Effect of Sanding on Surface Properties of Medium Density Fiberboard

Utjecaj brušenja na svojstva površine MDF ploče

Original scientific paper • Izvorni znanstveni rad
Received – prispjelo: 19. 4. 2010.
Accepted – prihvaćeno: 14. 7. 2010.
*UDK: 630*829.1; 630*863.312; 674.07*

ABSTRACT • *The objective of this research was to investigate the effects of sanding on the surface properties of the medium density fiberboard (MDF) panels made from* Rhododendron ponticum *L. wood. The MDF panels were sanded with different sizes of the sand paper grit: 60-, 60+80- or 60+80+120-grit. Surface absorption and surface roughness of the MDF panels were determined based on EN 382-1 standard and ISO 4287 by using a fine stylus profilometer, respectively. Sessile water drop technique was used to determine contact angle values of the panel surface. The results indicated that sanding process improved the surface smoothness of the panels. However, the wettability and surface absorption of the panels were negatively affected by increasing grit size. The MDF surface sanded with 60-grit size had a lower contact angle, more wettable surface, compared to those that were sanded with 60+80+120-grit size. For example, the average contact angle value of the panels sanded with 60-grit sandpaper was 43.3° as compared to the panels sanded with 60+80+120-grit sand paper which was 76.1°. The rougher surface was more wettable and absorbent compared to smoother surface. Based on the findings obtained from the present study, sanding has a significant effect on the wettability, surface roughness, and surface absorption of the MDF panels, which could provide useful information on the bonding and finishing of the MDF panels.*

Key words: *contact angle, medium density fiberboard (MDF),* rhododendron *(R.)* ponticum *L., sanding, surface absorption, surface roughness, wettability*

SAŽETAK • *Cilj je istraživanja bio ispitati utjecaj brušenja na svojstva površine srednje gustih ploča vlaknatica (MDF ploča) proizvedenih od drva rododendrona (*Rhododendron ponticum *L.) MDF ploče brušene su brusnim papirima različitih granulacija: 60, 60+80 ili 60+80+120. Određena su apsorptivna svojstva prema normi EN 382-1 i hrapavost površine MDF ploča prema normi ISO 4287 uz pomoć finog profilometra. Za određivanje kontaktnog kuta površine ploča primijenjena je metoda ispitivanja s kapljicom vode. Rezultati istraživanja pokazuju da brušenje pozitivno utječe na glatkoću površine ploča. Međutim, povećanje granulacije brusnog papira negativno utječe na kvašenje i apsorpciju površine ploča. Površina MDF ploča brušenih brusnim papirom granulacije 60 imala je manji kontaktni kut i bolje kvašenje u usporedbi s površinom koja je brušena brusnim papirima granulacije 60+80+120. Na primjer, srednja vrijednost kontaktnog kuta ploča brušenih brusnim papirom granulacije 60 bila je 43,3°, a ploča brušenih papirom granulacija 60+80+120 bila je 76,1°. Hrapavija površina imala je bolje kvašenje i apsorpciju nego glatkije površine. Na temelju rezultata dobivenih istraživanjem može se zaključiti da proces brušenja ima znatan utjecaj na kvašenje i hrapavost te na apsorptivna svojstva površine MDF ploča, što je osobito važno za proces lijepljenja i površinske obrade brušenih površina.*

Ključne riječi: *kontaktni kut, MDF ploče,* Rhododendron *(R.)* ponticum *L., brušenje, apsorpcija površine, hrapavost površine, kvašenje*

[1] Authors are associate professor, graduate research assistant and professor at Forestry Faculty, Istanbul University, Istanbul, Turkey. [2]Author is scientist at Department of Forest Products, Central Anatolia Forestry Research Institute, Ankara, Turkey.
[1] Autori su izvanredni profesor, asistent i profesor na Šumarskom fakultetu Sveučilišta u Istanbulu, Istanbul, Turska. [2]Autor je znanstvenik Odjela za šumske proizvode, Središnji anatolijski šumarski institut, Ankara, Turska.

1 INTRODUCTION
1. UVOD

Rhododendron ponticum L. of the Ericaceae is one of the largest genera of dicotyledons. There are about 700 species in the area of China, Tibet, Burma, Assam and Nepal; almost 300 species in New Guinea; many in Japan, tropical Asia from Indochina to Indonesia and the Philippines; while a small number occur in Europe and North America (Terzioglu, 2000). The habitats of *Rhododendron* species also show a wide range, from low-mountain forests to alpine regions more than 4000 m high. The species are usually shrubs of low to medium height, sometimes dwarfed with creeping fine stems in alpine regions, while certain members in low mountain regions grow into fairly tall trees of about 30 m in height and 100 cm in diameter. *R. ponticum* has flowers of different colors. Spots of corolla changing from deep purplish-pink to pure white are arranged regularly (Terzioglu, 2000). Turkish *Rhododendron* species grow naturally from sea level to altitudes of 2500 (3100) m. They take the form of shrubs (*R. luteum* Sweet), dwarf shrubs (*R. caucasicum* Pallas) and large shrubs (*R. ponticum* L., *R. ungernii* Trautv., *R. smirnovii* Trautv.). *Rhododendron* wood is diffuse-porous, growth ring boundaries distinct or indistinct. Some anatomical properties of *R. ponticum* wood used in this study are shown in Table 1 (Balkiz, 2006).

R. ponticum having a density of 0.671±0.018 g/cm^3 is a raw material used for manufacturing of wood-based panels such as particleboard and MDF in Turkey (Balkiz, 2006; Oktem, 1982). Quality of furniture products made from MDF depends on finishing quality of MDF. The finishing quality depends on the quality of surface prior to applying the finishing materials. When the panels are used as substrate for thin overlays and liquid surface coatings their surface characteristics such as roughness and wettability play an important role in determining the quality of the final product. Most MDF panels are used as a substrate for thin overlays such as melamine-impregnated papers in the furniture industry. In addition, various types of finishes such as paint and lacquer are directly applied to the sanded panel surface to be used as furniture panels. In both applications, surface characteristics of the substrate panel, including absorption ability, wettability, and roughness properties, are important factors affecting better use of the panel products. For example, surface roughness of MDF prior to finishing is very important in determining the quality of the finished product. Any irregularity on the surface may show through thin layer of the finishing materials. Standard contact measuring devices employing a stylus tracer, such as used in the metal and plastic industry, were successfully used to evaluate roughness characteristics of various wood composites (Hiziroglu, 1996). One of the main advantages of the stylus method is to have an actual profile of the surface and standard numerical roughness parameters that can be calculated from the profile. Any kind of irregularities and magnitude of show-trough on the overlaid substrate can be objectively quantified. Therefore, it is important to quantify surface roughness of the panel to have a better overlaying of the substrate.

Rough wood surface could limit surface contact and result in weak glue or poor finishing quality (Sulaiman *et al*., 2009). According to Petri (1987) surface roughness affects adhesion of two surfaces because it increases the total contact area between adhesive and substrate. It could also provide mechanical interlocking effect that could trap the adhesive in the cavities and act like an anchor to each other. Roughness of wood based panels could be decreased to a certain extent by sanding. Besides the measurement of the surface roughness, it could also be estimated from wettability of the surface (Akbulut *et al*., 2000). Wettability is defined as a surface condition that determines how good wetting and spreading on the surface of a liquid will be or whether it will be repelled and not spread on the surface. Wettability is crucial for good adhesion in wood bonding and it is important to determine the adhesive and coating properties of wood and wood-based composite surfaces (Ayrilmis and Winandy, 2009; Petrissans *et al*., 2003). Wettability of the wood can be characterized by various methods (Gray, 1962; Casilla *et al*., 1981; Gardner *et al*., 1991). Recently, contact angle method has been commonly used to determine surface characteristics of wood and wood based composites (Petrissans *et al*., 2003; Ayrilmis and Winandy, 2009; Ayrilmis *et al*., 2009). Contact angle is the angle at the three-point contact between solid-liquid-gas interface and this gives a degree of wettability of solid by liquid. A smaller contact angle means that the surface is more wettable and if contact angle is measured with water more hydrophilic (Fig. 1). Contact angle is directly influenced by the comparable surface roughness and also indicates an average wettability of the surface.

Table 1 Some anatomical properties of *Rhododendron ponticum* wood
Tablica 1. Neka anatomska svojstva drva rododendrona (*Rhododendron ponticum*)

Anatomical properties /*Anatomska svojstva*	***Rhododendron ponticum* wood** / *Drvo rododendrona*
Fiber length /*duljina vlakanaca*	0.92 mm
Cell-wall thickness / *debljina stijenke*	2 μm
Lumen diameter / *promjer lumena*	6 μm
Trache diameter / *promjer traheje*	30 μm
Trache numbers per mm² / *broj traheja po mm²*	491
Trache content in wood / *udio traheja u drvu*	26 %
Fiber content in wood / *udio vlakanaca u drvu*	34 %
Parenchyma content in wood / *udio parenhima*	24 %
Runkel ratio / *Runkelov omjer*	0.7

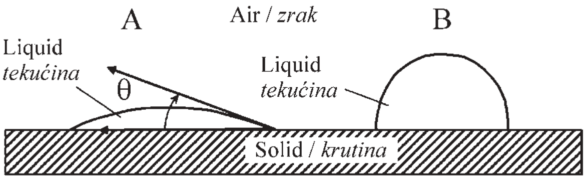

Figure 1 Apparent contact angle (θ) of a sessile drop resting on a MDF surface, showing a high degree of wetting (A) and a low degree of wetting (B)
Slika 1. Kontaktni kut (θ) kapljice tekućine na površini MDF ploče koji pokazuje velik stupanj kvašenja (A) i mali stupanj kvašenja (B)

Wood species has long been recognized as a major variable in the manufacture of MDF. Although previous studies reported that R. *ponticum* wood could be utilized in manufacture of wet and dry-process fiberboard, there is no information about the surface characteristics of the panels (Taskin, 1977; Balkiz, 2006). The objective of this study was to evaluate the surface characteristics of the panels such as surface roughness, surface absorption, and wettability in terms of overlaying of the panels made from R. *ponticum* wood. Secondary objective was to investigate the effect of the sanding treatment at various grit sizes of sand paper on the surface properties of the panels.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Materials
2.1. Materijali

R. ponticum woods (purplish-pink flowered *R. ponticum*) with a top end diameter of more than 5 cm were obtained from the Black Sea region in Turkey. The chips produced from *R. ponticum* woods were converted into fibers in a defibrator at SFC Integrated Wood Company located in Kastamonu, Turkey. The wood fibers were produced using a thermo-mechanical refining process without any chemical and resin. The moisture content of the fibers, as determined by oven-dry weight, was 8 % prior to treatment. A commercial liquid urea-formaldehyde (UF) resin with 50 % solid content was used as an adhesive in the manufacture of the experimental MDF panels.

2.2 MDF panel preparation
2.2. Priprema MDF ploče

Three experimental MDF panels (2800 mm x 2100 mm x 18 mm) were manufactured at SFC Integrated Wood Company located in Kastamonu, Turkey from round wood. After the chips were converted to fibers, the following was added to the fibers: 1 % hydrophobic paraffin, 1 % NH_4Cl (30 % solid content) as hardener, and 11 % UF resin. The mats with average moisture content of 10 % were pressed at temperature of 200 °C for 240 s at a pressure of 4 N/mm². The panels were sanded with different types of abrasive grit sizes: 60-, 60+80- or 60+80+120-grit following the cooling process.

A total of three MDF panels were tested, one panel for each level of sanding. The resulting MDF panels had 7-8 % moisture content based on the weight of oven dry fibers. The average density values of the panels varied from 0.781 to 0.790 g/cm³. Before the surface roughness, contact angle, and surface absorption measurements, the samples were conditioned in a climate chamber having 65 % relative humidity and 20 °C until no changes in the weights were detected.

2.3 Determination of surface roughness
2.3. Određivanje hrapavosti površine

Fifteen samples with dimensions of 50 mm × 50 mm × 18 mm were used from each type of sanding treatment for surface roughness measurements. A total of thirty roughness measurements (two from each of fifteen samples: one measurement parallel to the sand mark and one measurement perpendicular to the sand mark from each of the samples) were taken from each type of sanding treatment. A Mitutoyo SJ-301 surface roughness tester, stylus type profilometer, was used for the surface roughness tests (Fig. 2). Three roughness parameters characterized by ISO 4287: 1997, respectively, average roughness (R_a), mean peak-to-valley height (R_z), and maximum peak-to-valley height (R_y) were considered to evaluate the surface characteristics of the panels. The surface roughness parameters can be calculated from the profiles. R_a is the arithmetic mean of the absolute values of the profile deviations from the mean line and is by far the most commonly used parameter in surface finish measurement. Specification of this parameter is described in previous studies (Hiziroglu, 1996; Hiziroglu and Graham, 1998; Mummery, 1993). Roughness values were measured with a sensitivity of 0.5 μm. Measuring speed, pin diameter and pin top angle of the tool were 10 mm/min, 4 μm and 90°, respectively. The length of tracing line (L_t) was 12.5 mm and the cut-off was λ = 2.5 mm. Measuring force of the scanning arm on the samples was 4 mN (0.4 gf). Measurements were done at room temperature and pin was calibrated before the tests.

2.4 Determination of surface absorption
2.4. Određivanje apsorpcije površine

Surface absorption tests were carried out based on the EN 382-1:1993 standard, which uses toluene as a surface liquid. Twenty surface absorption test specimens (300 mm x 100 mm x 18 mm) were cut from each type of sanding treatment. Each individual sample was put on the test apparatus with a 60° angle and 1 mL toluene is dropped from 1 cm above the surface at a 90° angle to the panel surface according to EN 382-1 standard. The maximum distance in which the toluene drop spread on the panel surface was measured from the starting point, and this value was used as a measure of absorption ability of the samples. The shorter the spreading distance, the greater the absorption of the panels. The minimum spread of toluene drops on the panel surface should be 150 mm based on **Euro MDF Board** (EMB:1993) industrial standard. A total of twenty measurements, one from each of twenty samples, were performed for each type of sanding treatment.

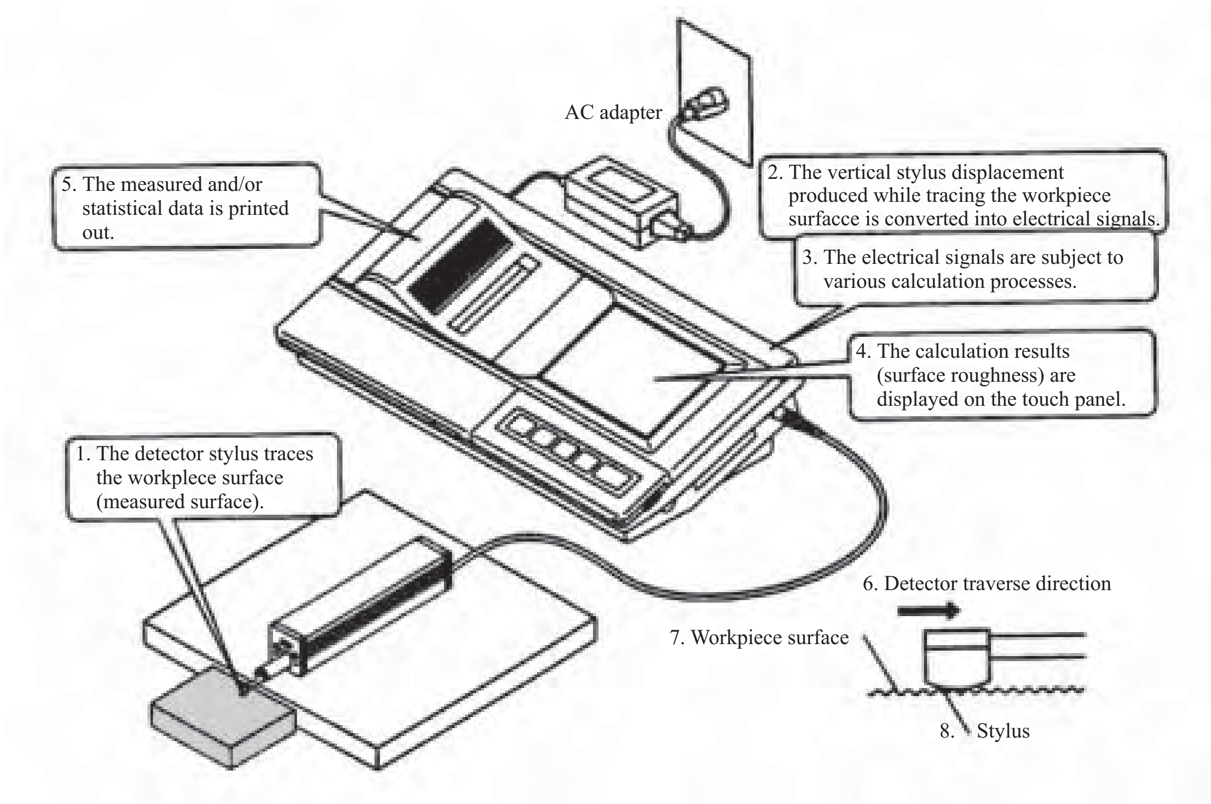

Figure 2 Outline of the stylus type profilometer (Model: Mitutoyo Surftest SJ-301)
Slika 2. Mjerni sustav s profilometrom za mjerenje hrapavosti površine (model Mitutoyo Surftest SJ-301)

2.5 Determination of wettability
2.5. Određivanje kvašenja

The contact angle was defined as the angle through the liquid phase formed between the surface of a solid and the line tangent to the droplet radius from the point of contact with the solid. The contact angles were obtained using a KSV Cam-101 Scientific Instrument (Helsinki, Finland). A sessile drop method was used to measure the contact angle (θ) of a 5-μL distilled water drop that was applied to the surface by means of a pipette (Fig. 3). An image analyze software was used to measure contact angle and shape and size of water droplets for the tested surfaces of MDF samples.

The contact angle measurements were obtained by using a goniometer system connected with a digital camera and computer system. The contact angle measurements were done from one point of view (one-camera device) since MDF surface was isotropic (random orientation of the fibers on the surface). The liquid used for the measurements was distilled water at 20°C with a surface tension of 72.80 mN/m. After the 5-μL droplet of distilled water was placed on the sample surface, the contact angles from the images were measured at 1 sec time intervals up to 60 sec total. Twenty samples with a size of 50 mm x 50 mm x 18 mm were taken used from each type of the treatment for contact angle measurements.

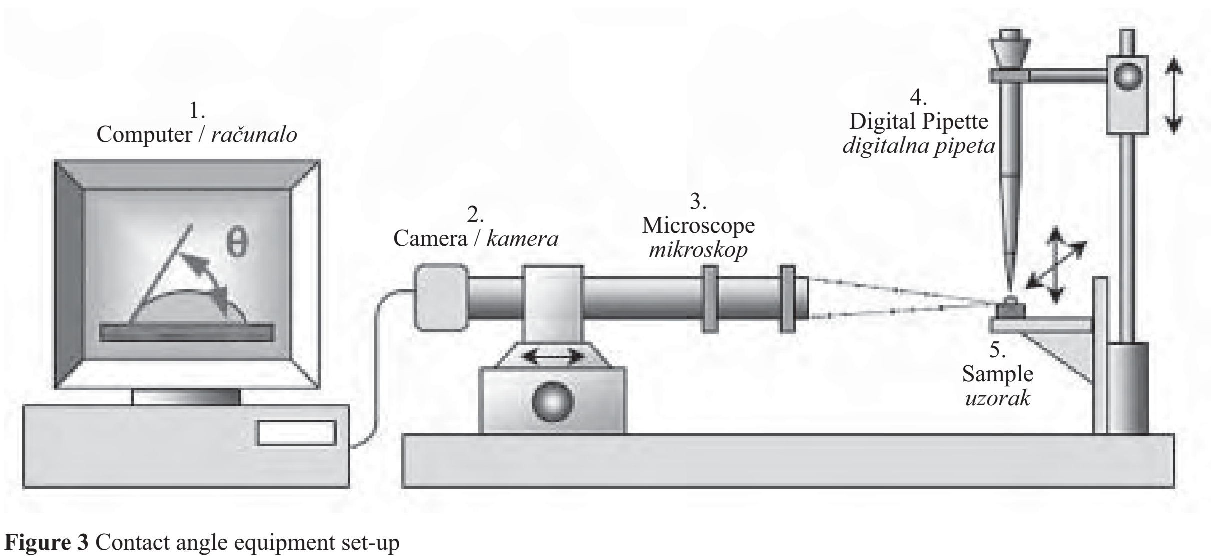

Figure 3 Contact angle equipment set-up
Slika 3. Oprema za mjerenje kontaktnog kuta

2.6 Statistical analysis
2.6. Statistička analiza

For the surface roughness and surface absorption tests, all multiple comparisons were first subjected to an analysis of variance (ANOVA) at $p<0.01$ and significant differences between mean values of the control and treated MDF test samples were determined using Duncan's multiple range test.

3 RESULTS AND DISCUSSION
3. REZULTATI I DUSKUSIJA

3.1 Surface roughness and surface absorption
3.1. Hrapavost i apsorpcija površine

Table 2 shows the results of surface roughness parameters of the MDF samples. The surface smoothness of the MDF panels significantly improved with increasing grit size of sand paper. This was in agreement with the results reported by de Moura and Hernández (2006) and Sulaiman et al. (2009). Statistical analysis showed some significant differences ($p<0.01$) between the average roughness values of the samples. The differences between the sanding treatment groups are given in Table 2 as letters. The R_a, R_z and R_y showed a significant reduction as the sanding grit became higher. The panels sanded with 60-grit sand paper had the roughest surface with an R_a value of 7.01 μm while the smoothest surface was found for the panels sanded with 60+80+120-grit sand paper having an R_a value of 4.15 μm. The R_y and R_z values of the panels also decreased with increasing sand paper grit size. This can be clearly observed by inspection of raw data from the surface roughness profilometer that recorded noticeably shallower ridges and valleys when compared to control panels as it traversed the MDF surface at a constant speed. With the increase of grit size, the size of the aluminum oxide on sand paper gets smaller. The size of the aluminum oxide affects the smoothness of the panel surface. It is obviously clear that application of higher grit of sanding reduced the surface roughness of MDF panels made from *R. ponticum* wood fibers. Sanding process smoothens the panel surface, because small particles (dust) from broken cells fill up the pore area on the surface.

Anatomical structure of wood, determined by elements such as fiber length, width and wall thickness, vessel element length and diameter, and pore density (pore number/1mm^2 in cross section), is one of the important factors affecting surface roughness and surface absorption of wood-based panels. For example, the porous anatomical structure of wood (i.e. oak) is a prime factor influencing its higher surface roughness (Akbulut *et al.*, 2000). In a previous study, average surface roughness of commercial MDF panels (sanded 150+180+200) made from oak, beech, or pine were found as 4.1μm, 3.6 μm, and 3.8 μm, respectively (Akbulut *et al.*, 2000).

The surface absorption values showed trends similar to the results of the surface roughness measurements (Table 2). The surface absorptivity decreased with increasing grit size of the sand paper. This was clearly observed for the MDF samples sanded with 60+80+120-grit sand paper having the average surface absorption value of 255.2 mm, while it was found as 166.4 mm for the samples sanded with a 60-grit size sand paper. Akbulut et al. (2000) reported that the average surface absorption values of MDF panels made from oak and beech wood fibers were 179.1 mm and 197.4 mm, respectively. The MDF panels (sanded with 60-grit size sand paper) made from *R. ponticum* wood had higher absorptivity as compared to the panels made from beech and oak wood fibers. In general, surface absorption of the MDF can be related to raw material characteristics. For example, the porous anatomical structure of oak is a prime factor influencing its surface absorptivity, which is higher than surface absorptivity of beech and *R. ponticum* woods.

3.2 Wettability
3.2. Kvašenje

The surface with lower grit sanding size had a lower contact angle value. Typical contact angle values of the MDF samples sanded with different sizes of sand paper grit are shown in Fig. 4. A smaller contact angle means that the surface is more wettable and more hydrophilic. Contact angle is directly influenced by the comparable surface roughness and also indicates an average wettability of the surface. For example, the MDF samples sanded with 60-grit size have 43.3° contact an-

Table 2 Variations in average surface roughness and surface absorption values of the MDF panels as a function of the grit size of sand paper
Tablica 2. Promjene srednje hrapavosti površine i vrijednosti apsorpcije površine MDF ploča ovisno o granulaciji brusnog papira

Sanding treatment level *Granulacije brusnog papira*	Panel density *Gustoća ploče*	Surface roughness parameters *Parameter hrapavosti površine*			Surface absorption *Apsorpcija površine*
		R_a	R_y	R_z	
	g/cm³	μm	μm	μm	mm
60-grit	0.785 (0.03)	7.01 A[a] (1.68)	56.64 A (5.08)	45.99 A (4.15)	166.4 (9.0) A
60+80-grit	0.790 (0.04)	5.10 B (0.92)	43.99 B (7.10)	35.60 B (4.98)	201.7 (10.6) B
60+80+120-grit	0.781 (0.02)	4.15 C (0.57)	38.60 C (5.17)	30.76 C (3.53)	255.2 (14.4) C

[a] Groups with the same letters in the column indicate that there was no statistical difference ($p<0.01$) between the samples according Duncan's multiple range test. Values in parentheses are standard deviations.
[a] Grupe s istim slovom u koloni pokazuju da ne postoji statistički značajna razlika (p<0,01) između uzoraka prema Duncanovu testu. Vrijednosi u zagradama standardne su devijacije.

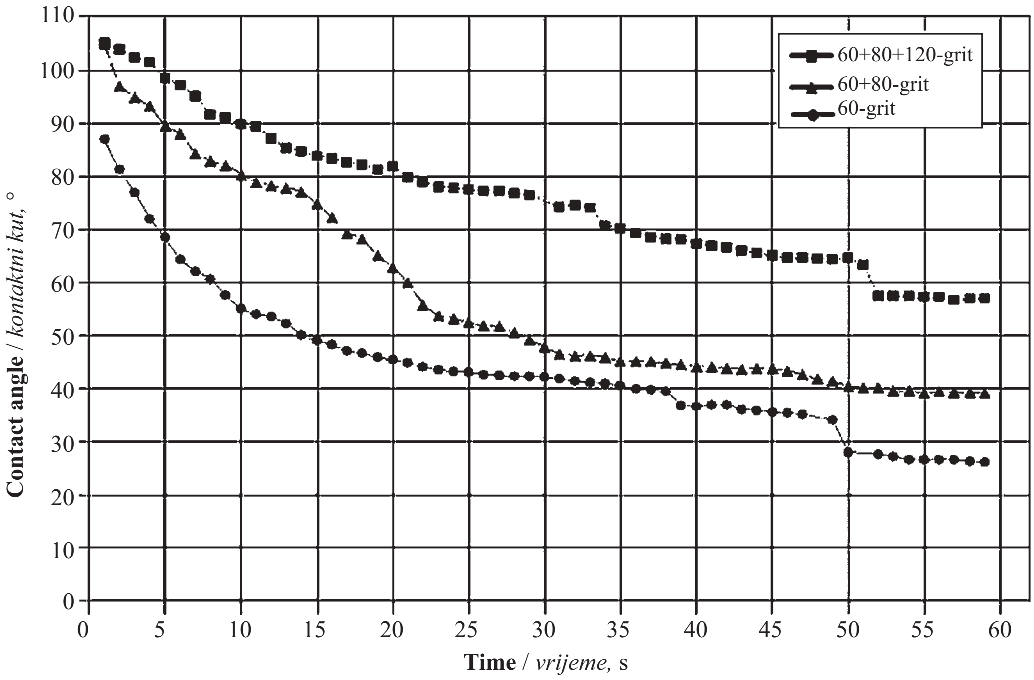

Figure 4 Typical time-dependent contact angles of the MDF samples sanded with different sizes of sand paper grit
Slika 4. Tipična krivulja ovisnosti kontaktnog kuta MDF ploča brušenih brusnim papirom različitih granulacija

gles after 29 s while the surface that was sanded with 60+80+120-grit size showed a contact angle of 76.1°. The MDF surface that was sanded with 60-grit size was certainly more wettable compared to those that were sanded with 60+80+120-grit size. The contact angle of water decreased significantly over time on surface of different grit size.

With increasing surface roughness, the surface absorption of the MDF samples increased (Table 2). This will increase the tendency of water to be captured by capillary forces emerging from greater surface area exposed on the rough wood surface. It should be noted that the higher wettability of rough surfaces may be due to the higher amount of peaks and valley points on the surface where liquid can be captured by capillary force. Surface roughness was proposed to enhance intrinsic adhesion by providing greater interfacial area and some mechanical interlocking mechanism. A low contact angle is very important to capillary flow into the complex porous structure of wood to achieve a strong bond between adhesive and material surface. Therefore, the lower contact angle on the surface should be analyzed as a function of surface roughness.

4 CONCLUSIONS
4. ZAKLJUČCI

The following general conclusions were drawn from the study provided in the paper:

1. Sanding with higher grit size increases the surface smoothness. The average roughness values of the MDF samples decreased by 41 % when comparing 60-grit and 60+80+120-grit sand papers.
2. The MDF surface that was sanded with lower grit size was more wettable compared to those sanded with higher grit size. This means that rougher surface is more wettable compared to smoother surface.
3. The surface absorption showed a similar trend to the results of the surface roughness measurements. The surface absorption values of the MDF panels sanded with lower grit size (60) were 53% lower than higher grit size (60+80+120).
4. The surface properties have a significant impact on bonding and finishing of the MDF panels.

ACKNOWLEDGEMENT - ZAHVALA

The authors gratefully acknowledge Research Fund of Istanbul University for the laboratory testing equipment for evaluating surface properties of MDF panels.

5 REFERENCES
5. LITERATURA

1. Akbulut, T.; Hiziroglu, S.; Ayrilmis, N., 2000: Surface absorption, surface roughness, and formaldehyde emission of Turkish medium density fiberboard. Forest Products Journal, 50 (6): 45-48.
2. Ayrilmis, N.; Winandy, J.E., 2009: Effects of post heat-treatment on surface characteristics and adhesive bonding performance of medium density fiberboard. Materials and Manufacturing Process, 24 (5): 594-599.
3. Ayrilmis, N.; Dundar, T.; Candan, Z.; Akbulut, T., 2009: Wettability of fire retardant treated laminated veneer lumber (LVL) manufactured from veneers dried at different temperatures. Bioresources, 4: 1535-1543.
4. Balkiz, O.D., 2006: Production of medium density Fiberboard (MDF) by using Rhododendron Ponticum L. fibers. Zonguldak Karaelmas University Graduate School of Natural and Applied Sciences, Zonguldak, Turkey, 316 p.

5. Casilla, R. C.; Chow, S.; Steiner, P. R., 1981: An immersion technique for studying wood wettability. Wood Science and Technology, 15: 31-43.
6. Gardner, D. J.; Generella, N. C.; Gunnells, D. W.; Wolcott, M. C., 1991: Dynamic wetting of wood. Langmuir, 7: 2498-2502.
7. Gray, V. R., 1962: The wettability of wood. Forest Products Journal, 12 (9): 452-461.
8. Hiziroglu, S., 1996: Surface roughness analysis of wood composites: A stylus method. Forest Products Journal, 46 (7/8): 67-72.
9. Hiziroglu, S.; Graham, M., 1998: Effect of press closing time and target thickness on surface roughness of particleboard. Forest Products Journal, 48 (3): 50-54.
10. Oktem, E., 1982: Investigations on utilization of Rhododendron Ponticum L. wood in manufacture of particleboard. Technical Bulletin, Forest Research Institute Publications, No: 113, Ankara, 60 p.
11. de Moura, L.F.; Hernández, R.E., 2006: Effects of abrasive mineral, grit size and feed speed on the quality of sanded surfaces of sugar maple wood. Wood Science and Technology, 40 (6), 517–530.
12. Mummery, L., 1993: Surface texture analysis. The handbook. Hommelwerke, Muhlhausen, 106 p.
13. Petri, E.M., 1987: Handbook of Adhesives and Sealants. McGraw-Hill, New York.
14. Petrissans, M.; Gerardin, P.; Elbakali, D.; Serraj, M., 2003: Wettability of heat-treated wood. Holzforschung, 57: 301-307.
15. Sulaiman, O.; Hashim, R.; Subari, K.; Liang, C.K., 2009: Effect of sanding on surface roughness of rubberwood. Journal of Materials Processing Technology, 209, 3949-3955.
16. Taskin, O., 1977: An investigation on utilization of Rhododondron ponticum L. wood in manufacture of wet-process fiberboard. Ph.D. Thesis. Institute of Natural Sciences, Istanbul University, Istanbul, 247 p.
17. Terzioglu, S.; Merev N., Ansin, R., 2001: A Study on Turkish Rhododendron L. (Ericaceae). Turkish Journal of Agriculture and Forestry, 25: 311-317.
18. EN 382-1, 1993: Determination of surface absorption. Part 1. Test methods for dry process fiberboard. European Committee for Standardization. European Standard. Brussels, Belgium.
19. EMB, 1993: A users manual. (Euro MDF Board. (EMB). European Association of Medium Density Fiberboard Manufacturers, Giessen, Germany.
20. ISO 4287, 1987: Geometrical product specifications (GPS)-surface texture: profile method-terms, definitions, and surface texture parameters, International Organization for Standardization, Geneva.

Corresponding address:

Assoc. Prof. NADIR AYRILMIS, Ph.D.

Istanbul University, Forestry Faculty
Department of Wood Mechanics and Technology
Bahcekoy, Sariyer
34473 Istanbul, TURKEY
E-mail: nadiray@istanbul.edu.tr