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Surface characteristics of spruce veneers and shear strength of plywood as a function of log temperature in peeling process

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Abstract

The objective of this study was to determine the effect of temperature of spruce (*Picea orientalis* L.) logs during peeling process on surface roughness, adhesive wettability, colour variation of veneer, and shear strength of plywood made from these veneer sheets. Veneer samples were manufactured from the logs after they were kept for 3 h and 24 h to reach to average temperatures of 52 °C and 32 °C, respectively. A fine stylus method was used for surface roughness evaluation of the veneer produced from two types of the logs and it was found that the samples peeled from the logs with a temperature of 52 °C had significantly better roughness values than those of manufactured from the logs with 32 °C at a 95% confidence level. Wettability of veneer samples was determined with contact angle measurements according to the sessile drop method. Urea formaldehyde (UF) and phenol formaldehyde (PF) resin drops were used in contact angle measurements. Contact angles of PF resin drops on veneers were similar for each peeling temperature while the contact angles of UF glue resin on veneers produced from the logs with 32 °C were lower than those of produced from the logs with 52 °C. Small colour difference was measured (indicated by a low ΔE value) on veneer samples depending on the log temperature. The highest shear strength value was determined for the plywood manufactured from veneers obtained from the logs with 52 °C by using UF glue.

Keywords: Surface roughness; Wettability; Surface colour; Veneer; Plywood; Log temperature; Shear strength

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1. Introduction

Heating of logs with steam is one of the most important processes during the veneer manufacturing. The main function of steam heating is to soften veneer log temporary and making it more plastic, pliable, more readily peeled, and improving the quality and quantity of material recovered from the log. Steam heating is more efficient than water heating in terms of its safety aspects and shorter heating time (Baldwin, 1995). Some of the other advantages of steam log heating include decrease in energy use during the peeling, reducing cracks on the veneer due to knife checks, improve tensile strength, and produce veneers having small colour variations. Surface characteristics, uniform thickness of veneer, and bonding quality for plywood manufacture are influenced by steaming temperature and duration between steaming and peeling processes (Berkel et al., 1969; Bozkurt and Goker, 1986; Goker and Akbulut, 1992; Lutz, 1978; Ozen, 1981). Above benefits can also be reached by determining the optimum steaming temperature, steaming time as function of wood density and log diameter.

Gupta and Bist (1981) found that the optimum heating temperatures of logs for obtaining higher shear strength of plywood varied by wood species. In a previous investigation, quality of veneer obtained from Canadian pine and Norway spruce logs was also influenced by the temperature of the logs during the peeling (Anon., 1998). Another study showed that surface roughness and the quality of the veneer obtained from Douglas fir logs harvested following heavy rainy days were better than those of harvested during dry times in summer (Hecker, 1995). In the same study, it was also reported that Douglas fir logs left in the rain for 13 days after harvesting produced veneer with smoother surface. Resch and Parker (1979) stated that optimum peeling temperature of Douglas fir logs ranged from 49 °C to 60 °C to have veneer with better quality. In general peeling temperature of the softwood logs are lower than that of hardwood logs due to their higher density. Currently there is no comprehensive information about the quality of veneer and plywood manufactured from spruce logs peeled at different temperature levels. Therefore, the main objective of this work is to determine the influence of two different log temperatures on surface roughness, wettability, and colour variation of the veneer sheets. Shear strength of the experimental plywood panels made from veneer samples was also evaluated as function of log temperature to provide an initial data to plywood manufacturers to enhance the overall quality of the final product.

2. Material and methods

Spruce logs with and average diameter at breast height of 38 cm were harvested from Trabzon region/Turkey for the experiments. Logs were debarked and bucked into 55 cm long sections for veneer manufacture. Each section of the logs was steamed at a temperature of 80 °C in a vat for 12 h. The logs were classified into two groups, the logs in the first group logs were kept for 24 h to reach an average core temperature of 32 °C while logs of the other group were only kept for 3 h to have a target core temperature of 52 °C prior the peeling process. A commercial rotary type peeler with a maximum horizontal holding capacity of 80 cm was used for veneer production. Horizontal opening was 85% of veneer thickness and vertical opening was 0.5 mm in the peeling process. Veneer sheets with dimensions of 50 cm × 50 cm × 2 mm were clipped from each group and dried at 100 °C to a target moisture content of 6% in a continuous dryer.

A fine stylus type profilometer, Mitutoyo Surftest SJ-301 was used for roughness evaluation of the samples. The device consisted of the main unit and the pick-up. The pick-up has a skid-type diamond stylus with a radius of 5 μm and a tip angle of 90°. The stylus traverses the surface and its vertical displacement is converted into an electrical signal. Numerical surface roughness parameters can be calculated form digital information, which is transmitted into a computer. Cut-off length (λ_c) and tracing length were 2.5 mm and 12.5 mm, respectively. Three roughness parameters, average roughness (R_a), mean peak-to-valley height (R_z), and maximum roughness (R_{max}) were used to evaluate surface roughness of the samples as function of log temperature according to DIN 4768 (1990). Detailed information about such parameters has been presented in previous studies (Hiziroglu, 1996; Ilter et al., 2002; Mummery, 1993). Thirty veneer samples with 50 mm × 50 mm size were used for each test group to evaluate surface roughness. Measurements were taken across the grain orientation.

There are different methods for measuring colours. Colour of wood surfaces can be measured by using optical devices such as spectrophotometers. With optical measurement methods, the uniformity of colour can be evaluated and presented as L^*, a^* and b^* coordinates named by CIELAB colour space values. The CIELAB system defined by the Commission Internationale de l'Eclairage (CIE) is described by three parameters: L^* axis represents the lightness, a^* and b^* are the chromaticity coordinates; $+a^*$ for red, $-a^*$ for green, $+b^*$ for yellow and $-b^*$ for blue as shown in Fig. 1. The L^* value varies from 100 (white) to zero (black) (Aydin and Colakoglu, 2002; Temiz et al., 2003).

A spectrophotometer, Minolta CM-2600d, was employed for colour measurement in this study. CIE Illuminant D65 was used in the colour measurements as light source. Measurements were made over a 8 mm diameter spot with 10° observer angle. Three measurements taken from the sapwood portion of the samples were expressed by CIELAB colour space values. No heartwood veneer could be obtained in this study because it was not possible to peel from the core parts of the logs under the diameter of spindle heads holding and rotating log in the peeling machine. Therefore, all veneer samples were obtained from sapwood portions of logs.

L^*, a^* and b^* colour space values were used to calculate the total colour change (ΔE) as a function of log temperature according to the following equations:

$$\Delta L^* = L^*_{\mathrm{f}} - L^*_{\mathrm{i}}, \quad \Delta a^* = a^*_{\mathrm{f}} - a^*_{\mathrm{i}}, \quad \Delta b^* = b^*_{\mathrm{f}} - b^*_{\mathrm{i}},$$

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

where; the subscripts 'f' and 'i' indicate the final and initial values of measurements, respectively. L^*, a^* and b^* values contribute to the total colour change ΔE^*. A value of $\Delta E < 1.0$ indicates a small colour difference. Low ΔE values correspond to low colour change or a stable colour (Temiz et al., 2003).

Contact angle method was employed to determine wettability of veneer samples. A goniometer with 12× magnification was used to obtain static contact angles of urea formaldehyde (UF) and phenol formalde-

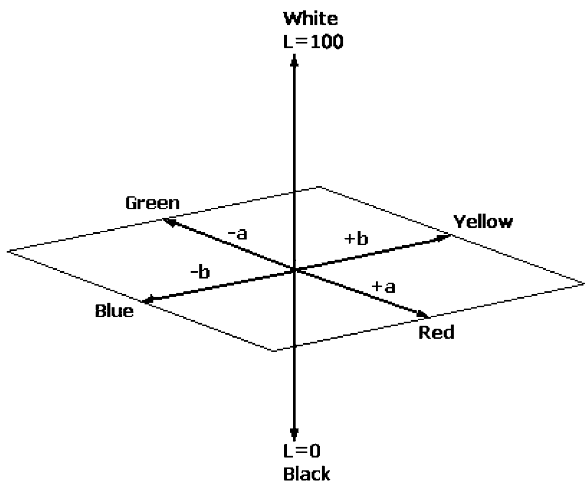

Fig. 1. The CIELAB colour space.

Table 1
The formulations of urea formaldehyde (UF) and phenol formaldehyde (PF) glue mixtures used for the manufacturing of plywood panels

	Adhesive ingredient	Parts by weight
UF glue	UF resin (with 55% solid content)	100
	Wheat flour	30
	NH_4Cl (with 15% concentration)	10
PF glue	PF resin (with 47% solid content)	100
	Hardener (POLIFEN 10)[a]	30

[a] Polifen 10 is the commercial name of the hardener for phenol formaldehyde.

hyde (PF) resins. Thirty 5 μl resin drops were randomly deposited on the surfaces of 5 cm × 5 cm veneer samples to evaluate their wettability characteristics. Contact angles were measured within 5 s after the drops were deposited on the surfaces and a computer program was used to determine drop shapes and contact angle values of each sample.

Three 3-ply plywood panels with dimension of 50 cm × 50 cm and 6 mm thick were manufactured for two types of veneer sheets by using UF and PF resins. The formulations of UF and PF adhesive mixtures used for gluing veneers are given in Table 1. Both types of resins were applied at a rate of 160 g/m^2 to the single surface of veneer using a four-roller spreader. Assembled samples were pressed in a hot press at a pressure of 8 kg/m^2 using a temperature of 140 °C for PF and 110 °C for UF for 5 mins, respectively. Shear strength test of plywood panels was conducted according to EN 314 (1993) on a universal testing machine with a load cell capacity of 10,000 kg. Plywood panels manufactured with UF glue were tested after the test samples immersed for 24 h in water at 20 ± 3 °C, while the panels manufactured with PF glue were tested after the shear test samples immersed for 6 h in boiling water, followed by cooling in water at 20 ± 3 °C for at least 1 h to decrease the temperature of test pieces to 20 °C.

3. Results and discussion

3.1. Surface roughness and surface colour as a function of log temperature

Figs. 2A and 2B show typical surface profiles of the specimens peeled from the logs with different temperature and Fig. 3 shows average values of roughness parameters obtained from the veneer surfaces peeled from logs with two temperature levels. Average R_a, R_z, and R_{max} values of the samples manufactured from the logs with a temperature of 52 °C were 9.7 μm, 59.4 μm, and 71.7 μm, respectively. These values were significantly lower than those of the samples produced from the logs with a temperature of 32 °C at a confidence level of 95%. Findings in this study suggest that surface roughness of the veneer improved with increasing log temperature. On the other hand, a research conducted in Canada has shown that higher quality veneer can be achieved using log temperatures in the 32–38 °C (90–100 F) range for spruce–pine–subalpine fir species compared to 55 °C (130 F) commonly used by the plywood industry (Anon., 1998). Hecker (1995) reported that heating time and log temperature influenced significantly surface characteristics of veneer samples. Other studies also stated that surface roughness of veneer are function of species, width of annual ring, wood density, and ratio of early wood late wood in addition to log temperature and log storage conditions (Hecker, 1995; Ilter et al., 2002; Mothe et al., 1992; Sachsse and Roffael, 1993). It seems that higher temperature resulted in better surface properties of the samples based on the results of the tests. This finding would also contribute to reduced resin consumption during the gluing and making veneer more plastic during the peeling so that veneer with enhanced surface quality can be produced without any defects.

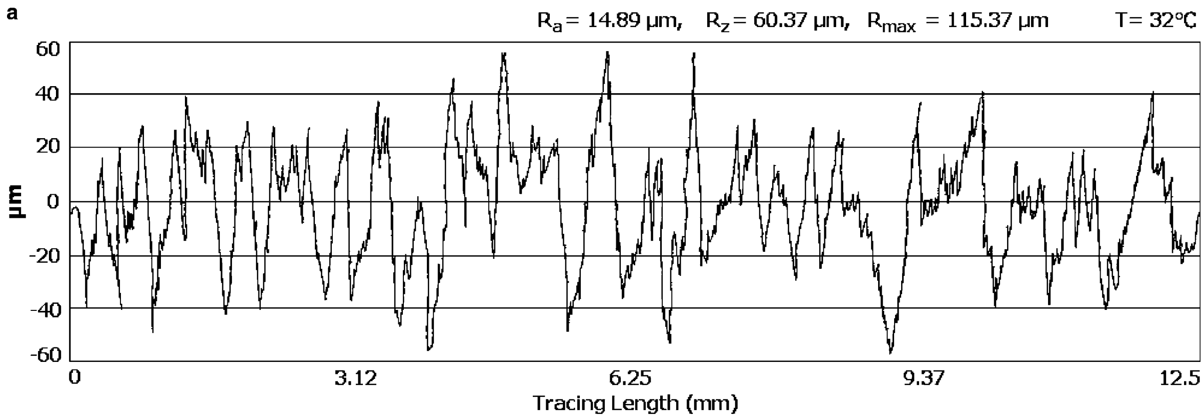

Fig. 2A. Typical surface profiles of veneers samples obtained from the logs with 32 °C.

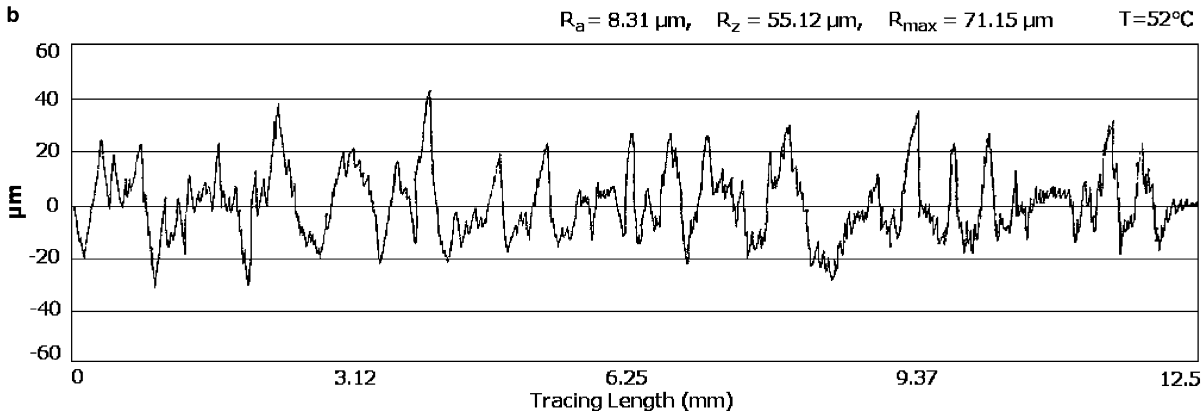

Fig. 2B. Typical surface profiles of veneers samples obtained from the logs with 52 °C.

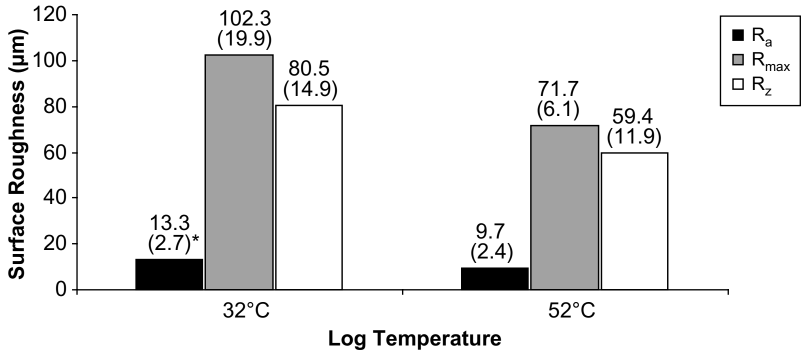

Fig. 3. Average values of roughness parameters obtained from the veneer surfaces based on the log temperature (values in parenthesis are standard deviations).

Table 2
Effect of log temperature in peeling process on the surface colour of veneers

Log temperature	L^*	a^*	b^*	ΔL^*	Δa^*	Δb^*	ΔE^*
32 °C	85.00 (0.88)[a]	2.49 (0.29)	24.66 (0.66)				
52 °C	85.23 (0.44)	2.71 (0.46)	24.37 (0.70)	0.23	0.22	−0.29	**0.43**

[a] Values in parenthesis are standard deviations.

No clear changes in colour on the surfaces of spruce veneers depending on the log temperature were obtained as can be seen from Table 2. L^*, a^* and b^* colour space values were almost not influenced by variation of the log temperature. ΔE value (0.43) also strengthening this statement because a ΔE value smaller than 1.0 indicates a small colour difference. It was stated that sapwood of spruce has generally uniform colour as compared to many other softwood species such as eastern redcedar, fir, or pine (Sundqvist, 2002). Therefore, difference in surface colour of veneers produced from the logs with different temperatures was not prominent.

3.2. Adhesive wettability

Adhesive wettability of the samples determined by contact angle analysis showed that veneer with smooth surfaces (for 52 °C log temperature) had higher contact angle values for both types of resin. Contact angles were found smaller on rough wood surfaces due the higher surface area than those of smooth surfaces (Buscher et al., 1983). Results of the test also showed that veneer with average roughness value of 13.3 μm had 52.1° contact angle in the case of UF was used (Fig. 4). Contact angle value increased as surface of the veneer get smoother. The variation of the contact angle is related to the nature of the adhesives used. PF resins are more hydrophobic that UF resins because of the phenyl rings present in their structures. Consequently the contact angles of PF resins should be larger than that experienced by UF resins. On the other hand, viscosity of UF and PF used for the measurements is also important parameter influencing the results. Since the recipes suggested by the producer firm of glue resins were taken into consideration when preparing glue mixtures, no adjustment was made on the viscosity of the glues used in this study. Because of having different viscosity values of UF and PF resins, contact angles obtained showed diversity depending

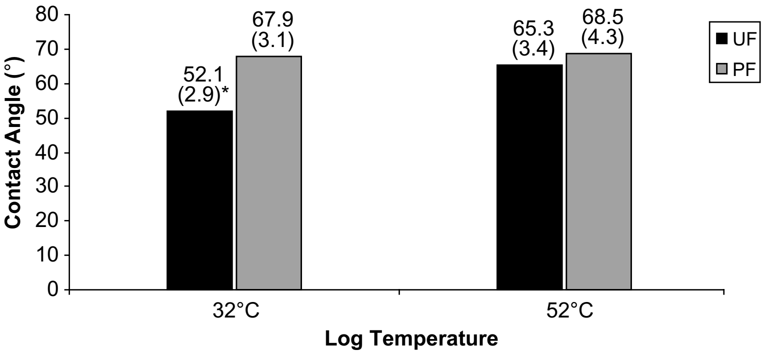

Fig. 4. Average values of contact angles on veneer surfaces based on glue type and log temperature (values in parenthesis are standard deviations).

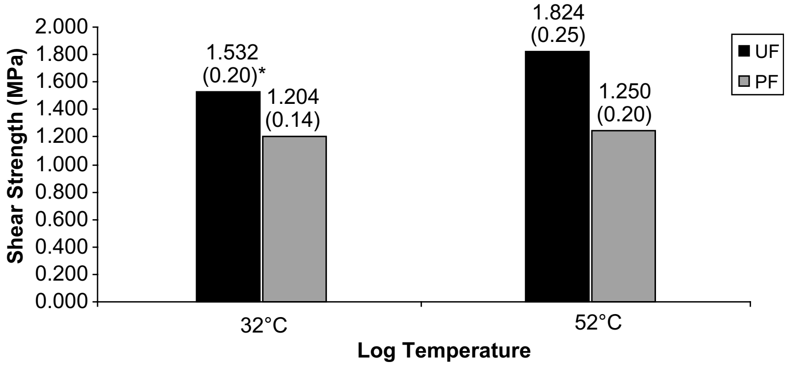

Fig. 5. Shear strength values of plywood panels manufactured from veneers peeled from logs with two temperature levels based on glue type (values in parenthesis are standard deviations).

on the glue type. The viscosity values of UF and PF resins used in this study were 700–900 MPa s and 3900–4500 MPa s (cup Ø = 6 mm), respectively. Scheikl reported that contact angle on wood surface increased with increasing viscosity of the liquid deposited on the surface (Scheikl, 1995). Viscosity of PF is almost 5 times higher than that of UF which resulted in larger values of contact angle measurements as can be seen in Fig. 4. Difference between PF contact angle values for two types of veneers is not substantial in contrast to that of UF resin. If PF resin drop were left longer than 5 s on the surfaces to compensate its higher viscosity above differentiation would have had similar trend to differences of the samples used with UF.

3.3. Plywood shear strength

Higher shear strength values were obtained for plywood samples manufactured from veneers having smoother surfaces with both types of resin as shown in Fig. 5. Some other studies also determined that improved surface roughness of veneer increased shear strength of the plywood made from them (Faust and Rice, 1986; Aydin, 2004). Effect of surface roughness of the veneer samples on the shear strength of plywood was more noticeable in the case of UF resin was used, increasing from 1.532 MPa to 1.824 MPa (Fig. 5). However shear strength of the samples made with PF almost stayed at the same level. This can be related to high viscosity of PF. Contact angle value for wettability test of PF only increased 0.8% as surface characteristics of the veneer enhanced supporting above finding.

4. Conclusions

This study investigated the relationship between temperature of logs and surface roughness, wettability, colour variation of veneer, and shear strength of the plywood manufactured from the veneer sheets. It appears that log temperature have some effect on roughness variation of veneer. However, colour variation of the veneer is not function of log temperature for the temperatures investigated. It is suggested tests carried out in this work can be used to evaluate basic properties of veneer and plywood as function of log temperature to attain a better understanding properties of the final panel products. In further studies performed should evaluate more than two log temperature levels and additional roughness parameters such as core roughness (R_k), reduced valley height (R_{vk}) and, reduced peak height (R_{pk}) should also be included to generate more comprehensive data. Also heartwood veneers can be investigated besides sapwood veneers to make a comparison.

References

Anon., 1998. Forintek Canada Corp, Wood-based panel products technology roadmap: Special report. Forest Industries and Building Products, Canada, ISSN 0381-7733. URL: <http://strategis.ic.gc.ca/SSI/fb/engmap.pdf> (accessed 21.05.2005).

Aydin, I., 2004. Activation of wood surfaces for glue bonds by mechanical pre-treatment and its effects on some properties of veneer surfaces and plywood panels. Applied Surface Science 233 (1–4), 268–274.

Aydin, I., Colakoglu, G., 2002. The effects of steaming and veneer drying temperature on the weathering reactions. In: The Proceedings of Wood Based Materials Wood Composites and Chemistry International Symposium, COST E-13, Final Workshop, Vienna, Austria, 19–20 September 2002.

Baldwin, R., 1995. Plywood and Veneer Based Products: Manufacturing Practices. Miller and Freeman Publication Inc., San Francisco, 388p.

Berkel, A., Bozkurt, Y., Goker, Y., 1969. On the manufacture of veneer from different oak species grown in Turkey. Istanbul University, Faculty of Forestry, Pub. No.: 1430. 152p (in Turkish).

Bozkurt, Y., Goker, Y., 1986. Composite wood products technology. Istanbul University, Faculty of Forestry, Pub. No.: 3401. 316p (in Turkish).

Buscher, H.J., Pelt, A.W., Boer, P., Jong, H.P., Arends, J., 1983. The effect of surface roughness of polymers on measured contact angles of liquids. Unpublished Report, University of Groningen, Laboratory for Material Technica, the Netherlands.

DIN-4768, 1990. Determination of values of surface roughness parameters R_a, R_z, R_{max} using electrical contact (stylus) instruments, concepts and measuring conditions. Deutsches Institut für Norming, Berlin, Germany.

EN-314, 1993. Wood-based panels, determination of mechanical properties. European Standardization Committee, Brussels, Belgium.

Faust, T.D., Rice, J.T., 1986. Effect of veneer surface roughness on glue bond in Southern Pine plywood. Forest Products Journal 36 (4), 57–62.

Goker, Y., Akbulut, T., 1992. Factor influencing some of the properties of particleboard and plywood. In: The Proceedings of the First International Forest Industry Congress, vol. 1, Karadeniz Technical University, Trabzon, Turkey, 22–25 September 1992. pp. 269–287.

Gupta, R.C., Bist, B.S., 1981. Effect of peeling variables on strength of plywood. Part 1. Effect of heating log. Holzforschung un Holzverwertung 33 (1), 6–8.

Hecker, M., 1995. Peeled veneer from Douglas fir influence of round wood storage, cooking and peeling temperature on surface roughness. In: The Proceedings of the 12th International Wood Machining Seminar, Kyoto, Japan.

Hiziroglu, S., 1996. Surface roughness analysis of wood composites: a stylus method. Forest Products Journal 46 (7/8), 67–72.

Ilter, E., Camliyurt, C., Balkiz, O., 2002. Research on the determination of the surface roughness values of Bormulleriana fir (*Abies bornmulleriana* Mattf.). Central Anatolia Forestry Research Institute, Ankara, Turkey, Tech. Bulletin No.: 281. 48p.

Lutz, J.F., 1978. Wood veneer: Log selection, cutting and drying. Forest Service, US Department of Agriculture, Technical Bulletin No.: 1577. 137p.

Mothe, F., Movassaghi, H., Thibaut, B., 1992. Le deroulage du Doughlas et de Epicea: quelques resultants de la recherché. Forest Enterprise 80, 28–36.

Mummery, L., 1993. Surface Texture Analysis. The Handbook. Hommelwerke, Muhlhausen, Germany, 106p.

Ozen, R., 1981. Various factors which affect some of the physical and mechanical properties of plywood. Karadeniz Technical University, Faculty of Forestry, Trabzon, Turkey, Pub. No.: 120 (in Turkish).

Resch, H., Parker, R., 1979. Heat conditioning veneer blocks. Research Bulletin 29. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Sachsse, H., Roffael, E., 1993. Untersuchung der Schalfurnier-Eignung von in Deutschland erwaschsenem Douglasienholz. Holz als Roh-und Werkstoff 51, 167–176.

Scheikl, M., 1995. Wettability of wood determined with urea formaldehyde adhesive. Ph.D. Thesis, Institut fur Holzforschung, University of Bodenkultur, Wien, Austria.

Sundqvist, B., 2002. Wood colour control during kiln-drying. Forest Products Journal 52 (2), 30–37.

Temiz, A., Eikenes, M., Yılıdz, U.C., Evans, G.F., Jacobsen, B., 2003. Accelerated weathering test for the evaluation of wood preservative efficacy, In: The Proceedings of the 34th Annual Meeting of the International Research Group on Wood Preservation, Brisbane, Australia, IRG/Wp 03-20262, 18–23 May 2003.