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SURFACE ROUGHNESS OF THIN WOOD VENEERS SLICED FROM LAMINATED GREEN WOOD LUMBER

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ABSTRACT

Freshly-felled Chinese fir (*Cunninghamia lanceolate)*, Masson Pine (*Pinus massoniana)* and Camphor Tree (*Cinnamomum camphora)* logs were reconstituted to form laminated lumber with moisture content above fiber saturation point by slicing, finger-jointing, gluing, and cold-pressing processes. The laminated lumber was then sliced into wood veneers, which were air-dried to about 15% moisture content. The surface roughness of the veneer was tested in comparison with two commercial engineered wood veneers using a stylus tracing method. The influence of the wood surface roughness was relatively small for the wood species chosen due to their similar densities. All roughness parameter values were consistently larger along the transverse direction compared with these along longitudinal direction. The values of surface roughness at the finger-joint region were higher than these that at the non-finger-joint region along both longitudinal direction and transverse direction. The two engineered wood veneers had surface roughness values noticeably smaller in the longitudinal direction, but their values in transverse direction were comparable and even larger compared with these of the prepared wood veneers including both non-finger-joint and finger-joint regions. Overall, the process of laminating finger-jointed green wood planks and subsequently slicing can be used to yield acceptable wood veneers with sufficient surface quality.

Keywords: *Cinnamomum camphora, Cunninghamia lanceolate*, finger joints, laminated lumber, moisture content, *Pinus massoniana.*

INTRODUCTION

Low-quality, small-diameter logs are currently reconstituted to form laminated lumber, which is then used to produce a variety of thin wood veneers to replace precious solid wood with natural texture and color. It has become one of the practical ways to supplement natural decorative veneers (Peng and Wang 2004, Liu *et al.* 2003, Deng and Liu 2010, Yu and Yu 2013, Dumitrascu *et al.* 2013). Surface roughness of wood and wood-based products is one of the most important factors for decorative wood elements targeted for interior and exterior uses. Low surface quality not only negatively affects the appearance of the finished products, but also affects further manufacturing processes including glue adhesion, and adhesive strength (Budakci *et al.* 2007, Aslan *et al.* 2008, Coelho *et al.* 2008).

Wood material is highly heterogeneous at the microscopic level, and the surface quality (e.g., roughness) of wood is affected by its anatomic feature. Thus, it is quite complicated to make a detailed assessment of wood surface quality (Hendarto *et al.* 2006). Among various testing techniques for

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determining surface roughness of wood and wood composites, the stylus method has been most widely used in the past studies (Hiziroglu 1996, Zhong *et al.* 2013). The stylus method can help measure actual surface profile, from which standard numerical roughness parameters can be derived (Kilic *et al.* 2006). With this test method, the roughness characteristics of the sliced thin wood veneer surface can be assessed by determining the shape, height, and width of the roughness peaks and valleys on wood surface as influenced by wood processing operations or by inherent anatomical structural properties (Magoss 2008).

The roughness of solid wood surface is highly related to processing conditions and wood properties, including species (hardwood versus softwood), density (low versus high), moisture content (MC), annual ring pattern, and cell type and structure, earlywood and latewood percentage ratio, and number and distribution of tracheid and vessel elements (Wang *et al.* 2005, Magoss 2008, Brémaud *et al.* 2011, Csanády *et al.* 2015). Several studies have been conducted to investigate the influence of machine processing (i.e., sawing, sanding, and planning), early- and late-wood distribution, and material directions (i.e., longitudinal, radial and tangential) on the surface roughness quality of wood and laminated wood composites (Malkoçoğlu 2007, Dundar *et al.* 2008, Kilic *et al.* 2006, Sulaiman *et al.* 2009).

Wood cell walls take on a greater tenacity at high MCs. Free water in the cell lumen helps somewhat strengthen the toughness of wood, reduce the cutting resistance (e.g., during slicing), decrease the damage to the cell wall, and improve the quality of sliced wood veneer (Li *et al.* 2015, Liu *et al.* 2003). Thus, if laminated wood lumber at MC well above fiber saturation point can be successfully sliced to yield high surface quality veneers, significant saving can be achieved in raw lumber processing (e.g., kiln-drying) and veneer manufacturing (e.g., slicing dry laminated lumber with more energy input). In this work, fresh wood logs were reconstituted to form laminated wood lumber by slicing, finger-jointing, gluing and cold pressing. The lumber was subsequently sliced to produce wood veneers. The objective of this work was to measure the surface roughness of the wood veneers and to examine if the processed veneers can meet the requirements of subsequent processing technology.

MATERIALS AND METHODS

Experimental Materials and Sample Preparation

The freshly-felled Chinese fir (*Cunninghamia lanceolate Hook.)*, Masson Pine (*Pinus massoniana Lamb.)* and *Camphor Tree* (*Cinnamomum camphora)* logs were used as raw material. The green logs were sliced into thin planks, which were cross-cut to remove any knots and other defect and then finger-jointed as shown in Figure 1. The machining variables of finger jointing operation included the milling cutter thickness of 4,2 mm (equal to milled tenon's pitch), milling cutter tip width of 0,85 mm (equal to milled tenon's slot bottom width), milling cutter tip angle of 9,77º (equal to milled tenon's wedge angle), and the slope of finger-joint's edge of 1/11,7 (related to the cutter tip slope). Figure 1a shows the lamination process using individual wood species (Chinese fir, Masson pine, and Camphor wood). Figure 1b shows the lamination process for using combined wood species (alternating finger-jointed Masson pine and *Campho*r wood). The laminated lumbers at MC about 40% were sliced into thin veneers parallel to the radial face of the lumber. The veneer size was 2550 mm in length x 450 mm in width x 0,38 mm in thickness. The veneers were air-dried to a MC about 15%, and the dry veneer samples were taken for surface roughness testing.

For a comparative purpose, commercial engineered wood veneers (0,38 mm in thickness) from *Triplochitin scleroxylon* (designated as EWV1) and *Tilia amurensis Rupr* (designated as EWV2) were selected. The veneers from both species groups were sliced from their respective laminated lumber, which was made up of single component 0,8 mm thick planks. The raw lumber material was glued by a two-component polyvinyl acetate (PVA) adhesive. The end pressure of the finger joint was 3,5 MPa and the joints were then cold pressed to form square laminates. The size of sliced veneer from the large-scale production process was 2550x450x0,38 mm.

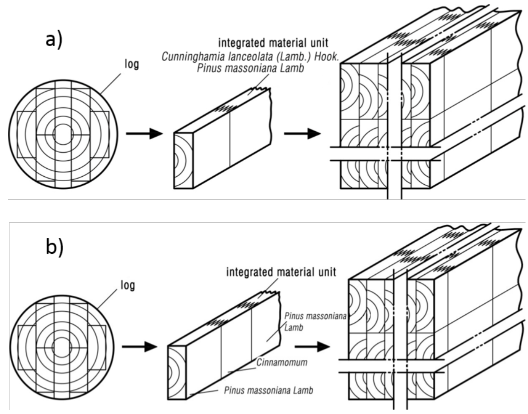

Figure 1. Schematic diagram of manufacturing laminated wood lumber with MC above fiber saturation point. a) lamination process using individual wood species; and b) lamination process for using combined wood species.

Surface Roughness Test Apparatus and Method

The veneer specimens for surface roughness testing were laterally cut from the large dry veneer sheets as shown in Figure 2. The planning was performed with a cabinet single-axed straight-knife peripheral planer, equipped with two freshly-sharpened knives installed in a 3000 rpm cutter-head. The planer was set to work at 12 m/min feed speed, which resulted in approximately 10 knife marks per 25 mm. Knife rake and clearance angles were set to 12º and 15º, respectively. Planer feeding was carried out parallel to the radial face of the lumber. The sample sections were from two ends and central part of each large veneer. Each surface roughness specimen was measured at the 5 selected positions with no-finger joints (NFJs – original wood surface) and 5 selected positions with finger-joints (NJs- 5 measurements at each position) along both longitudinal direction (LD) and transverse direction (TD). The average value and standard deviation for each parameter were established and reported.

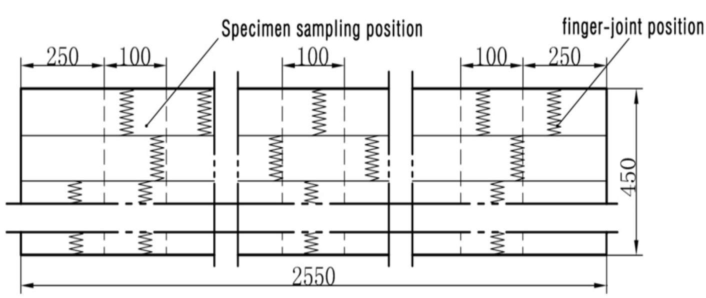

Figure 2. Schematic diagram of the sliced wood veneers for surface roughness testing (unit shown as mm).

A model JB-5C (Shanghai Optical Instrument Factory Co., Ltd., Shanghai, China) stylus surface roughness profilometer was used to measure the roughness of the prepared veneer surfaces. The measuring conditions of the surface roughness included sampling length of 2,5 mm, evaluation length of 12,5 mm (five times of the sampling length), and scanning speed of 0,5 mm/sec. The profile filter was an ISO 2CR Filter and stylus tip radius was 10 um. The surface roughness parameters include the profile's arithmetic mean deviation (i.e., *Ra*, µm), the profile's maximum height (i.e., *Rz*, µm), the profile's average distance of the microscopic unevenness (*RSm*, µm) and the profile's root mean square deviation (*Rq*, µm) were determined and used to quantify the veneer surface quality. Among the five parameters, *Ra* and *Rz* are most often used to characterize a wood surface (Kilic *et al.* 2006).

RESULTS AND DISCUSSION

Typical Surface Roughness Profiles

Figure 3 shows two representative surface roughness profiles from the Chinese fir wood veneers sliced from laminated wood lumber at green (along the TD with and without finger-joints). The measurement yielded surface roughness profile for the selected parameter and a summary of the numerical values of different parameters. As shown, the regions that included finger-joints had an apparent larger surface roughness values, compared with the regions without finger-joints. Similar results were seen for other veneer types.

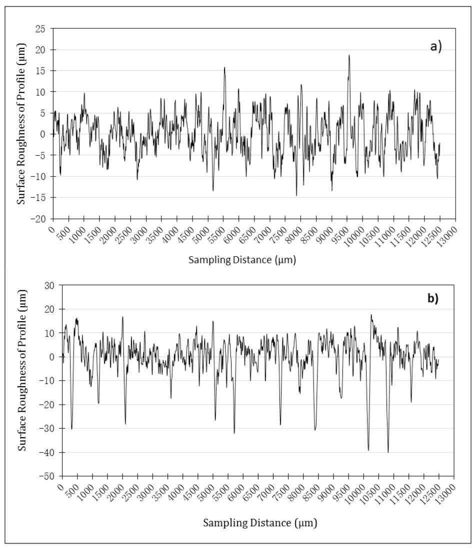

Figure 3. Typical transverse section surface roughness profile of the Chinese fir (*Cunninghamia lanceolata)* veneer samples sliced from laminated lumber at green. a) with no-finger joints, and b) with finger-joints.

Measured Veneer Surface Roughness

Table 1 lists summarized surface roughness parameters from different veneers. The mean wood moisture contents when the laminated lumber were sliced are respectively 40,2%; 42,1%; and 43,3% for $Wood_A$ – Chinese fir, $Wood_B$ - *Camphor Tree,* and $Wood_C$ – Masson Pine and *Camphor* wood combination.

Effect of wood type

Among the three types of wood veneers ($Wood_A$, $Wood_B$, and $Wood_C$), the surface roughness parameters in the no-finger joint (NFJ) region (i.e., original wood surface) varied inconsistently along both LD and TD. For example, the mean *Ra* values for veneers from $Wood_A$, $Wood_B$, and $Wood_C$ are, respectively 13,55; 9,55 and 14,57 μm in the LD and 19,87; 11,19 and 14,72 μm in TD. Similar trends of variations are seen for parameters *Rz, Rsm*, and *Rq*. Thus, the effect of wood type on surface roughness data seemed to be small for the species of wood chosen. The basic wood densities for Chinese pine, Masson pine, and Camphor wood are generally similar in the range of 0,40-0,50 g/cm^3 depending on the source. Thus, the chosen wood species had much similar response to slicing at green conditions, leading to overall similar surface roughness. Kilic *et al*. (2006) showed that beech (density=0,70 g/cm^3) and Aspen (density=0,40 g/cm^3) wood did show surface roughness value difference (*Rz* parameter) in both radial and tangential directions given similar processing conditions (i.e., aspen wood with smoother surface). Thus, wood density difference played a more significant role in controlling shrinkage and swelling characteristics of wood, leading to different surface properties.

Table 1. A summary of the surface roughness parameters for various wood veneers sliced from laminated wood lumber at green.

Parameters[a]	Test Area[b]	Test Direction[c]	$Wood_A$[d]	$Wood_B$[d]	$Wood_C$[d]
			40,2%MC	42,1%MC	43,3% MC
Ra (µm)	NFJ	LD	13,55(0,55)	9,59(0,26)	14,57(0,06)
		TD	19,87(0,36)	11,19(0,98)	14,72(0,38)
	FJ	LD	18,76(0,61)	11,33(0,31)	15,36(0,52)
		TD	22,89(0,37)	13,85(1,03)	15,85(1,33)
Rz (µm)	NFJ	LD	77,31(5,19)	78,37(11,32)	97,84(1,00)
		TD	109,08(9,45)	85,98 (11,01)	102,11(3,56)
	FJ	LD	85,78(8,11)	82,35(12,89)	100,99(9,87)
		TD	115,32(8,18)	93,21(12,03)	108,78(2,90)
RSm (µm)	NFJ	LD	0,217(0,017)	0,247(0,018)	0,267(0,004)
		TD	0,324(0,018)	0,232(0,014)	0,225(0,006)
	FJ	LD	0,276(0,018)	0,301(0,012)	0,237(0,012)
		TD	0,404(0,011)	0,263(0,013)	0,309(0,012)
Rq (µm)	NFJ	LD	16,67(0,56)	12,31(0,16)	18,08(0,15)
		TD	23,88(0,11)	13,99(1,23)	18,55(0,60)
	FJ	LD	20,12(0,62)	16,31(0,22)	21,13(0,43)
		TD	27,39(0,21)	17,21(0,47)	23,58(1,39)

Notes: [a] Ra is the arithmetic mean deviation, Rz is the maximum height, RSm is the average distance microscopic unevenness, and Rq is the root mean square deviation. [b] NFJ – no finger joint, FJ – finger joint. [c] LD-longitudinal direction, TD- transverse direction. [d] $Wood_A$ – Chinese fir; $Wood_B$ - Camphor wood; $Wood_C$ – Masson Pine and Camphor wood combination. Data shown are mean and standard deviation.

Effect of test direction

The average surface roughness values of the sliced wood veneers from the same material in the different grain directions (longitudinal versus transverse) varied significantly (Table 1). All roughness parameter values are consistently larger along the TD compared with these along the LD. For example, the mean *Rz* values for veneers from $Wood_A$, $Wood_B$, and $Wood_C$ in NFJ region are, respectively 77,31; 78,37 and 97,84 µm in the LD and 109,08; 85,98 and 102,11 µm in TD. Similar trends of variations are seen for parameters *Ra, Rsm*, and *Rq*. de Moura *et al.* (2014) reported surface roughness data for *Eucalyptus grandis* wood (heat treated) after machining. They showed that wood across the grain was much rougher after planning and sanding. This work showed a similar behavior with slicing at green condition and subsequent drying. As the wood is a non-homogeneous material, its expansion and shrinkage deformation are different along tangential direction (the largest), radial direction (the second), and longitudinal direction (the smallest). Thus, the differential shrinkage led to differences in the surface roughness values along different grain directions.

Effect of Finger-jointing

The values of surface roughness in the FJ region were higher than these in the NFJ region along both LD and TD. For the Chinese fir, Camphar, and Masson pine-Camphor wood veneers, the maximum values of the parameter *Ra* are, respectively 22,89; 13,85 and 15,85 µm (along TD within FJ region). The corresponding values for the parameter *Rz* are 115,32; 93,27 and 108,78 µm (along TD within FJ region). As there exists difference in the structure and density of different timbers, the state of stress experienced by each type of wood varied during finger jointing and subsequent slicing. In order to make firm and tight finger joints, the fitness ratio value of the joint must be positive. When lumber was jointed along the length, the body of the fingers was compressed and the compression deformation was built in the finger region. However, the compressive stresses were released when the lamination lumber was sliced into thin wood veneers, causing various degrees of expansion near the finger joint, which led to increased surface roughness. Nevertheless, due to small finger-joints used, the resulting surface roughness variation was not significant in practice, which had small negative effect on the subsequent application of the sliced thin wood veneers.

Comparison with EWVs

Table 2 shows surface roughness data (*Ra* and *Rz*) from the two commercial engineered wood veneers (EWVs). Overall, ENV2 from *Tilia amurensis* was slightly rougher compared with EWV1 from *Triplochitin scleroxylon* in terms of both *Ra* and *Rz* values. This could be related to the difference in wood properties of the two species, given the lamination and slicing processes the same.

Table 2. Surface Roughness Data of Sliced Commercial Wood Veneers from *Triplochitin scleroxylon* and *Tilia amurensis.*

Roughness Parameters	Test Direction [a]	Maximum Value	Minimum Value	Mean Value
Sliced Wood Veneers - *Triplochitin scleroxylon*				
Ra (µm)	LD	7,232	6,184	6,635
	TD	15,713	11,546	13,922
Rz (µm)	LD	45,591	34,583	40,793
	TD	98,980	82,137	90,028
Sliced Wood Veneers - *Tilia amurensis*				
Ra (µm)	LD	7,872	7,075	7,494
	TD	20,741	20,577	20,673
Rz (µm)	LD	48,203	37,964	44,331
	TD	120,730	115,683	118,475

Notes: [a] LD-longitudinal direction, TD- transverse direction.

Comparative plots of *Ra* and *Rz* values for all five veneers including three manufactured wood veneers and two EWVs are shown in Figure 4 (NFJ region) and Figure 5 (FJ region). The data shows that surface roughness values were noticeably smaller for the two EWV groups in the LD (Figure 4 a:*Ra* and Figure 4 b:*Rz*). For example, *Ra* values varied from 6184 to 7232 µm for EWV1 and 7075 to 7872 µm for EWV2. The corresponding mean values for $Wood_A$, $Wood_B$, and $Wood_C$ are, respectively 13,55; 9,59 and 14,57 µm. However, the roughness data from the three wood veneers manufactured were more comparable and even smaller than these of EWVs (especially EWV2) in TD for both NFJ and FJ regions. Thus, the process of laminating finger-jointed green wood planks and subsequently slicing can be used to yield acceptable wood veneers with sufficient surface quality. The process can lead to significant saving in raw lumber processing (e.g., kiln-drying) and veneer manufacturing (e.g., slicing dry laminated lumber with more energy input).

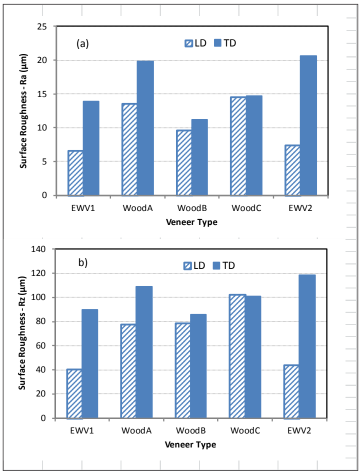

Figure 4. Comparison of surface roughness data from various veneers with no-finger joint region for $Wood_A$, $Wood_B$ and $Wood_C$. ENV1 and EWV2 are engineered wood veneers from *Triplochitin scleroxylon* and *Tilia amurensis*, respectively. a) *Ra* and b) *Rz*.

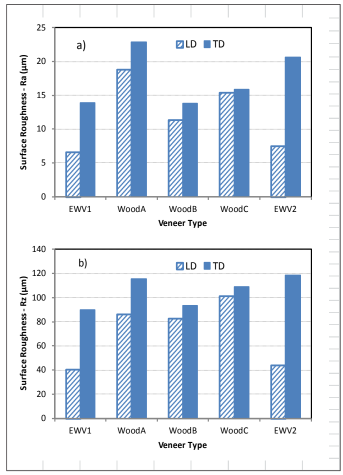

Figure 5. Comparison of surface roughness data from various veneers with finger joint region for $Wood_A$, $Wood_B$ and $Wood_C$. ENV1 and EWV2 are engineered wood veneers from *Triplochitin scleroxylon* and *Tilia amurensis*, respectively. a) *Ra* and b) *Rz*.

CONCLUSIONS

The green Chinese fir, Masson pine and Camphor tree logs were successfully reconstituted and sliced to produce wood veneers. The surface roughness of the veneers at 15% MC was studied in comparison with two commercial EWVs. The following conclusions can be reached:

The influence of wood type on surface roughness data was relatively small for the wood species chosen in the study due to their similar densities.

All roughness parameter values were consistently larger along TD compared with these along LD.

The surface roughness data at the finger-joint region were higher these that at the non-finger-joint region along both LD and TD, probably due to the release of stresses generated during finger jointing processes.

The two EWV veneers had surface roughness values noticeably smaller for in the LD, but their values in TD were comparable and even larger compared with these of the prepared wood veneers including both NFJ and FJ regions.

Overall, the process of laminating finger-jointed green wood planks and subsequently slicing can be used to yield acceptable wood veneers with sufficient surface quality. The process can lead to significant saving in raw lumber processing (e.g., kiln-drying) and veneer manufacturing (e.g., slicing dry laminated lumber with more energy input).

REFERENCES

Aslan, S.; Coşkun, H.; Kılıç, M. 2008. The effect of the cutting direction, number of blades and grain size of the abrasives on surface roughness of Taurus cedar (*Cedrus Libani A. Rich.*) woods. *Build Environ* 43:696-701.

Brémaud, I.; Gril, J,; Thibaut, B. 2011. Anisotropy of wood vibrational properties: dependence on grain angle and review of literature data. *Wood Sci Technol* 45:735-754.

Budakci, M.; Gurleyen, L.; Cinar, H.; Korkut, S. 2007. Effect of Wood Finishing and Planing on Surface Smoothness of Finished Wood. *J Appl Sci* 7:2300-2306.

Coelho, C.L.; Carvalho, L.M.H.; Martins, J.M.; Costa, C.A.V.; Masson, D.; Meausoone, P. J. 2008. Method for evaluating the influence of wood machining conditions on the objective characterization and subjective perception of a finished surface. *Wood Sci Technol* 42:181-195.

Csanády, E.; Magoss, E.; Tolvaj, L. 2015. Surface Roughness of Wood. In: Quality of Machined Wood Surfaces. *Springer International Publishing*. Cham, pp 183-236. ISBN:978-319-22418-3.

de Moura, G. P.; de Figueired, J. V.; de Moura, L F.; Nolasco, A M.; de Carvalho, A. M.; Garcia, R. A. 2014. Surface roughness of heat treated *Eucalyptus grandis* wood. *Maderas-Cienc Tecnol 16*(1): 3 -12.

Deng, H.; Liu, Y. 2010. Study on Environmental-Friendly Dyeing Processes of Fast-Growing Plantation Veneers. In: *2010 4th International Conference on Bioinformatics and Biomedical Engineering*. IEEE, pp 1-4.

Dumitrascu, A.E.; Ciobanu, V.D.; Lepadatescu, B. 2013. Valorization of Wood Resources for the Cutting of Decorative Veneer in the Context of Sustainable Development of Romanian Forests. *BioResources* 8:4298-4311.

Dundar, T.; Ayrilmis, N.; Candan, Z. 2008. Evaluation of surface roughness of laminated veneer lumber (LVL) made from beech veneers treated with various fire retardants and dried at different temperatures. *For Prod J* 78:71-76.

Hendarto, B.; Shayan, E.; Ozarska, B.; Carr, R. 2006. Analysis of roughness of a sanded wood surface. *Int J Adv Manuf Technol* 28:775-780.

Hiziroglu, S. 1996. Surface roughness analysis of wood composites: A stylus method. *For Prod J* 46:67-69.

Kilic, M.; Hiziroglu, S.; Burdurlu, E. 2006. Effect of machining on surface roughness of wood. *Build Environ* 41:1074-1078.

Li, G.; Lv, Z.; Liu, Z. 2015. A preliminary study on the main mechanical properties of the high moisture content wood after finger-jointed. *J Northwest For Univ* 30:224-227.

Liu, Z.; Li, Y.; Du, C.; Zhang, Y. 2003. A study on production technology of sliced bamboo veneer. *J Zhejang For Coll* 20:227-231.

Magoss, E. 2008. General Regularities of Wood Surface Roughness. *Acta Silvatica et Lignaria Hungarica* 4:81-93.

Malkoçoğlu, A. 2007. Machining properties and surface roughness of various wood species planed in different conditions. *Build Environ* 42:2562-2567.

Peng, L.; Wang, J. 2004. A study on processing edge jointed veneer. *China Wood Ind* 18:72-76.

Sulaiman, O.; Hashim, R.; Subari, K.; Liang, C.K. 2009. Effect of sanding on surface roughness of rubberwood. *J Mater Process Technol* 209:3949-3955.

Wang, M.; Wang, J.; Li, L. 2005. Roughness and roughness sense of wood surface from different machining processes. *Journal Beijing Forestry University* 27:14-18.

Yu, W.; Yu, Y. 2013. Development and prospect of wood and bamboo scrimber industry in China. *China Wood Industry* 27:5-8.

Zhong, Z.W.; Hiziroglu, S.; Chan, C.T.M. 2013. Measurement of the surface roughness of wood based materials used in furniture manufacture. *Measurement* 46 1482-1487.