

## Effects of plasma treatment and sanding process on surface roughness of wood veneers

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Received: 24.12.2013 • Accepted: 24.03.2014 • Published Online: 15.08.2014 • Printed: 12.09.2014

**Abstract:** An ideal veneer surface is crucial for good panel properties in plywood manufacturing. The aim of this study was to compare plasma treatments and sanding (mechanical) processes with respect to the surface roughness of veneers. Rotary-cut veneers with a thickness of 2 mm from Scots pine (*Pinus sylvestris*) logs were used as material. After rotary peeling, veneer sheets were dried at 110 °C in a veneer dryer. Veneer sheets were divided into 4 main groups. The surfaces of the control veneer sheets were left untreated. Two different grits of sandpaper, 80 and 180, were used for sanding the surfaces of veneers. Plasma treatment was applied to the last veneer group with 3 different gases (oxygen, nitrogen, and ammonia) and 3 different plasma times (1 min, 5 min, and 15 min). The Mitutoyo Surftest SJ-301 instrument was used to determine surface roughness of samples. Average roughness (Ra), mean peak-to-valley height (Rz), and maximum roughness (Rmax) parameters were measured to evaluate the surface roughness of the samples based on DIN 4768. It was found that the smoothest veneer surfaces were obtained with the sanding processes. Surface roughness values (Rz) of veneer sheets sanded with 180 grit sandpaper were lower than those of veneers sanded with 80 grit sandpaper. Compared with the plasma treatment in terms of surface roughness, plasma-treated veneers had higher Rz values. It was also determined that Rz values were the lowest in the veneers treated with nitrogen plasma. Additionally, the surface roughness values of Scots pine veneers treated with ammonia plasma were a little higher than those of veneer sheets treated with oxygen plasma. The effect of plasma treatment time on surface roughness was not found to be statistically significant.

**Key words:** Plasma treatment, sanding process, surface roughness, veneer

### 1. Introduction

Surface roughness and machining processes have an important effect on the quality of finishing and adhesive bonding for the veneer-based panel industry. Increasing the surface roughness of veneers reduces contact between veneer and substrate, which causes a weak glue line and low strength properties of panels manufactured from these veneers. Veneers with smooth surfaces have higher adhesive strength than those with rough surfaces, as reported by Dundar et al. (2008). Bekhta et al. (2009) also stated that improving the surface roughness of veneer enhances glue bonding during the press. Increases in surface roughness of veneers can also cause excessive resin use, and then production costs increase. Therefore, it is crucial to obtain an ideal veneer surface to supply good panel properties for plywood manufacturing.

Some mechanical processes such as sanding, planing, and chemical pretreatments with chemical reagents are widely applied to wood surfaces in order to improve bonding ability and wettability and to reactivate wood

surfaces for glue-wood bonds (Aydin, 2004). The surface characteristics of solid wood can be affected by machining processes and knife marks per centimeter, not only by cutterhead speed alone (Davis, 1962; Wengert and Lamb, 1994; Sofuoğlu and Kurtoğlu, 2014). Sand marks are also important parameters that influence the quality of the surface as a function of grit size (Mitchell and Lemaster, 2002). One of the alternative technologies for creating an ideal wood surface is plasma treatment. Plasma techniques can be used for the surface treatment and modification of lignocellulosic materials (Aydin and Demirkir, 2010). Plasma treatment technology is simple and has low operating costs. Plasma is a state of ionized gas containing excited atomic, ionic, molecular, and free-radical species. Power, frequency, and flow rate of feed gases are defined as plasma parameters controlling the process (Pykönen et al., 2008). In addition, there is no environmental pollution created by this treatment process, and it has a very promising future for engineering applications. Plasma treatment only affects the near surface of a material without changing bulk

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material properties, as opposed to chemical modifications. When the substrate passes through the plasma state, a number of chemical reactions occur due to exposure of the substrate to reactive particles; these reactions increase the surface energy and change the chemical composition of the surface molecules (Pykönen et al., 2009). Plasma treatment has many advantages: compared to conventional wet-chemical surface modification techniques, plasma treatment is a dry, environmentally friendly surface modification without any energy-intensive drying processes or chemical waste (Dilsiz, 1994). It is thought that plasma modification causes increased surface polarity induced by oxidation reaction, leading to the formation of hydroxyl, carboxyl, aldehyde, and other polar functional groups (Acda et al., 2012). The increased surface polarity, obtained with 1-butene liquid, improves wettability and penetration behavior (hydrophilicity) of wood (Acda et al., 2012). Several publications also showed that plasma treatment is one of the most effective ways to improve wood wettability and different treatment parameters, which may lead to different surface properties (Custodio et al., 2008; Liu et al., 2010). There are some studies concerning the plasma treatment of wood or wooden materials (Vader Wielen et al., 2006; Wolkenhauer et al., 2007), but no study exists comparing sanding and plasma treatments of wood materials with respect to surface roughness. The principle difference between sanding and plasma treatments is that sanding creates a new and fresh surface by removing the material, whereas plasma treatment primarily affects the material's chemical composition (Wolkenhauer et al., 2009). The aim of this study was to compare plasma treatments and sanding (mechanical) processes with respect to the surface roughness of veneers.

## 2. Materials and methods

Scots pine (*Pinus sylvestris*) logs with an average diameter of 40 cm were obtained from the Trabzon region of northeastern Turkey for veneer manufacturing. A rotary-type peeler with a maximum horizontal holding capacity of 80 cm was used for veneer manufacturing. Pine logs were peeled freshly, veneer sheets were scaled to dimensions of 40 cm × 40 cm × 2 mm, and then veneer sheets were dried at 110 °C in a dryer. All veneer sheets were obtained from the sapwood portion of the logs. Veneer sheets were divided into 4 main groups. The surfaces of control veneer sheets were not treated. One veneer group was sanded with 80 grit sandpaper and another group was sanded with 180 grit sandpaper by using a sanding machine (Sandya) in laboratory conditions. Plasma treatments were applied to the last veneer group. Surface modification of Scots pine veneers was achieved with a Diener Nano LF type plasma treatment apparatus with a 40 KHz generator and up to 300 W power supply (Diener Electronic GmbH, Germany), as schematically shown in Figure 1.

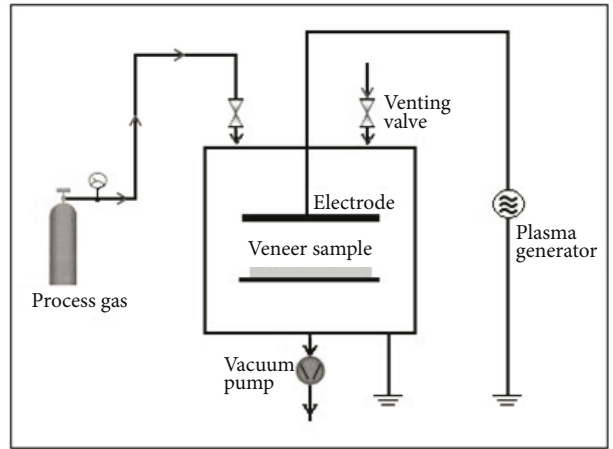


Figure 1. Scheme of the plasma treatment system.

Samples having dimensions of up to 40 cm × 40 cm were treated in the plasma chamber of this instrument. First, the air pressure in the chamber was reduced to below 40 Pa with a rotation pump. O<sub>2</sub>, N<sub>2</sub>, and NH<sub>3</sub> were introduced at about 80–150 Pa pressure and a flow rate of 15 standard cubic centimeters per minute. Plasma power was applied at 300 W. Plasma gas and treatment time applied in this study and test groups are given in Table 1.

The effects of oxygen, nitrogen, ammonia plasma treatments, and sanding processes on the surface roughness of Scots pine veneers were investigated. The Mitutoyo SurfTest SJ-301 instrument was used to determine surface

Table 1. Test groups.

Test groups	Grit of sandpaper	Plasma	
		Plasma gas	Plasma time
Control	Nonsanded	-	-
S80	80	-	-
S180	180	-	-
OP1	-	Oxygen	1 min
OP5	-	Oxygen	5 min
OP15	-	Oxygen	15 min
NP1	-	Nitrogen	1 min
NP5	-	Nitrogen	5 min
NP15	-	Nitrogen	15 min
NHP1	-	Ammonia	1 min
NHP5	-	Ammonia	5 min
NHP15	-	Ammonia	15 min

roughness of samples. Three roughness parameters were measured to evaluate surface roughness of the samples based on DIN 4768 (Deutsches Institut für Normung, 1990): average roughness (Ra), mean peak-to-valley height (Rz), and maximum roughness (Rmax). Rz is the arithmetic mean of the 10-point height of irregularities. Measurements were taken across the grain orientation. All veneer samples were conditioned to equilibrium moisture content so that the moisture content could not alter the results of measurements before measurements of the surface roughness. Cut-off length was 2.5 mm, sampling length was 12.5 mm, and the detector tip radius was 5  $\mu\text{m}$  in the surface roughness measurements. Ten veneer samples of 50 mm  $\times$  50 mm in size were used for each test group to determine the surface roughness values. The Student–Newman–Keuls test with a 99% confidence level was used to compare the mean values of variance sources and the results for statistical evaluation.

### 3. Results and discussion

Average values of surface roughness of veneer sheets based on sanding processes, grit numbers, and plasma treatments are given in Table 2.

As can be seen from Table 2, the smoothest surfaces were observed in the veneers subjected to the sanding processes. Surface roughness values of the veneer sheets sanded with 180 grit sandpapers were lower than those of the veneers sanded with 80 grit sandpaper. Grit affected surface roughness because sandpaper with a higher grit size contains finer abrasive, producing finer sanded surfaces (Gurau et al., 2007; Tan et al., 2012). In another study, it was found that surface roughness of wood material decreased as the grit number of sandpaper increased from 60 to 240 (Hendarto et al., 2006). Compared to the sanding processes, plasma-treated veneers had higher Rz values. However, those values were still lower than those of the control veneers. There are few studies about the effect of plasma treatment on wood surfaces. Contrary to the results obtained from this study, Yaman et al. (2009) reported that surface roughness increased after the plasma treatment. Furthermore, it is important to know that veneers with rough surfaces require much more sanding, which leads to a decrease in the thickness of the material. The results of ANOVA also proved that the difference between sanding processes and plasma treatments was significant at the  $\alpha = 0.01$  level (Table 3). Univariate analysis of variance was

**Table 2.** Surface roughness test results.

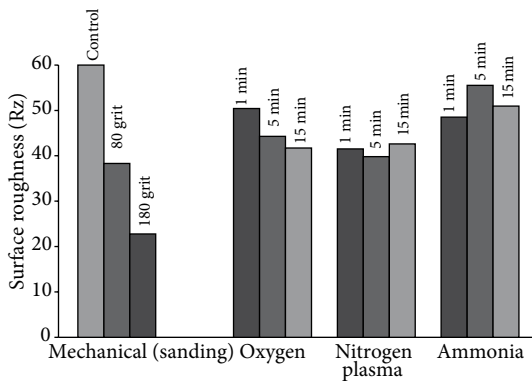
Process	Test groups		Surface roughness ( $\mu\text{m}$ )			
			Ra	Rmax	Rz	
Sanding	Grit number of sandpaper	Control (nonsanded)	9.29 (0.81*)	71.56 (7.18)	60.98 (5.58)	
		S80	5.32 (0.76)	48.97 (13.98)	38.30 (6.40)	
		S180	2.85 (0.34)	31.39 (11.67)	22.78 (4.47)	
Plasma	Gas	Time				
		1 min	OP1	9.09 (0.98)	71.71 (12.68)	50.43 (7.94)
	Oxygen	5 min	OP5	6.08 (0.80)	58.26 (10.35)	44.28 (6.33)
		15 min	OP15	5.93 (0.65)	48.81 (6.51)	41.72 (4.67)
	Nitrogen	1 min	NP1	5.94 (1.24)	50.69 (8.52)	41.53 (6.47)
		5 min	NP5	5.99 (0.40)	49.28 (7.41)	39.81 (3.11)
		15 min	NP15	6.40 (1.10)	52.59 (10.06)	42.63 (6.67)
	Ammonia	1 min	NHP1	7.04 (1.74)	62.42 (12.56)	48.53 (6.98)
		5 min	NHP5	8.24 (2.94)	67.07 (12.21)	55.53 (8.10)
		15 min	NHP15	7.78 (1.03)	63.91 (9.13)	50.94 (5.58)

\*: Values in parentheses are standard deviations.

**Table 3.** Results of the Student–Newman–Keuls test at a 99% confidence level.

Properties	Factors	LS mean	Homogeneous groups*	
Surface roughness	Groups			
		Nonsanded	60.98	a
		80 grit	38.30	b
		180 grit	22.78	c
		Plasma	47.59	d
		Plasma gas		
		Nitrogen	41.25	a
		Oxygen	43.86	b
		Ammonia	45.24	b
		Plasma time		
		1 min	44.58	a
		5 min	43.11	a
	15 min	42.66	a	

\*: Different letters denote a statistically significant difference.

**Figure 2.** Surface roughness values of the test groups.

performed for the statistical evaluation of the changes in surface roughness of the veneers, depending on grit numbers of sandpapers, plasma gas species, and plasma treatment time. The Student–Newman–Keuls test with a 99% confidence level was used to compare the mean values of variance sources and the results are presented in Table 3.

The effects of sanding processes and plasma treatments on the surface roughness of Scots pine veneers are shown in Figure 2. The veneers treated with nitrogen plasma had the lowest Rz values as compared to oxygen and ammonia. This can be explained by the increasing polarity of the carbon surface as an effect of nitrogen and its specific interactions with polar species via electrostatic forces or via hydrogen bonding (Seredych et al., 2008).

There was no statistically clear difference between oxygen and ammonia plasma in terms of surface roughness (Table 3). However, as seen in Figure 2, surface roughness values of Scots pine veneers treated with ammonia plasma were a little higher than those of veneer sheets treated with oxygen plasma. This may be explained by the cleaning properties of oxygen plasma, which is used for the removal of organic compounds. Greater reactive ions of oxygen are reported to form volatile species upon bombardment of the surface, resulting in cleaning of the surface (Berman and Krim, 2012). Mahlberg et al. (1999) determined that surface roughness of lignocellulosic material decreased with the application of oxygen plasma treatment by using atomic force microscopy. The effect of plasma treatment time on the surface roughness was not significant, as shown in Table 3. There were differences in surface roughness values after oxygen and ammonia plasma treatments with different times; these differences were not found to be statistically significant (Table 3). However, Podgorski et al. (2000) also emphasized that the influence of the treatment parameters (time, power, frequency) is not negligible and the most important parameters are time and power.

The effects of plasma treatments and sanding (mechanical) processes on the surface roughness of veneer sheets were investigated and compared in this study. The smoothest surfaces were obtained with on veneers subjected to sanding processes. It was determined that the Rz values of veneers treated with plasma were higher than those of sanded veneers. It is obvious that the veneers subjected to plasma treatments had smoother surfaces than the control veneers. Veneers treated with nitrogen

plasma showed the lowest Rz values among all of the plasma-treated veneers. Consequently, plasma processes could be used to obtain smoother surfaces in the wood industry without decreasing the thickness of the material.

## References

- Acda MN, Devera EE, Cabangon RJ, Ramos HJ (2012). Effects of plasma modification on adhesion properties of wood. *Int J Adhes Adhes* 32: 70–75.
- Aydin İ (2004). Activation of wood surfaces for glue bonds by mechanical pre-treatment and its effects on some properties of veneer surfaces and plywood panels. *Appl Surf Sci* 233: 268–274.
- Aydin I, Demirkir C (2010). Activation of spruce wood surfaces by plasma treatment after long terms of natural surface inactivation. *Plasma Chem Plasma P* 30: 697–706.
- Bekhta P, Hiziroglu S, Shepelyuk O (2009). Properties of plywood manufactured from compressed veneer as building material. *Mater Design* 30: 947–953.
- Berman D, Krim J (2012). Impact of oxygen and argon plasma exposure on the roughness of gold film surfaces. *Thin Solid Films* 520: 6201–6206.
- Custodio J, Broughton J, Cruz H, Hutchinson A (2008). A review of adhesion promotion techniques for solid timber substrates. *J Adhesion* 84: 502–529.
- Davis EM (1962). *Machining and Related Characteristics of United States Hardwoods*. Washington, DC, USA: USDA.
- Deutsches Institut für Normung (1990). DIN 4768. Determination of Values of Surface Roughness Parameters Ra, Rz, Rmax Using Electrical Contact (Stylus) Instruments, Concepts and Measuring Conditions. Berlin, Germany: Deutsches Institut für Normung.
- Dilsiz N (1994). Plasma modified carbon fiber-epoxy composite system. PhD, Middle East Technical University, Ankara, Turkey.
- Dundar T, Akbulut T, Korkut S (2008). The effects of some manufacturing factors on surface roughness of sliced Makoré (*Tieghemella heckelii* Pierre Ex A.Chev.) and rotary-cut beech (*Fagus orientalis* L.) veneers. *Build Environ* 43: 469–474.
- Gurau L, Mansfield-Williams H, Irle M (2007). Separation of processing roughness from anatomical irregularities and fuzziness to evaluate the effect of grit size on sanded European oak. *Forest Prod J* 57: 110–115.
- Hendarto B, Shayan E, Ozarska B, Carr R (2006). Analysis of roughness of a sanded wood surface. *Int J Adv Manuf Tech* 28: 775–780.
- Liu Y, Tao Y, Lv X, Zhang Y, Di M (2010). Study on the surface properties of wood/polyethylene composites treated under plasma. *Appl Surf Sci* 257: 1112–1118.
- Mahlberg R, Niemi HE, Denes FS, Rowell RM (1999). Application of AFM on the adhesion studies of oxygen-plasma-treated polypropylene and lignocellulosics. *Langmuir* 15: 2985–2992.
- Mitchell P, Lemaster R (2002). Investigation of machine parameters on the surface quality in routing soft maple. *Forest Prod J* 52: 85–90.
- Podgorski L, Chevet B, Onic L, Merlin A (2000). Modification of wood wettability by plasma and corona treatments. *Int J Adhes Adhes* 20: 103–111.
- Pykönen M, Silvaani H, Preston J, Fardim P, Toivakka M (2009). Effects of atmospheric plasma activation on surface properties of pigment-coated and surface-sized papers. *Colloid Surface A* 352: 103–112.
- Pykönen M, Sundqvist H, Jarnstrom J, Kaukoniemi OV, Tuominen M, Lahti J, Peltonen J, Fardim P, Toivakka M (2008). Effects of atmospheric plasma activation on surface properties of pigment-coated and surface-sized papers. *Appl Surf Sci* 255: 3217–3229.
- Seredych M, Hulicova-Jurcakova D, Lu GQ, Bandosz TJ (2008). Surface functional groups of carbons and the effects of their chemical character, density and accessibility to ions on electrochemical performance. *Carbon* 46: 1475–1488.
- Sofuoğlu SD, Kurtoğlu A (2014). Some machining properties of 4 wood species grown in Turkey. *Turk J Agric For* 38: 420–427.
- Tan PL, Sharif S, Sudin I (2012). Roughness models for sanded wood surfaces. *Wood Sci Technol* 46: 129–142.
- Vander Wielen LC, Östenson M, Gatenholm P, Ragauskas AJ (2006). Surface modification of cellulosic fibers using dielectric-barrier discharge. *Carbohydr Polym* 65: 179–184.
- Wengert EM, Lamb FM (1994). *A Handbook for Improving Quality and Efficiency in Rough Mill Operations*. Princeton, WV, USA: RC Byrd Hardwood Technology Center.
- Wolkenhauer A, Avramidis G, Cai Y, Militz H, Viöl W (2007). Investigation of wood and timber surface modification by dielectric barrier discharge at atmospheric pressure. *Plasma Process Polym* 4: S470–S474.
- Wolkenhauer A, Avramidis G, Hauswald E, Militz H, Viöl W (2009). Sanding vs. plasma treatment of aged wood: a comparison with respect to surface energy. *Int J Adhes Adhes* 29: 18–22.
- Yaman N, Özdoğan E, Seventekin N (2009). A study on changing properties of polyamid fabrics by using atmospheric plasma treatments. *Electronic Journal of Textile Technologies* 3: 1–10 (in Turkish with English abstract).

## Acknowledgment

The authors acknowledge the financial support of this study by the Scientific and Technological Research Council of Turkey (TÜBİTAK, Project No.: 108O655).