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Influence of Initial Wood Quality and Drying Process on Utilization Grades of Sawn Spruce Timber

Utjecaj polazne kvalitete drva i procesa sušenja na klasu kvalitete smrekove piljene građe

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ABSTRACT • *European spruce (*Picea abies *Karst.) belongs to the most easily dried wood species, but nevertheless cracking and warping often reduce the quality of dried sawnwood. Larger surface and end cracking was noticed at industrial drying practice in cold winter season, especially in using fast drying schedules. For the assessment of factors influencing the quality of dried wood some drying runs with varying drying conditions were carried out in an experimental kiln dryer. The quality of sawnwood was evaluated on green material using standard procedures and compared with the quality at the end of drying processes. Drying of spruce sawnwood at sharper drying conditions was more risky, resulting in a larger number of cracks as well as larger final MC distribution, larger MC gradients and casehardening. Additionally, significant correlation was confirmed between the quality of dried wood and input quality of fresh material. More downgrading after the drying was observed in case of initially low graded material.*

Keywords: *wood, drying, drying quality, grading*

SAŽETAK • *Europska smreka (*Picea abies *Karst.) pripada skupini vrsta drva koje se lako suše, ali pukotine i deformacije koje nastaju u procesu sušenja često umanjuju kvalitetu osušenih piljenica. Pukotine na većim površinama i čelu piljenica zabilježene su u praksi industrijskog sušenja tijekom hladnih zima, posebno pri brzim režimima sušenja. Za ocjenu utjecajnih činitelja na kvalitetu sušenog drva, u eksperimentalnoj je sušionici provedeno nekoliko ciklusa sušenja s različitim uvjetima sušenja. Kvaliteta sirovih piljenica procijenjena je standardnim metodama i uspoređena s kvalitetom na kraju procesa sušenja. Sušenje smrekovih piljenica u oštrijim je uvjetima rizičnije jer rezultira mnogim pukotinama i većom raspodjelom konačnog sadržaja vode, većim gradijentom sadržaja vode i pojavom skorjelosti. Uz to, potvrđena je i signifikantna korelacija između kvalitete sirovih i osušenih piljenica. Više grešaka i smanjenje kvalitete osušenih piljenica zabilježeno je pri sušenju sirovih piljenica lošije kvalitete.*

Ključne riječi: *drvo, sušenje, kvaliteta sušenja, klasiranje*

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1 INTRODUCTION
1. UVOD

To be competitive in wooden industry and in the open market, the quality of our products and processes must be well defined. Wood quality depends on many different factors, related to wood material itself and to factors within industrial production.

The definition of round and sawn wood quality includes such properties as knots, annual ring width, fibre orientation and resin pockets, together with defects caused by insects and fungi (EN 1310, EN 1311). Actually, the European spruce sawn timber classification, is often performed by visual grading (EN 1611-1), or in case of more strict demands, especially in construction sector, by machine grading. Wood quality assessment is necessary at several production levels for increasing the utilization rate of material and shortening of processing. For maintaining the wood quality through its processing, it is necessary to apply successful production methods. Wood drying, as one of the primary processing steps, plays an important role for achieving applicable material characteristics. Therefore, several standards for the assessment of drying quality have been recently prepared, defining measuring techniques (EN 13183-1, EN 13183-2, EN 13183-3), sampling requirements and criteria of drying quality (EN 14298, ENV 14464).

Quality of dried wood might diverge due to different parameters, such as the drying schedule, wood moisture gradient, and also due to the structure of different wood species and dimension of specimens (Oltean *et al.*, 2007). In most studies the accelerated drying schedule significantly reduced the strength of wood while the allowable stiffness was not affected (Bekhta and Niemz, 2003; Müller *et al.*, 2003). Higher temperature during the drying process is the main reason for decomposition of hemicelluloses, celluloses and lignin as the principal wood components with the permanent influence on strength reduction (Tjeerdsma *et al.*, 1998). Otherwise, conventional kiln drying had only minor effects on the microstructure of wood (Terziev and Daniel, 2002).

Another negative outcome of the loss of mechanical properties of wood during drying is the occurrence of different cracks, such as surface cracks, end cracks and splits, collapse and honeycomb. Most of cracks (even honeycomb) were initiated during first stages of drying, caused by high tensile stresses on the surface of the dried boards. The potential way to confirm the appearance of micro-cracks on the surface of sawn timber at the early stage of drying and monitor their development and growth was achieved by the method with the focus laser beam reflection (Hanhijärvi *et al.*, 2003).

Occurrence of warp, mainly twist, crook and bow caused most severe problems leading to wood downgrading during drying. The grain angle and distance from the pith to the centre of the board cross-section are the two material parameters most commonly associated with warp (Booker, 2005; Bäckström and Johansson, 2006). Twisting of the dried boards generally increased proportionally to the reduction in average moisture content (Gorišek *et al.*, 2006; Gorišek and Straže, 2005; Straže *et al.*, 2010). Decrease in torque and twist was achieved by increasing the drying temperature and presteaming of the material prior to drying (Kliger *et al.*, 2005; Frühwald, 2006).

The aim of this paper is to verify the influence of various conventional kiln drying procedures on the quality of European spruce sawnwood. In addition, the objective of the survey is to examine the difference in grading prior and after kiln drying and the usability of pre-sorting of sawn wood in green state.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

Fifteen randomly selected logs of European spruce (*Picea abies* Karst.), having an average diameter of 26 cm, 4 m in length, were used in the experiment. Logs were sawn into 19 mm thick boards, which were additionally shortened to 2 m in length, to suit the kiln drier dimensions. Afterwards, classification of 90 green boards, of radial (1/3), radial-tangential (1/3) and tangential orientation (1/3) was performed, following standard quality assessment and appearance grading rules (EN 1310, EN 1311, EN 1611-1).

Three conventional kiln drying experiments were carried out afterwards in laboratory kiln drier, using stepwise raising drying temperature from 60 °C to 70 °C, at 2.5 m/s air velocity. Different drying rates were achieved by varying the drying gradient. Wood moisture content (MC) was continuously determined by electrical resistance method and gravimetrically, by weighting of timber stack. Appearance grading was carried out once again on the same population of boards at the end of each drying procedure. Drying quality of boards was additionally assessed by gravimetrical determination of final MC, moisture gradient (EN 14298) and by casehardening determination (ENV 14464).

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Drying kinetics
3.1. Kinetika sušenja

The slowest drying, taking 56 h, was achieved at drying under mild drying conditions (procedure 1), which is generally ascribed to high equilibrium moisture content (EMC) (Fig. 1). Sharper drying condition attained with decreasing of EMC (on average by 2%) significantly increased the drying rate in drying procedure 2. The drying procedure 2 was 14% shorter, and lasted 47.5 h (Fig. 2). The fastest drying was attained by additional decrease of EMC in the third run, with EMC below 7%, while the average MC was still above fibre saturation. Consequently, the drying procedure 3 lasted only 43.5 h (Fig. 3).

3.2 Drying quality
3.2. Kvaliteta sušenja

The final MC was less than 9% in all examined drying procedures, where the lowest and most homo-

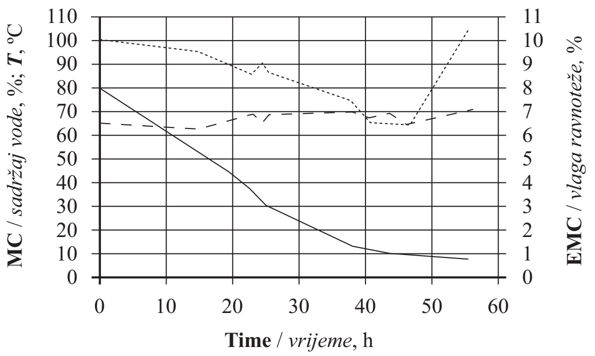

Figure 1 Moisture content – timber stack weight basis (—), drying temperature (- - -) and EMC (…) in drying procedure 1
Slika 1. Sadržaj vode na osnovi mase složaja piljenica (—), temperatura sušenja (- - -) i EMC (…) pri 1. procesu sušenja

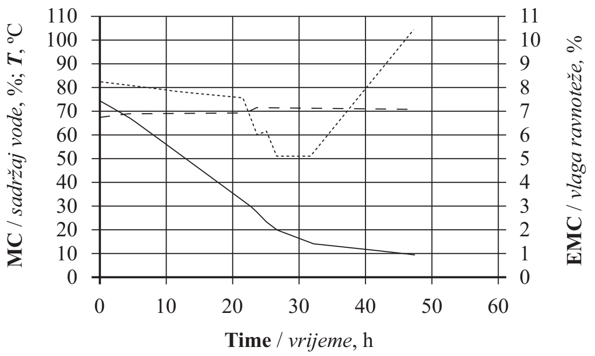

Figure 2 Moisture content – timber stack weight basis (—), drying temperature (- - -) and EMC (…) in drying procedure 2
Slika 2. Sadržaj vode na osnovi mase složaja piljenica (—), temperatura sušenja (- - -) i EMC (…) pri 2. procesu sušenja

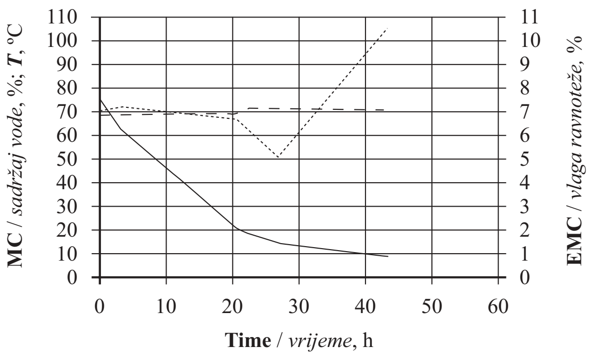

Figure 3 Moisture content – timber stack weight basis (—), drying temperature (- - -) and EMC (…) in drying procedure 3
Slika 3. Sadržaj vode na osnovi mase složaja piljenica (—), temperatura sušenja (- - -) i EMC (…) pri 3. procesu sušenja

genous final MC was achieved under mild drying conditions. Accelerated drying, in case of procedure 2 and 3, significantly increased the final MC variation (Fig. 4a). The final moisture gradient, using slicing of specimens into 3 layers, was also the lowest and most homogeneous with boards dried in drying procedure 1. Similar average moisture gradient, namely 1.3 %/cm, was also achieved in drying procedure 2, and however it was more variable (CV = 0.43; Coeff. of Variation). The highest average moisture gradient of 1.8 %/cm was achieved in drying procedure 3 (Fig. 4b).

Similar differences in drying quality between the examined procedures confirmed also the comparison of casehardening, using slicing method (ENV 14464).

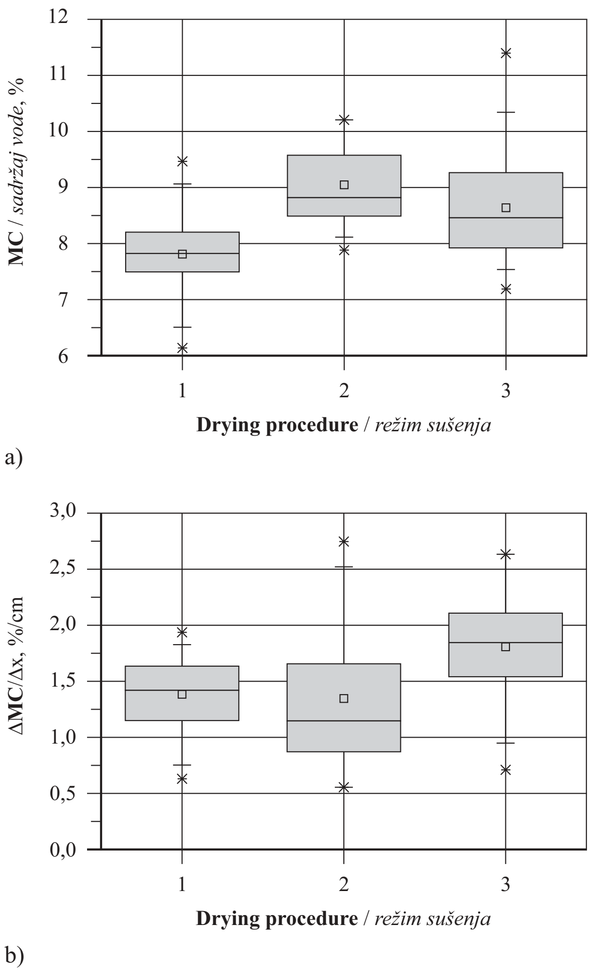

Figure 4 Average final moisture content and its variation (a) and achieved moisture gradient (b) in examined drying procedures
Slika 4. Prosječni konačni sadržaj vode i njegova varijacija (a) te postignuti gradijent sadržaja vode (b) u istraživanim režimima sušenja

The smallest casehardening was determined with boards in drying procedure 1, whereas accelerated drying, in procedures 2 and 3, significantly increased its values (Fig. 5).

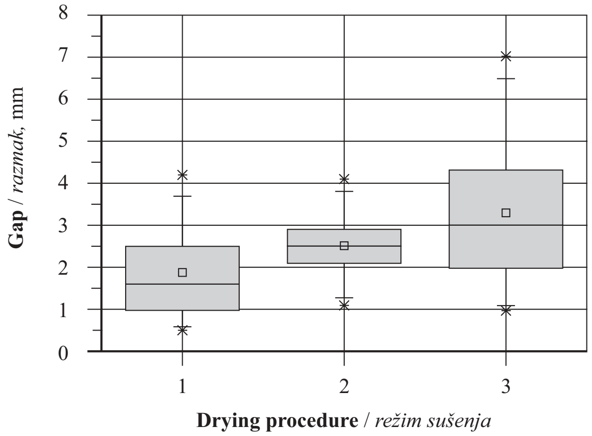

Figure 5 Average casehardening and its variation with boards dried in examined drying procedures
Slika 5. Prosječna skorjelost osušenih piljenica i njezina varijacija u istraživanim režimima sušenja

3.3 Appearance grading
3.3. Klasiranje na temelju izgleda piljenica

Consecutive grading, i.e. before and after drying, into five grading classes (G2-0 to G2-4) confirmed significant influence of the drying process on sawn wood quality. Most often, defects like surface and end checks and warping degraded the dried sawnwood. Surface- and end checking of wood started already in the early beginning of all drying procedures and reached final state of MC around FSP. Warping of wood followed afterwards, during drying at MC bellow FSP, and reached maximum values at final MC. In general, significantly different drying quality changes occurred on initially equally graded sawnwood depending on used drying procedures.

The slowest drying procedure caused negligible downgrading of sawnwood, i.e. 1 class reduction, only on the initially low quality material, graded in class 3 (G2-2) or less (Fig. 6). Acceleration of kiln drying, by using procedure 2 and 3, consequently distinctly downgraded dried sawnwood. The use of drying procedure 2 caused severe downgrading, namely 25% of boards, at initially low graded sawn wood, from classes 3 and 4 (G2-2 and G2-3) (Fig. 7). The highest quality decrease, reduction of even 4 classes, was observed for the fastest drying, using drying procedure 3. Downgrading was present with 33% of boards, irrespective of the sawnwood grading before drying (Fig. 8).

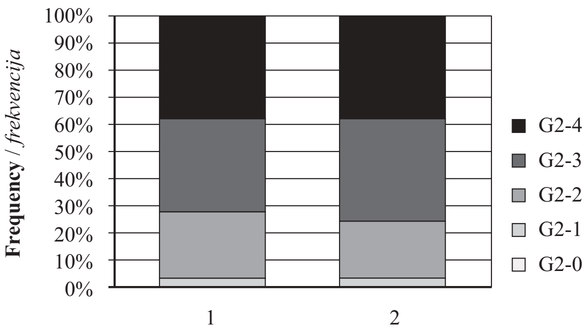

Figure 6 Frequency distribution of graded spruce sawnwood before (1) and after drying (2) by procedure 1 (G2-0…1st class; G2-4…the last class)
Slika 6. Raspodjela frekvencija klasa kvalitete piljenica prije sušenja (1) i nakon sušenja (2) pri 1. režimu sušenja (G2-0…prva klasa; G2-4…posljednja klasa)

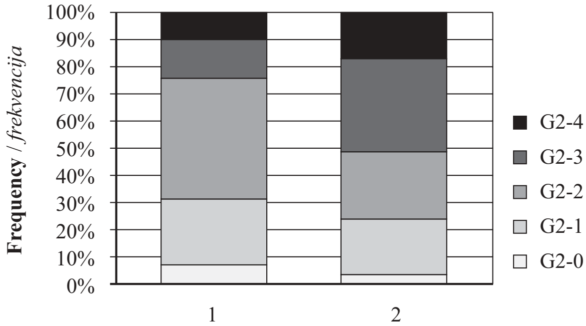

Figure 7 Frequency distribution of graded spruce sawnwood before (1) and after drying (2) by procedure 2.
Slika 7. Raspodjela frekvencija klasa kvalitete piljenica prije sušenja (1) i nakon sušenja (2) pri 2. režimu sušenja

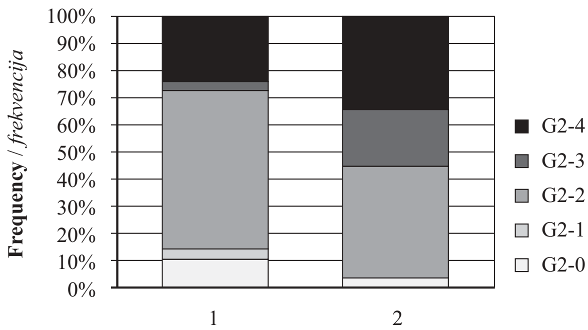

Figure 8 Frequency distribution of graded spruce sawnwood before (1) and after drying (2) by procedure 3.
Slika 7. Distribucija frekvencija klasa kvalitete piljenica prije sušenja (1) i nakon sušenja (2) pri 3. režimu sušenja

Reduction of the moisture gradient was in many conventional kiln drying processes achieved by interphase or final conditioning of material (Salin, 2004). The conditioning phase is also recommended to decrease the drying stress, to lessen the visibility of cracks and even to reduce possibly present honeycomb and collapse (Keey, 2002). In addition, low graded material often possesses inherent specific structural properties, like high knottiness, high slope of grain, presence of reaction and juvenile wood (Folvik, 2004). To prevent downgrading and incorrect grading results, slow drying and use of conditioning phase is recommend with initially low graded material, or grading of the material after the drying procedure.

4 CONCLUSIONS
4. ZAKLJUČCI

This survey confirmed the dependence of the results of sawnwood grading on the used drying procedure. The research showed the applicability of appearance grading of sawnwood before the drying process, when the latter is properly and carefully performed. On the other hand, too aggressive or inappropriately controlled drying process easily downgrades dried sawnwood. In such cases, the shortened drying procedure contributes to greater drying capacities and simultaneously increases the risk of wood quality degradation. Generally, grading of sawnwood after kiln drying is recommended.

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