). In eastern Finland, the twist in the pieces from butt logs was slightly larger than in the pieces from other logs. In the Russian regions the pieces from butt logs twisted less than those from other logs. Overall decrease in twist in ripping was in slight contrast with the outcome from Rikala (2003), for example, but not uncommon if the moisture content is homogeneous within individual pieces and air humidity in the working environment is well-controlled; this was observed also in practical mill operations (Kärkkäinen 1985, Hoadley 2000).

Twist of sawn timber should be in relation to a large microfibril angle (Danborg 1994, Perstorper et al. 2001), which, in turn, is in relation to a rapid growth or presence of compression wood. Larger twist of sawn timber pieces of eastern Finland and the Republic of Karelia compared with other regions reflected the impact of the rapid growth, and the positive correlation of twist with the dimensions (Johansson et al. 2001, Saranpää 2002). The effect of compression wood on the occurrence of twist was detectable only when it was present in both ends of sawn piece.

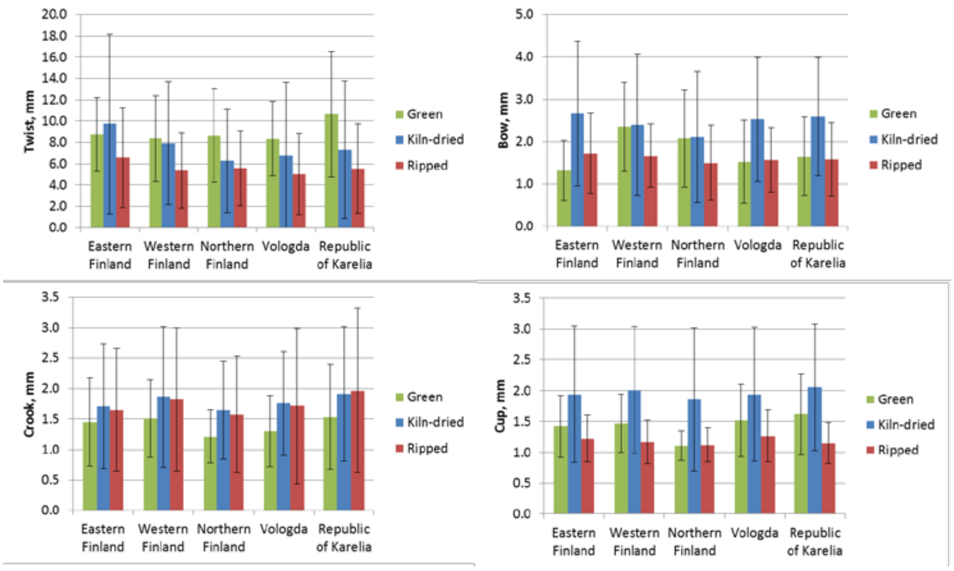

Fig. 2.
Twist, bow, crook, and cup of green (MC 21-22%), kiln-dried, and ripped sawn timber in the different regions. Twist, bow and crook are expressed per two-meter length of sawn piece

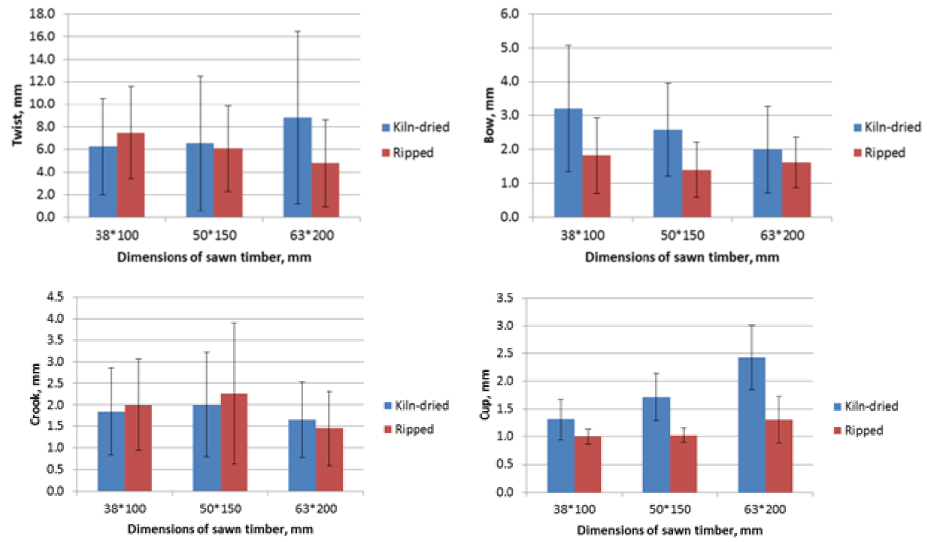

Fig. 3.
Twist, bow, crook, and cup of kiln-dried and ripped sawn timber by the dimensions. Twist, bow and crook are expressed per two-meter length of sawn piece

Bow

The bow of sawn timber before drying varied regionally between 1.3 – 2.3 mm being higher in western and northern Finland than in other regions (Fig. 2) (F: 25.841, p: 0.000). In this phase the bow of different dimensions was on the same level. After drying the bow increased to 2.1 – 2.7 mm, the increase being the highest in eastern Finland and Russia. Thus, bow did not differ between regions after drying any longer (F: 1.215, p: 0.304). During drying, the bow increased the more the smaller the dimension of the sawn timber (Fig.3). The level of bow was generally lower both before and after drying compared with previous studies on Norway spruce (e.g., Perstorper et al. 1995, Johansson and Kliger 2002, Saranpää 2002). Increase in bow during drying was consistent with those studies, as well. Ripping decreased the bow clearly and the differences in bow between regions became insignificant. However, the bow of the sawn timber was still the highest with the smallest dimension and the lowest with the centermost dimension (F: 4.580, p: 0.011). The small difference in bow between butt logs and other logs of dried sawn timber disappeared in ripping (c.f., Riala 2003).

High bow of sawn timber from northern Finland before drying was related to the sweep of logs. In Russian regions, this relationship was not observed until after drying. However, the presence of compression wood, which is generally related to the sweep of logs, did not indicate any higher bow values. The largest reduction of bow in the largest dimensions as the result of ripping was, as such, self-evident due to the technical principle of ripping.

Crook

The crook values of sawn timber before drying did not differ between geographic regions (Fig. 2) or sawn timber dimensions (Fig. 3). Drying increased the crook from 1.2 – 1.5 mm to 1.7 – 1.9 mm, the increase being the larger the smaller the dimension. Ripping did not affect the crook values. The sweep of logs indicated higher crook values as well as compression wood if it was detected in both ends of sawn pieces. This result was in accordance with those of Perstorper et al. (1995), who found the core wood associated crook larger in butt logs than in top logs. The level of crook was around similar to previous studies on Norway spruce, both before and after drying (e.g., Perstorper et al. 1995, Johansson and Kliger 2002, Saranpää 2002). The effect of ripping was also similar, however, smaller than in Rikala (2003).

Cup

No regional variation was observed in cup (Fig. 2). The cup was the highest in the largest sawn timber dimension. After drying, it increased little in the smallest dimension, but doubled and tripled in the two largest dimensions (Fig. 3). Cup reduced the more the larger the sawn timber dimension. Thus, the difference in cup between the dimensions was insignificant after ripping. The level of cup was similar to most previous studies (Perstorper et al. 1995, Johansson and Kliger 2002, Rikala 2002), however, after drying double compared with the results of Saranpää (2002).

Intensive cupping is, on one hand, related to the radial location of wood in the outer parts of logs and, on the other hand, to the rapid growth (Danborg 1994, Perstorper et al. 1995). The results obtained from the sawn timber with large dimensions and, at the same time, with the highest log grade including only butt logs indicated the effect of rapid growth. The highest reduction in cup when ripping sawn timber with large dimensions was, as such, self-evident due to the technical principle of ripping.

Pith checking

The proportion of pith checking of the total length of dried sawn timber was the highest in the Republic of Karelia, 40%, and the lowest in northern Finland, 30% (Fig. 4). The lowest proportion was found in the sawn timber with the smallest dimension (F: 11.565, p = 0.000). In the thickest dimension of dried sawn timber, pith checking was similar in the regions, but in the thinnest and centremost dimension, it was the smallest in western Finland. Ripping decreased pith checking in all regions except the Republic of Karelia, which was in accordance with the results of Rikala (2003). In other regions, pith checking occurred only in the largest dimension. In the dried material, pith checking was higher in the sawn timber from butt logs than in other logs in western Finland and Vologda. Presumably, the high age of trees predisposing internal defects (heart checks, resin pockets) was associated with the high pith checking values in Russian regions and in the log classes of the largest diameter. Generally, rapid growth should increase the probability of checking in sawn timber, but this was found only after ripping and in the sawn timber from the largest log class. Pith checking may be connected with cupping which was observed in the thickest and centremost dimensions after drying.

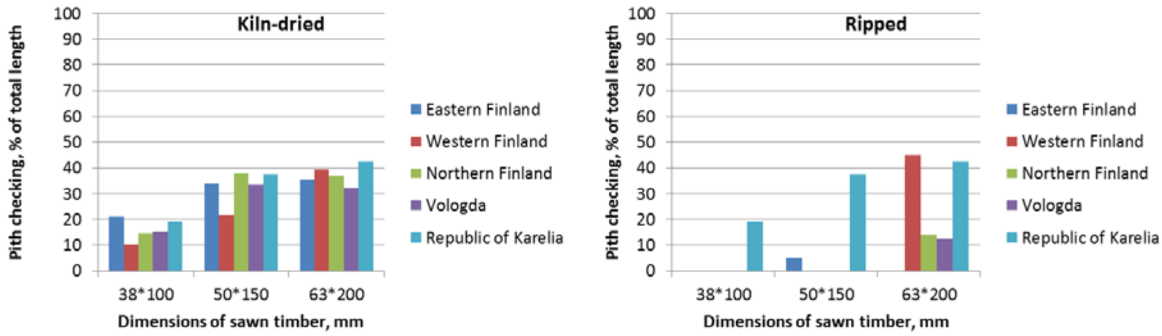

Fig. 4.
Pith checking of kiln-dried and ripped sawn timber by dimension in the different regions

CONCLUSIONS

Tendencies to twist and pith checking are regarded as the most critical factors in assessing the eligibility of sawn timber for further processing (Rikala 2003). Based on the results of this study, the following recommendations can be addressed on the technical suitability of different materials of Norway spruce to some value-added wood products, from the geographic regions in focus:

- 38mm thick dimension: ripped timber for interior panelling from logs and sawn timber from western Finland, northern Finland and Vologda region, based on the low tendency to pith checking, bow and crook.
- 50 mm thick dimension: ripped timber for cladding from logs and sawn timber from western Finland, based on the low tendency to pith checking in contrast to logs and sawn timber from the Republic of Karelia with high tendency to crook.
- 63mm thick dimension: a) ripped timber for flooring boards or parquetry from logs and sawn timber from eastern Finland, northern Finland and Vologda region, based on the low tendency to pith checking; b) non-ripped timber for log-house beams, i.e., lamella logs from sawn timber of northern Finland can be recommended based on low tendency to twist.

Overall management of the saw-dry-rip process is important for further processing of sawn timber, because different types of deformation and checking occur during different steps of the process, and the significance of different defects depends largely on the quality requirements of individual end-products. Management of timber drying, both to the moisture content of sawmill products (MC export grades), thereafter to the actual moisture content required in the end-product (MC joinery/carpenter grades) or combined, is in the key role to ensure a good basis for further processing, ripping of sawn timber among other things. In this study, ripping had a positive effect on the form of timber regarding twist, bow and cup (not crook) and the apparent pith checking. This was obviously due to the successful preceding drying process, indicated by the smaller increase in the deterioration during it, storage of the materials between the operations in well-controlled environment for air humidity, and careful management of the ripping operation.

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