EVALUATING THE SURFACE ROUGHNESS OF HEAT-TREATED WOOD CUT WITH DIFFERENT CIRCULAR SAWS

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The effects of different circular saws on surface roughness were determined for heat-treated wood, including Scots pine (*Pinus sylvestris* L.), eastern beech (*Fagus orientalis* L.), Uludağ fir (*Abies bornmülleriana* Mattf.), and sessile oak (*Quercus petraea* L.), which are used commonly in Turkey. Samples were heat-treated for 3, 5, or 7 hours at 140 or 160ºC, and cut with circular saws with 28, 48, 60, 72, or 96 teeth. Then, the surface roughness of the samples was determined using a scanning device (TIME TR200) with respect to the ISO 4287 standard. Heat treatment increased the surface roughness of the wood used, and changed the colour of the wood. To obtain smooth surfaces with or without heat treatment, a circular saw with 28 teeth and a double chamfered (WZ) mouth profile is recommended.

Keywords: Wood; heat treatment; Criteria of cutting theory; Surface roughness; Circular saws

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INTRODUCTION

To glue, putty, varnish, or paint the wood surfaces of furniture or decorative items, a flat surface is useful, especially for surface treatments (Budakçı et al. 2007; Stumbo 1960). However, all surfaces are covered with microscopic hills and valleys, the dimensions and areal distributions of which affect the surface qualities. Many international standards have been devised for measuring surface roughness and the parameters defining surface texture. Surprisingly, there are still basic problems complicating research, especially in the woodworking industry. To begin to address these problems, it has been proposed that surface definitions should be further developed (Sandak and Negri 2005).

Surface roughness depends largely on the cutting speed, the feed, the bite or average chip thickness, but in particular in the case of circular saws: the tooth shape, tooth geometry, and override, which directly affect the chip thickness. The chip formation mechanism is very important when changes are made to the rake angle, being closely related with wood physical–mechanical properties (wood density, flexion, and compression strength, MOE) (Aguilera 2011; Kılıc et al. 2006; Hernández and Cool 2008).

Wood surfaces are not planar because of surface irregularities, even after planning, milling, lathing, and sanding. Since wood has an anisotropic structure, the treatment technique should fit the structure, and depends on the feed rate, cutter geometry, sharpness, and maintenance of the cutters (Örs et al. 1991; Efe et al. 2007). Various studies have shown that tangential cuts result in a smooth surface than radial cuts, although the interaction between the cutting direction and kind of cutter is not important (Örs and Baykan 1999; Örs and Gürleyen 2002; Efe and Gürleyen 2003; Söğütlü 2004). Moreover, a smoother surface can be obtained with *Fagus orientalis* rather than with *Pinus sylvestris* wood (Örs and Baykan 1999). With *Pinus sylvestris*, a planar surface can be obtained with a 24-tooth saw and a 5 m/min feed rate cutting in the radial direction (Örs and Demirci 1999). However, the quality depends heavily on the chip thickness and hence on the cutting speed and the rake angle as well.

The protection of wood materials using impregnated or toxic chemicals is limited or totally banned. Consequently, because of environmental concerns, research has concentrated on traditional wood impregnating materials, with the aim of developing new safer chemicals, methods, and products.

Thermal treatments have been applied to improve various qualities of wood. Heat treatment of wood results in a significant reduction of water adsorption. The availability and/or accessibility of the free hydroxyl groups of the wood carbohydrates play an important role in the process of water adsorption and desorption. One of the most striking effects of heat treatment is a reduction of the hygroscopicity, while the typical sigmoid curve of the hysteresis of the water isotherm is maintained. A positive effect of the hysteresis is that small changes in relative humidity do not immediately result in a change of the moisture content of the treated wood. This contributes to the dimensional stability of the treated wood, because swelling and shrinkage is due to the water absorption and desorption of wood. Moreover, a reduction in water absorption reduces the overall swelling and shrinkage of wood, hence improving its dimensional stability (Wikberg 2004; Enjily and Jones 2006; Boonstra 2008; Korkut and Kocaefe 2009).

Heat treatment is an inexpensive alternative method of wood protection that produces less pollution, while stabilizing the dimensions of wood and increasing its resistance to harmful organisms. Heat treatment also decreases the amount of moisture in the wood, while increasing its permeability and the performance of impregnating materials such as CCA and CCB, and surface treatments such as dyeing and varnishing (Yıldız 2002). Heat treatment is a physical process that alters the chemical composition of polymers in the cell walls of wood. Basically, the wood is heated above 150°C, temperatures at which chemical reactions are fast (Korkut and Kocaefe 2009).

Heat treatment causes a reduction of mechanical properties of wood, due to the relatively severe process conditions used, especially at high temperatures between 150 and 280°C. Degradation of the hemicelluloses reducing the load sharing capacity of the lignin-hemicelluloses matrix probably has a negative impact on the compressive strength. The decrease of the radial compressive strength after heat treatment might be caused by small radial fissures. There appears to be a relationship between the decrease of the bending strength and the degradation of the hemicelluloses, and it has been suggested that changes in the hemicelluloses content and structure are primarily responsible for the initial loss of the bending strength. Degradation of the hemicelluloses, disrupting the load-sharing capacity of the lignin-hemicelluloses matrix, and increasing of the relative amount of crystalline cellulose, could contribute to the increase of the modulus of elasticity (MOE) (Korkut and Kocaefe 2009).

Research on surface roughness phenomena is increasing because surface roughness directly affects the quality of material in the woodworking industry (Sandak and Negri 2005). In practice, it is important to quantify and control the surface roughness that results from differences in the treatment of wood with tools and machines (Efe et al. 2007).

Therefore, this study examined the effects of different circular saws on the surface roughness of heat-treated wood of Scots pine (*Pinus sylvestris* L.), eastern beech (*Fagus orientalis* L.), Uludağ fir (*Abies bornmülleriana* Mattf.), and sessile oak (*Quercus petraea* L.).

EXPERIMENTAL

Preparation of Test Samples

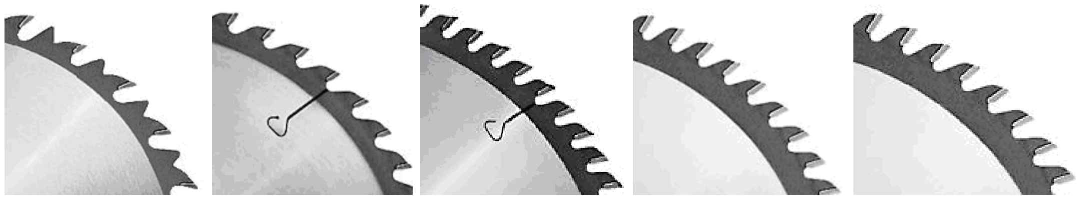
The Scots pine, eastern beech, Uludağ fir, and sessile oak examined are species commonly used in Turkey. Air-dried samples measuring 18 × 110 × 350 mm were designed according to TS 2470. The annual rings came to the surfaces vertically. The wood was top grade, finely fibrous, knotless, and crack-free, with no differences in colour or density (TS 2470 1976). The samples were kept at 103 ± 2°C until they reached a constant weight. Then, they were heated at 140 or 160ºC for 3, 5, or 7 hours. Subsequently, they were stored at 20 ± 2°C and 65 ± 5% relative humidity in air-conditioned closets until they reached a constant weight (TS 2471 1976; Korkut and Bakangil 2007).

The wood was cut with 28-, 48-, 60-, 72-, and 96-tooth saws tipped with hard metal (diamond) that were 300 mm in diameter. The geometries of the circular saws are summarised in Table 1, and shown in Fig. 1.

Table 1. Geometries of the Circular Saws

Tooth Type	Number of Teeth	Tooth Pitch (mm)	Tooth Height (mm)	Rake Angle (°)	Dimensions (mm)
WZ	28	33	15	20.5	300×3.2×30
WZ	48	20	13	9.5	300×3.2×30
FZ/TR	60	15	13	15	300×4.4×30
WZ	72	13	12	9	300×3.2×30
FZ/TR	96	10	10	12	300×3.2×30

WZ, variable teeth saw blades are for universal use in soft- and hardwood, plate materials, and grained materials. On the other hand, FZ/TR blades are for compound materials, veneered chipboards, plastic, Plexiglas, non-ferrous metals, and hardwood (http://www.bosch-pt.gen.tr/download/ACC_0910_CIRCULAR_SAWS_TR-tr. pdf.).



WZ-28 WZ-48 FZ/TR 60 WZ-72 FZ/TR-96

Fig. 1. Saws

To measure the surface roughness caused by the circular saws, the heat-treated samples measuring 18 × 110 × 350 mm were cut at a rate of 4 m/min and a cutting speed of 3000 rpm with the 28-, 48-, 72-tooth saws, and a rate of 6 m/min and 6000 rpm with the 60- and 96-tooth saws.

Surface Roughness Test

The surface roughness of the samples was defined according to ISO 4287 using spiny sweeping equipment (TIME TR200) (ISO 4287. 1997). The measurements were made vertical to the fibres at ten different points on each sample, marked as in Fig. 2. The measurements were done at 20 ± 2°C and 65 ± 3% relative humidity, in a vibration- and noise-free environment. The device was adjusted to 0.25-mm measurement steps and 5 measurement numbers (cut-off), and located between two lines with a rift of 5 mm. The measurements were made after ensuring that the sample and device were parallel. When the tip of the sweep needle stuck on a stomata, the measurement was repeated. The device was calibrated after every 100 measurements.

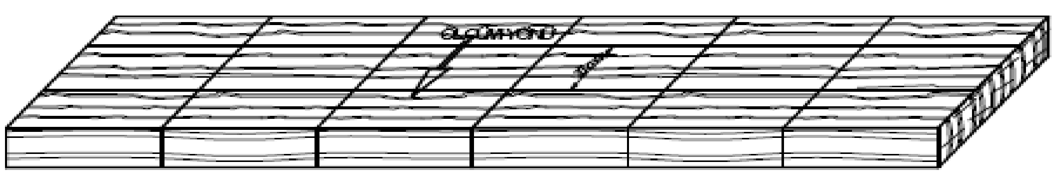


Fig. 2. Measurements on a sample surface

The device measures the surface roughness by constructing a profile of the valleys and ridges on the surface by moving the sweeping needle, which has a 5-µm-diameter diamond tip, up and down on the surface of the sample. The centreline between the profile valleys and ridges is the average roughness value (R_a) in microns (µm) (Fig. 3).

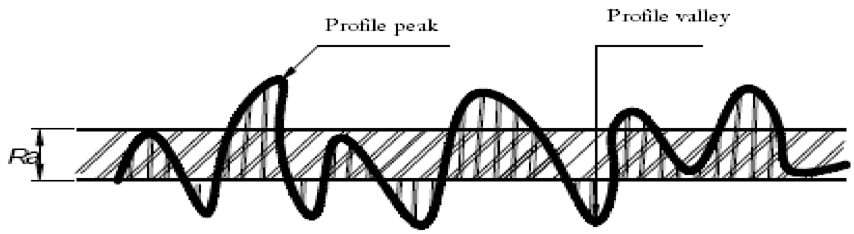


Fig. 3. Surface profile measured with a sweeping needle (Söğütlü 2005)

Statistical Method

The statistical package MSTATC was used for the analysis. Effects of the type of wood, number of saw teeth, heat treatment temperature, and time on the surface roughness, and interactions between these factors were subjected to analysis of variance (ANOVA). Comparisons were made using Duncan's test and the least significant difference (LSD) test.

RESULTS AND DISCUSSION

The results of the ANOVA of the surface roughness measurements of heat-treated and untreated wood cut with different circular saws are given in Table 2.

Table 2. ANOVA Results

Factor	Degrees of freedom	Sum of squares	Mean square	F-number	Level of Significance (P<0.05)
Wood type (A)	3	422.256	140.752	231.7134	0.0000*
Number of saw teeth (B)	4	62.237	15.559	25.6144	0.0000*
Interaction (AB)	12	28.800	2.400	3.9510	0.0000*
Temperature of heat treatment (C)	1	6.240	6.240	10.2720	0.0014*
Interaction (AC)	3	4.189	1.396	2.2989	0.0757
Interaction (BC)	4	15.242	3.811	6.2731	0.0001*
Interaction (ABC)	12	4.533	0.378	0.6218	ns
Length of heat treatment (D)	3	26.843	8.948	14.7303	0.0000*
Interaction (AD)	9	32.266	3.585	5.9019	0.0000*
Interaction (BD)	12	59.588	4.966	8.1748	0.0000*
Interaction (ABD)	36	56.254	1.563	2.5725	0.0000*
Interaction (CD)	3	6.232	2.077	3.4198	0.0167*
Interaction (ACD)	9	16.056	1.784	2.9369	0.0019*
Interaction (BCD)	12	18.136	1.511	2.4881	0.0031*
Interaction (ABCD)	36	38.861	1.079	1.7771	0.0033*
Fault	1440	874.713	0.607		
Total	1599	1672.445			

*: significant at 95% confidence level ns: not significant

According to the ANOVA, interaction AC was meaningless and interaction ABC was not significant. The other factors and interactions were significant at the $\alpha = 0.05$ level. Then, Duncan's test was used to compare the results according to wood type (Table 3).

Table 3. Results for Wood Type using Duncan's Test (µm)

Wood type							
Pine		Beech		Oak		Fir	
$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*
2.867	C	3.692	A*	2.288	D	3.232	B
LSD ± 0.1081							

$\bar{x}$, arithmetic mean; *HG*, homogeneity group; *, the greatest roughness value

As shown in Table 3, eastern beech had the greatest surface roughness and oak had the lowest. The low surface roughness of oak did not reflect its ringed, rough textured structure. In addition, there was an evident difference in roughness between spring and late wood. This discrepancy may have resulted from the fact that we measured only the late wood. The literature reports that late wood has lower roughness values than spring wood (Malkocoğlu 2007). Another study found that cavities formed among tracheids, parenchyma, resin canals, and fibres because the cells of the wood were cut with different teeth as the wood was being cut; the surface roughness is affected by these cavities, wood type, the proportions of spring and late wood, and whether they are cut horizontally, radially, or tangentially (Söğütlü 2005).

It is thought that eastern beech had the greatest surface roughness because the heat treatment caused surface roughness to develop. Heating wood causes a decrease in the volume and mass of the wood via increased stringiness, water loss from the structure of the wood because of the loss of hydroxyl groups, material losses in the cell wall, and the breakup of hemicelluloses (Fengel and Wegener 1989; Viitanen et al.1994; Korkut and Kocaefe 2009). The effect of the cutting direction is another reason for the difference in the surface roughness of two wood types. If wood cut radially and tangentially is not separated during sample preparation, it could affect the results. Kantay and Ünsal (2002) measured a surface roughness of 5.18 µm in oak and 4.73 µm in beech cut tangential to the annual rings, versus 5.07 µm in oak and 5.19 µm in beech cut radial to the annual rings. The roughness of the beech cut radially was higher than that of the oak samples. Our results are compatible with the literature.

Table 4 compares the effect of the number of saw teeth. The samples cut with the 60- and 70-tooth circular saws had the greatest surface roughness, and samples cut with the 28-tooth saw had the lowest surface roughness. This is because the 28-tooth saw, which is also known as a massive saw, has a double chamfered (WZ) sharp mouth profile, and sawdust spaces (Fig. 1) were shaped according to the tooth type. The results are compatible with the literature (Burdurlu and Baykan 1998; Örs and Demirci 1999).

Table 4. Effects of Saw Teeth Number Compared using Duncan's Test (μm)

Number of Saw teeth									
28		48		60		72		96	
$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*
2.744	C	2.890	B	3.186	A	3.290	A*	2.989	B
LSD ± 0.1208									

$\bar{x}$, arithmetic mean; *HG*, homogeneity group; *, the greatest roughness value

Table 5 compares the effect of heat treatment temperature. The samples treated at 160ºC had the greatest surface roughness, and the samples treated at 140°C had the lowest surface roughness. The higher the heat, the rougher the surface was. This occurs because the thermal degradation of wood starts at 100°C, while above 200°C, structural damage, a change in the compounds making up the wood, and the production of degradation products in the gas phase occur (Fengel and Wegener 1989; Boonstra and Tjeerdsma 2006). Below 140°C, particles that result from the loss of water and volatile extracts start to form, while above this temperature, cellular breakup particles, which are made up of looser structures that are tied to the cell wall polymers, start to form. This is exacerbated by acetic acid formation with the breakup of hemicelluloses. In addition, the formation of formic acid and methanol create an effect equivalent to that of the formation of condensing gases (especially CO_2) while wood is being heated. At above 140°C, dehydration reactions commence, causing a decrease in the hydroxyl content; this increases the surface roughness with increasing temperature (Bourgois et al. 1991).

Table 5. Effects of Heat Treatment Temperature Compared using Duncan's Test (μm)

Heat treatment temperature (°C)			
140		160	
$\bar{x}$	*HG*	$\bar{x}$	*HG*
2.957	B	3.082	A*
LSD ± 0.07641			

$\bar{x}$, arithmetic mean; *HG*, homogeneity group; *, the greatest roughness value

Table 6 compares the effects of heat treatment time. The control samples, which were not heated, had the lowest surface roughness. The three different heat treatment times (3, 5, and 7 hours) examined had an increasing effect on surface roughness. The physical qualities of wood are negatively affected by the amount of heat and how long the heat treatment is applied (Korkut et al 2008; Korkut and Budakçı 2009; González-Peña et al. 2009; Gündüz et al. 2009; Korkut and Budakçı 2010). Our results are compatible with the literature.

Table 6. Effects of Heat Treatment Time Compared using Duncan's Test (µm)

Heat treatment time (hours)							
Control		3		5		7	
$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*	$\bar{x}$	*HG*
2.798	B	3.117	A*	3.065	A	3.099	A
LSD ± 0.1081							

$\bar{x}$, arithmetic mean; *HG*, homogeneity group; *, the greatest roughness value

An overall comparison of the factors affecting surface roughness and their interactions using Duncan's test is shown in Table 7. According to the table 7, the greatest surface roughness was seen in the beech, cut with the 72-tooth circular saw after being heat-treated for 5 hours at 160°C, and the lowest was in oak, which was cut with the 60-tooth circular saw after being heat-treated for 5 hours at 140°C.

The lowest surface roughness values were 2.131 µm for pine wood, 2.960 µm for beech wood, 1.472 µm for oak wood, and 1.938 µm for fir wood heated at 160ºC for 7 h, 140ºC for 7 h, 140ºC for 5 h, and 140ºC for 5 h, while the surface roughness values of control specimens for pine, beech, oak, and fir wood were 2.888 µm, 3.187 µm, 2.140 µm and 2.528 µm, respectively.

CONCLUSIONS

In conclusion, many studies have suggested that there is value in heat-treating wood because it stabilises the material and makes it resistant to pests (Wikberk 2004; Enjily and Jones 2006; Kocaefe et al. 2007; Korkut et al 2008; Akyıldız and Ateş 2008; Sevim Korkut et al. 2008; Boonstra 2008; Korkut and Kocaefe 2009; Korkut and Budakçı 2009; González-Peña et al. 2009; Gündüz et al. 2009). However, we found that heat treatment caused the wood to become stiffer, resulting in increased the surface roughness after cutting with circular saws. High temperatures oxidised compounds in the wood and changed its colour. These facts should be considered.

Our results suggest that to obtain smooth surfaces, the wood should be cut with a 28-tooth circular saw that has a double chamfered (WZ) mouth profile, regardless of whether heat treatment is applied.

The needle sweep method of determining surface roughness can give faulty results when evaluating anisotropic surfaces like wood. Instead of this technique, measurements using a laser displacement sensor (LDS), which does not actually touch the surface, can provide more objective results in three dimensions.

Table 7. Comparison of Combined Effects of Wood Type, Teeth Number, Heat Treatment Temperature, & Heat Treatment Duration using Duncan's Test (μm)

Factor ABCD*			140°C				160°C			
			Control	3 h	5 h	7 h	Control	3 h	5 h	7 h
Pine	28	$\bar{x}$	2.883	2.650	2.348	2.757	2.883	3.008	2.460	2.131
		HG	K-e	N-g	[-h	L-f	K-e	I-c	V-h	_-h
	48	$\bar{x}$	2.437	2.604	3.439	2.839	2.437	2.965	2.800	2.441
		HG	W-h	O-g	D-[	K-f	W-h	I-d	L-f	W-h
	60	$\bar{x}$	3.193	2.666	2.866	2.716	3.693	3.302	3.352	3.536
		HG	G-_	N-g	K-e	M-f	B-Q	E-^	D-]	C-X
	72	$\bar{x}$	2.601	2.806	3.326	3.234	2.601	3.492	3.323	3.461
		HG	O-g	L-f	E-]	F-_	O-g	C-Y	E-]	C-[
	96	$\bar{x}$	2.283	2.427	3.070	3.037	2.283	2.385	2.936	3.011
		HG	\-h	X-h	H-b	I-c	\-h	Y-h	J-d	I-c
Beech	28	$\bar{x}$	3.187	3.799	3.696	2.960	3.187	3.069	3.548	3.378
		HG	G-_	A-M	B-Q	I-d	G-_	H-b	C-X	D-\
	48	$\bar{x}$	3.149	3.396	3.535	4.008	3.149	3.340	3.562	3.647
		HG	G-_	D-\	C-X	A-J	G-_	E-]	C-V	B-S
	60	$\bar{x}$	3.943	3.334	3.373	3.680	3.943	4.339	3.825	3.679
		HG	A-K	E-]	D-\	B-Q	A-K	A-F	A-M	B-Q
	72	$\bar{x}$	3.060	4.686	4.154	4.454	3.060	4.558	**4.791**	4.380
		HG	H-b	AB	A-H	ABCD	H-b	ABC	**A***	A-E
	96	$\bar{x}$	3.841	3.683	3.705	3.630	3.841	3.714	3.841	3.553
		HG	A-L	B-Q	B-P	B-T	A-L	A-L	A-L	C-W
Oak	28	$\bar{x}$	2.140	1.966	2.621	1.602	2.140	2.284	2.409	1.599
		HG	_-h	b-h	N-g	gh	_-h	\-h	Y-h	gh
	48	$\bar{x}$	2.616	2.394	3.231	1.736	2.616	1.978	2.582	1.994
		HG	O-g	Y-h	F-_	fgh	O-g	a-h	Q-g	`-h
	60	$\bar{x}$	1.814	2.722	**1.472**	2.716	1.814	2.252	2.531	2.466
		HG	efgh	M-f	**h**	M-f	efgh	]-h	R-h	V-h
	72	$\bar{x}$	1.872	2.811	2.487	2.781	1.872	3.035	3.082	2.645
		HG	defgh	L-f	U-h	L-f	defgh	I-c	H-a	N-g
	96	$\bar{x}$	1.799	1.924	2.542	2.187	1.799	2.116	2.516	2.360
		HG	efgh	cdefgh	R-h	^-h	efgh	_-h	T-h	Z-h
Fir	28	$\bar{x}$	2.528	3.260	2.978	2.880	2.528	2.966	2.664	3.295
		HG	S-h	F-^	I-d	K-e	S-h	I-d	N-g	E-^
	48	$\bar{x}$	2.454	2.711	2.746	3.741	2.454	3.663	2.716	3.098
		HG	V-h	M-f	L-f	A-N	V-h	B-Q	M-f	H-`
	60	$\bar{x}$	3.601	4.070	1.938	3.539	3.601	3.678	4.038	4.260
		HG	C-U	A-I	c-h	C-X	C-U	B-Q	A-J	A-G
	72	$\bar{x}$	2.591	4.070	1.938	3.539	2.592	3.678	4.038	4.260
		HG	P-g	A-I	c-h	C-X	P-g	B-Q	A-J	A-G
	96	$\bar{x}$	3.715	3.474	2.452	3.476	3.715	3.424	3.650	3.268
		HG	B-O	C-Z	V-h	C-Z	B-O	D-[	B-R	F-^

$\bar{x}$, arithmetic mean; *HG*, homogeneity group; *, the greatest roughness value; LSD±0.8382
**: A, wood type; B, number of saw teeth; C, heat treatment temperature; D, heat treatment time

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REFERENCES CITED

Aguilera, A. (2011). "Cutting energy and surface roughness in medium density fiberboard rip sawing," *European Journal of Wood and Wood Products* 69(1), 11-18.

Akyıldız, M. H., and Ateş, S. (2008). "Effect of heat treatment on equilibrium moisture content (EMC) of some wood species in Turkey," *Research Journal of Agriculture and Biological Sciences* 4(6), 660-665.

Boonstra, M. J., and Tjeerdsma, B. (2006). "Chemical analysis of heat treated softwoods," *Holz als Roh- und Werkstoff* 64, 204-211.

Boonstra, M. J. (2008). "A two-stage thermal modification of wood," *Ph.D. Dissertation Cosupervised at Ghent University and Université Henry Poincaré – Nancy* 1, 297 p. ISBN 978-90-5989-210-1.

Bourgois, J., Janin, G., and Guyonnet, R. (1991). "Measuring colour: A method of studying and optimising the chemical transformations of thermally-treated wood," *Holzforschung* 45(5), 377-382.

Budakçı, M., Gürleyen, L., Çınar, H., and Korkut, S. (2007). "Effect of wood finishing and planing on surface smoothness of finished wood," *Journal of Applied Sciences*, 7(16), 2300-2306.

Burdurlu, E., and Baykan, I. (1998). "Cutting theory in woodworking and industrial furniture production machineries," *Bizim Büro Basımevi*, Ankara.

Efe, H., and Gürleyen, L. (2003). "The effects of the cutting direction the number of cutter and the rotation value on surface smoothness for some wood species," *The Journal of the Industrial Arts Education Faculty of Gazi University* 11(12), 34-45.

Efe, H., Gürleyen, L., and Budakçı, M. (2007). "Effect of the cutting direction and number of knives on surface smoothness and bonding strength for *Acacia*," *Journal of Forestry Faculty*, *Kastamonu University*, 7(1), 13-23.

Enjily, V., and Jones, D. (2006). "The potential for modified materials in the panel products industry," *Wood Resources and Panel Properties* Conference, Spain, 12-14 June, COST Action E44/E49.

Fengel, D., and Wegener, G. (1989). *Wood: Chemistry, Ultrastructure*, *Reactions*, Walter De, Germany.

González-Peña, M .M., Curling, S. F., and Hale, M. D. C. (2009). "On the effect of heat on the chemical composition and dimensions of thermally-modified wood," *Polymer Degradation and Stability* 94(12), 2184-2193.

Gündüz, G., Korkut, S., Aydemir, D., and Bekar, I. (2009). "The density, compression strength and surface hardness of heat treated hornbeam (*Carpinus betulus* L.) wood," *Maderas Cienciay Tecnologia* 11(1), 61-70.

Hernández, R. E., and Cool, J. (2008). "Effects of cutting parameters on surface quality of paper birch wood machined across the grain with two planing techniques," *European Journal of Wood and Wood Products* 66(2), 147-154.

http://www.bosch-pt.gen.tr/download/ACC_0910_CIRCULAR_SAWS_TR-tr. pdf.

ISO 4287. (1997). "Geometrical product specifications surface texture profile method terms, definitions and surface texture parameters," *International Standards Organization*.

Kantay, R., and Ünsal, O. (2002). "Investigation of surface roughness of oak and beech wood parquets produced in Turkey," *Istanbul University Review of the Faculty of Forestry*, *Series: A* 52(1), 81-97.

Kılıc, M., Hiziroglu, S., and Burdurlu, E. (2006). "Effect of machining on surface roughness of wood," *Building and Environment* 41(8), 1074-1078.

Kocaefe, D., Younsi, R., Poncsak, S., and Kocaefe, Y. (2007). "Comparison of different high temperature wood heat treatment models," *International Journal of Thermal Sciences* 46(7), 707-716.

Korkut, S., and Bakangil, O. (2007). "Heat treatment methods," *Woodwork Furniture*, *Furniture Industry*, *Architecture*, *Decoration and Research Magazine*, 28-34.

Korkut, S., Kök, M. S., Sevim Korkut, D., and Gürleyen, T. (2008). "The effects of heat treatment on technological properties in red-bud maple (*Acer trautvetteri* Medw.) wood," *Bioresource Technology* 99(6), 1538-1543.

Korkut, S., and Kocaefe, D. (2009). "Effect of heat treatment on wood properties," *Düzce University*, *Journal of Forestry* 5(2), 11-34.

Korkut, S., and Budakçı, M. (2009). "Effect of high-temperature treatment on the mechanical properties of rowan (*Sorbus aucuparia* L.) wood," *Drying Technology* 27(11), 1240-1247.

Korkut, S., and Budakçı, M. (2010). "The effects of high-temperature heat-treatment on physical properties and surface roughness of rowan (*Sorbus aucuparia* L.) wood," *Wood Research* 55(1), 67-78.

Malkocoğlu, A. (2007). "Machining properties and surface roughness of various wood species planed in different conditions," *Building and Environment* 42(7), 2562-2567.

Örs, Y., Kalaycıoğlu, H., and Çolakoğlu, G. (1991). "The effect of saw tooth geometry on timber surface quality," *Doğa*, *Tr. J. of Agriculture and Forestry* 15, 777-784.

Örs, Y., and Demirci, S. (1999). "The effects of number of tooth, cutting direction and feed rate on surface roughness at wooden materials," Gazi University, Technical Education Faculty, *Journal of Polytechnic* 2(4), 1-5.

Örs, Y., and Baykan, I. (1999). "The effects of planning and sanding on surface roughness for solid wood material," *Turkish Journal of Agriculture and Forestry*, 23(3), 577-582.

Örs, Y., and Gürleyen, L. (2002). "Effect of the cutting direction, number of cutter and cutter type to surface smoothness on wood material for planning," Gazi University, Technical Education Faculty, *Journal of Polytechnic* 5(4), 335-339.

Sandak, J., and Negri, M. (2005). "Wood surface roughness – What is it?" *Trees and Timber Research Institute*, Ivalsa/Cnr, http://www.boku.ac. at/physik /coste35/Rosenheim/article/art_Sandak_COST_E35_Rosenheim_2005. pdf.
Sevim Korkut, D., Korkut, S., Bekar, İ., Budakçı, M., Dilik, T., and Çakicier, N. (2008). "The effects of heat treatment on the physical properties and surface roughness of Turkish hazel (*Corylus colurna* L.) wood," *International Journal of Molecular Sciences* 9, 1772-1783.
Söğütlü, C. (2004). "Using feasibility of some local wood species in making kündekâri," *Ph.D. Thesis*, Gazi University Institute of Science and Technology, 67-82.
Söğütlü, C. (2005). "The effect of some factors on surface roughness of sanded wood material," Gazi University, Technical Education Faculty, *Journal of Polytechnic* 8(4), 345-350.
Stumbo, D. A. (1960). "Surface texture measurement for quality and production control," *Forest Products Journal* 10(12), 122-124.
TS. 2470. (1976). "Methods of sampling for physical and mechanical testing of wood and general properties," *Turkish Standards Institution*.
TS. 2471. (1976). "Determination of moisture content for physical and mechanical tests of wood," *Turkish Standards Institution*.
Viitanen, H., Jämsä, S., Paajanen, L., Nurmi, A., and Viitaniemi, P. (1994). "The effect of heat treatment on the properties of spruce, a preliminary report," *International Research Group On Wood Preservation*, 03-06 May, Nusa Dua, Bali, Indonesia, Doc. No.IRG/WP 94-40032.
Yıldız, S. (2002). "Physical, mechanical, technological and chemical properties of beech and spruce wood treated by heating," *Ph.D. Thesis*, Karadeniz Technical University, Trabzon.
Wikberg, H. (2004). "Advanced solid state NMR spectroscopic techniques in the study of thermally modified wood," Academic Dissertation, University of Helsinki, Department of Chemistry, Laboratory of Polymer Chemistry, Helsinki, Finland.

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