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Full Length Research Paper

The effect of the process parameters in the planing processes on the surface roughness of cherry and pear woods

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In this study, the effects of the process parameters in the planing processes on the surface roughness were investigated. For this purpose, the experimental samples of cherry (*Prunus avium* L.) and pear (*Pirus communis* L.) wood species, which are commonly used in the Turkish decoration industry, were prepared. In preparing the experimental samples, the wood was planed tangentially and radially to the annual rings at a cutting depth of 1.4 mm in a milling machine with 4 blades 85 mm in diameter. The wood was planed into the direction of spindle rotation and in the direction against the spindle rotation at feed rates of 6, 9 and 12 m/min. The surface roughness values of the experimental samples were determined by using a stylus-type profilometer according to the ISO 4287 standards. The surface roughness was evaluated according to the R_a, R_z and R_y principles, which were three basic parameters of the determination method for surface roughness. According to the results, when the planing parameters were differentiated, the obtained surface roughness values also acquired a different character. The feed direction of work pieces for planing in the direction of spindle rotation was lower than the feed direction in the opposite to spindle rotation for the surface roughness.

KEYWORDS: Surface Roughness, Planing, Cherry, Pear.

INTRODUCTION

Wood is used in the production of some aspects of internal and external decorative elements by such processes as cutting, planing and sanding. However, when a piece of wood is processed repeatedly, production costs increases, and the quality of the product decreases as a result of the additional shaping, thus affecting the finishing quality.

In spite of the light feature of wood in weight, it has many superior characteristics for widespread interior and exterior decoration. For example, it can be easily shaped using a low consumption of energy. It has a low sound, heat and electrical transmission, and it has a high resistance to chemical substances. Moreover, wood can be finished aesthetically by staining and varnishing (Kopac and Sali, 2003; Aydin and Colakoglu, 2005; Kurtoglu, 2000). Cherry and pear woods are the preferred species in the wooden ornament applications.

Surface roughness is an important factor in the quality of the internal and external decorative elements produced from wood, and the fact that these qualities are at low values not only positively affect the appearance of the finished product, but they are also effective on both the upper surface requisites and the adhesion of the glues (Aslan et al., 2008; Richter et al., 1995; Malkocoglu, 2007; Coelho et al., 2008; Ozdemir et al., 2009; Budakci et al., 2007).

The methods for determining surface roughness and the standards developed in this study were first of all used in the metal industry, and these studies were also used in the determination of the surface roughness of wood in various countries at various times (Krisch and Csiha, 1999; Elmendorf and Vaughan, 1958; Lemaster and Beal, 1996).

Surface roughness can be determined by various techniques such as the optical, pneumatic, electrical, ultra-

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sonic, photographic and stylus methods (Gurau et al., 2005; Sandak and Tanaka, 2005). It has been found that the stylus-type profilometer was suitable within the tested methods for the measurement of the surface roughness of wood (Sieminski and Skarzynska, 1989). The surface roughnesses of Oriental beech (*Fagus orientalis* L.) and Trembling aspen (*Populus tremula* L.) were determined with a stylus-type profilometer after the wood underwent the cutting, planing and sanding processes. It was determined at the conclusion of the study that as the processing parameters changed the surface roughnesses also changed. Furthermore, it was stated that the stylus method could be used successfully to determine the surface roughness of the planed and sanded wood and in distinguishing the differences (Kilic et al., 2006).

Since cavities are formed among the vessels, tracheids, medullary rays, parenchyma, resin canals and fibers as a result of cutting the cells with different blades in the process of shaping the wood in machines, various processing systems such as cutting, peeling and planning (Sulaiman et al., 2009) further influence the surface roughness. The anatomic structure of the wood, especially the cell cavities, and the nonhomogeneous structure of the wood also affects the size of these cavities (Strumbo, 1963; Peters and Cumming, 1970; Morita et al., 1998). Surface roughness is also influenced by the cross grain annual ring width, rays, knots, reaction wood and the ratio of early wood and late wood (Taylor et al., 1999).

Tangential direction in the planing process produces a smoother surface when compared to a radial direction. As the number of blades increases, the surface roughness values decrease, and as the feed rate increases, the surface roughness also increases (Ors and Baykan, 1999; Roger and Cool, 2008). It has been confirmed in various studies that if variables such as the feed rate are not selected correctly, then the desired surface quality will not be obtained (Fujiwara et al., 2001).

It was found that when the Oriental beech (*Fagus orientalis* Lipsky) and Scotch pine (*Pinus silvestris* L.) wood specimens were prepared by planing, the surface roughness was less in the tangential cut as compared to the radial cut. Furthermore, the surface roughness was less in the planing with 4 blades when compared to planing with 2 blades, and the main effects of the cutting direction-number of blades were statistically insignificant (Ors and Gurleyen, 2002).

This study investigated the effect of the process parameters in the planing on the surface roughness of cherry (*Prunus avium* L.) and pear (*Pirus communis* L.) wood species that are grown and used in a widespread manner for ornamental work in Turkey.

MATERIALS AND METHODS

For the experiment preparation, the samples from cherry (*P. avium* L.) and pear (*P. communis* L.) were selected according to the provisions of Turkish Standards TS 2470 from the randomly selected first class wood material. The average air-dried (12% moisture content) densities of the wood used in the tests were 0.594 g/cm^3 for the cherry and 0.703 g/cm^3 for the pear samples. The preparation of the samples was carried out in accordance with the standards of the ASTM-D 1666-87. 240 samples were prepared in the dimensions of 22 x 60 x 600 mm; 10 for each of the following variables: wood species (2), feed direction (2), feed rate (3) and cutting direction (2). The rough samples were kept in a climatization chamber at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5% until they reached an unchanging weight of 12% moisture content (TS 2470, 1976). The rough samples were planed at feed rates of 6, 9 and 12 m/min on a tangential and radial direction to their annual rings by feeding in the direction of spindle rotation and in the direction against the spindle rotation. The planing procedure was realized in a horizontal milling machine with 4 blades having a diameter of 85 mm. In this process, the cutting depth was adjusted to 1.4 mm, and the spindle was rotated at 7200 rpm.

Three parameters are commonly used in the evaluation of surface roughness. These are the arithmetical mean deviation of profile (R_a), ten-point height of irregularities (R_z) and the maximum height of profile (R_y). R_a is the average distance from the profile to the mean line over the length of assessment. R_z can be calculated from the peak-to-valley values of five equal lengths within the profile, while maximum roughness (R_y) is the distance between peak and valley points of the profile, which can be used as an indicator of the maximum defect height within the assessed profile (Strumbo, 1963; Korkut and Guller, 2008; Hiziroglu, 1996; Togay et al, 2009).

The surface roughness was determined by conforming to the ISO 4287 standards (ISO 4287, 1997). A stylus-type profilometer (*TIME TR–200)* was used in the measurement of the surface roughness. This equipment had a 10 mm/min measuring speed, a 5 µm pin radius and a 90° probe angle (TS 2495 EN ISO 3274, 2005). After adjusting the equipment to a 5 cut-off length (λ_c) and a 2.5 mm sampling length, the measurements were made on the samples in a direction perpendicular to the fibers.

Statistical analysis

The analysis of variance was determined for the main effects among the wood species; cutting direction, feed direction and feed rate factors for every surface roughness parameter (R_a, R_z, R_y). In cases where the difference among the groups was found to be statistically significant at the level of 0.05, they were separated into homogeneity groups according to the critical values of the least significant difference (LSD) by using the Duncan test. The data was evaluated at a 0.95 level of reliability in the SPSS package program written for a PC.

Results and dıscussıon

The average surface roughness values (R_a, R_z, R_y) for the wood species, feed direction, feed rate and cutting direction is given in Table 1. As shown in Table 1, there was a difference in the surface roughness values according to the process parameters. The results of the analysis of variance made to determine from which factors these differences stemed from is given in Table 2. It can be observed that the wood species, feed direction, feed rate, cutting direction and some main effects of these for the surface roughness parameters (R_a, R_z, R_y) were statistically significant at the level of 0.05.

The Duncan test comparison results for the success

Table 1. Surface roughness values according to test variables.

Wood species	Feed direction	Feed rate (m/min)	Cutting direction	Surface roughness parameters (µm)					
				***R*a**		***R*z**		***R*y**	
				$\overline{X}$	*s*	$\overline{X}$	*s*	$\overline{X}$	*s*
Cherry	DOSR	6	R	3.156	0.147	22.07	0.91	27.17	1.09
			T	2.994	0.141	21.30	1.05	26.00	1.31
		9	R	4.025	0.158	24.52	0.98	31.18	1.18
			T	3.755	0.187	23.70	1.20	29.69	1.42
		12	R	4.246	0.165	25.55	1.14	32.54	1.44
			T	3.967	0.205	24.59	1.34	30.78	1.46
	DSR	6	R	3.012	0.093	21.39	0.62	26.57	1.02
			T	2.853	0.117	20.21	1.06	24.63	1.05
		9	R	3.776	0.105	23.17	0.72	30.29	0.76
			T	3.581	0.125	22.21	0.88	29.08	1.20
		12	R	4.099	0.109	24.63	1.05	31.55	1.18
			T	3.802	0.131	23.34	1.06	30.18	1.30
Pear	DOSR	6	R	3.303	0.094	22.69	0.87	28.56	1.35
			T	2.274	0.111	17.43	1.04	21.32	1.46
		9	R	3.852	0.180	23.99	1.00	30.07	1.58
			T	3.265	0.188	19.64	1.02	25.52	1.38
		12	R	4.157	0.196	25.88	1.01	32.16	1.73
			T	3.505	0.177	21.50	1.10	27.53	1.41
	DSR	6	R	3.367	0.101	23.45	1.04	29.72	1.45
			T	2.396	0.133	17.82	1.09	21.95	1.26
		9	R	4.112	0.232	25.40	0.94	32.67	1.62
			T	3.435	0.173	20.41	1.22	26.27	1.36
		12	R	4.347	0.233	26.94	1.06	33.88	1.69
			T	3.650	0.193	22.62	1.37	28.64	1.46

$\overline{X}$: Arithmetic means (µm); s: Standard deviation; R: Radial; T: Tangential; DSR: Direction of spindle rotation; DOSR: Direction opposite to spindle rotation.

Table 2. Results of the variance analysis for the surface roughness values of processing parameters.

	Source	Sum of squares	df	Mean square	F	Significance
***R*a**	Wood species (A)	1.073	1	1.073	42.190	0.000*
	Feed direction (B)	1.616	1	1.616	63.522	0.000*
	A x B	0.002	1	0.002	0.079	0.778
	Feed rate (C)	48.468	2	24.234	952.560	0.000*
	A x C	0.037	2	0.019	0.733	0.482
	B x C	0.092	2	0.046	1.802	0.167
	A x B x C	0.011	2	0.005	0.215	0.807
	Cutting direction (D)	14.880	1	14.880	584.895	0.000*
	A x D	4.410	1	4.410	173.353	0.000*
	B x D	0.008	1	0.008	0.298	0.585
	C x D	0.227	2	0.114	4.468	0.013*
	A x B x D	0.000	1	0.000	0.006	0.939
	A x C x D	0.663	2	0.332	13.038	0.000*
	B x C x D	0.031	2	0.016	0.615	0.542

Table 2. cont.

	A x B x C x D	0.010	2	0.005	0.190	0.827
	Error	5.495	216	0.025		
	Total	77.024	239			
***R*$_z$**	Wood species (A)	33.220	1	33.220	30.409	0.000*
	Feed direction (B)	62.925	1	62.925	57.600	0.000*
	A x B	0.675	1	0.675	0.618	0.433
	Feed rate (C)	518.426	2	259.213	237.279	0.000*
	A x C	6.258	2	3.129	2.864	0.059
	B x C	2.849	2	1.424	1.304	0.274
	A x B x C	0.348	2	0.174	0.159	0.853
	Cutting direction (D)	508.523	1	508.523	465.491	0.000*
	A x D	219.134	1	219.134	173.353	0.000*
	B x D	0.002	1	0.002	.002	0.967
	C x D	2.727	2	1.363	1.448	0.028*
	A x B x D	1.400	1	1.400	1.281	0.259
	A x C x D	3.949	2	1.975	1.980	0.036*
	B x C x D	0.517	2	0.259	0.237	0.789
	A x B x C x D	0.228	2	0.114	0.105	0.901
	Error	235.968	216	1.092		
	Total	1 597.148	239			
***R*$_y$**	Wood species (A)	55.912	1	55.912	30.536	0.000*
	Feed direction (B)	68.395	1	68.395	37.353	0.000*
	A x B	4.161	1	4.161	2.272	0.133
	Feed rate (C)	1 111.211	2	555.606	303.438	0.000*
	A x C	6.445	2	3.223	1.760	0.174
	B x C	1.115	2	0.558	0.305	0.738
	A x B x C	2.190	2	1.095	0.598	0.551
	Cutting direction (D)	843.525	1	843.525	460.682	0.000*
	A x D	296.726	1	296.726	162.054	0.000*
	B x D	2.953	1	2.953	1.613	0.206
	C x D	21.269	2	10.635	5.808	0.003*
	A x B x D	4.532	1	4.532	2.475	0.117
	A x C x D	16.184	2	8.092	4.419	0.013*
	B x C x D	4.111	2	2.055	1.123	0.327
	A x B x C x D	1.470	2	0.735	0.401	0.670
	Error	395.504	216	1.831		
	Total	2 835.703	239			

*: Significant at 99% confidence level; **: significant at 95% confidence level.

orders and homogeneities of the wood species and the process parameters were shown to be statistically significant at the level of 0.05 according to the surface roughness parameters and are given in Table 3 for the wood species and in Table 4 for the feed direction.The surface roughness (R_a, R_z, R_y) were at lower levels in the pear as compared to the cherry (Table 3). This situation could have come from the fact that the texture in the pear was finer than that in the cherry. With respect to Table 4, when the piece been worked in the planing process was advanced in the direction of spindle rotation, then it was observed that the roughness was at low values. This situation could have been from the fact that the blades did not break the fibers from the surface of the wood during the removal of chips. The Duncan test results made for the feed rate and the cutting direction are given

Table 3. Results of the Duncan test for the wood species.

Wood species	R_a (LSD ± 0.083)		R_z (LSD ± 0.363)		R_y (LSD ± 0.578)	
	$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
Pear	3.472	**A**	22.31	**A**	28.19	**A**
Cherry	3.605	B	23.06	B	29.16	B

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

Table 4. Results of the Duncan test for the feed direction.

Feed direction	R_a (LSD ± 0.098)		R_z (LSD ± 0.392)		R_y (LSD ± 0.579)	
	$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
DSR	3.456	A	22.17	A	28.19	A
DOSR	3.621	B	23.06	B	29.16	B

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

in Tables 5 and 6.

According to Table 5, as the feed rate increased, the surface roughness values also increased. When the studies in the literature were examined, it can be stated that there was proportional relationship between the feed rate and the surface roughness. The values obtained in this study are in conformance with the values in literatures (Malkocoglu, 2007; Ors and Baykan, 1999; Roger and Cool, 2008; Fujiwara et al., 2001). Therefore, because feed rate influenced the average thickness of chips, it could be the reason for the different surface roughness when feed rate increased.

From Table 6, it can be observed that, the surface roughness values (R_a, R_z, R_y) were higher in the radial direction as compared to the tangential direction. At the end of the tests realized with similar conditions in the literature, it was shown that the radial direction produced rougher surfaces when compared to the tangential direction. The findings obtained in this study support the information given in literatures (Roger and Cool, 2008; Ors and Gurleyen, 2002).

The Duncan test results for the surface roughness parameters (R_a, R_z and R_y) of the wood species-cutting direction main effects are shown in Table 7.

In line with the Table 7, the lowest surface roughness (R_a, R_z, R_y) was found in the pear at the tangential direction, whereas, it was the highest in the pear at the radial direction. At the end of the planing processes, R_a values for radial direction between pear and cherry were statistically insignificant at a reliability level of 0.05. The fact that the radial direction produced rougher surfaces as compared to the tangential direction, could have come from the fact that the structural configuration of the wood was different in this direction and from the fact that fibers broke off from the springwood tissue (Strumbo, 1963; Peters and Cumming, 1970).

The Duncan test results for the surface roughness parameters (R_a, R_z and R_y) of the wood species-feed rate main effects are given in Table 8. As seen in Table 8, it was found that the surface roughness values (R_a, R_z and R_y) were found in the tangential direction at a 6 m/min feed rate, whereas, it was highest in the radial at a 12 m/min feed rate. The Duncan test results for the surface roughness parameters (R_a, R_z and R_y) of the wood species-feed rate-cutting direction main effects are given in Table 9.

According to Table 9, the lowest surface roughness (R_a, R_z and R_y) was found in pear at a 6 m/min feed rate. In evaluation of the results, it was observed that the pear had lower surface roughness values when compared to the cherry and at the same time, as the feed rate increased, the roughness also increased. This situation was also influential on the dual comparisons and showed a similarity with the studies in literatures (Malkocoglu, 2007; Ors and Baykan, 1999; Roger and Cool, 2008; Fujiwara et al., 2001).

CONCLUSION

According to the test results, when the planing parameters were different, the surface roughness values obtained also acquired a different character. In the case where the feed direction of the work piece in planing was in the direction of spindle rotation (cutting speed), the surface roughness values of R_a, R_z and R_y were lower than in the case where the feed direction was opposite to the spindle rotation (cutting speed). Furthermore, the radial direction produced rougher surfaces when compared to the tangential direction, and as the feed rate increased, the surface roughness also increased. When the pear was compared to the cherry and the tangential direction was compared to the radial direction, a lower feed rate produced smoother surfaces. Importantly,

Table 5. Results of the Duncan test for the feed rate.

Feed rate (m/min)	R_a (LSD ± 0.077)		R_z (LSD ± 0.338)		R_y (LSD ± 0.567)	
	$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
6	2.919	A	20.80	A	25.77	A
9	3.725	B	22.88	B	29.35	B
12	3.971	C	24.38	C	30.91	C

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

Table 6. Results of the Duncan test for the cutting direction.

Cutting direction	R_a (LSD ± 0.086)		R_z (LSD ± 1.268)		R_y (LSD ± 2.486)	
	$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
Tangential	3.290	A	21.23	A	26.80	A
Radial	3.788	B	224.14	B	30.55	B

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

Table 7. Results of the Duncan test for the wood species-cutting direction.

Wood species	Cutting direction	R_a (LSD ± 0.086)		R_z (LSD ± 1.268)		R_y (LSD ± 2.486)	
		$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
Cherry	Tangential	3.492	B	22.56	B	28.39	B
	Radial	3.719	C	23.56	C	29.92	C
Pear	Tangential	3.087	A	19.90	A	25.20	A
	Radial	3.856	C	24.73	D	31.18	D

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

Table 8. Results of the Duncan test for the feed rate-cutting direction.

Feed rate (m/min)	Cutting Direction	R_a (LSD ± 0.025)		R_z (LSD ± 1.063)		R_y (LSD ± 1.610)	
		$\bar{X}$	DH	$\bar{X}$	DH	$\bar{X}$	DH
6	Tangential	2.629	A	19.19	A	23.47	A
	Radial	3.209	B	22.40	C	28.06	B
9	Tangential	3.509	C	21.49	B	27.64	B
	Radial	3.941	E	24.27	D	31.05	D
12	Tangential	3.731	D	23.01	C	29.28	C
	Radial	4.212	F	25.75	E	32.53	E

$\bar{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

Table 9. Results of the Duncan test for the wood species-feed rate-cutting direction.

Wood species	Feed rate (m/min)	Cutting Direction	R_a (LSD ± 0.160)		R_z (LSD ± 0.829)		R_y (LSD ± 1.317)	
			$\overline{X}$	DH	$\overline{X}$	DH	$\overline{X}$	DH
Cherry	6	Tangential	2.923	B	20.76	C	25.32	B
		Radial	3.084	C	21.73	D	26.98	C
	9	Tangential	3.668	E	22.95	E	29.39	E
		Radial	3.901	F	23.85	F	30.73	F
	12	Tangential	3.885	F	23.96	F	30.48	F
		Radial	4.172	G	25.09	G	32.05	G
Pear	6	Tangential	2.334	A	17.62	A	21.63	A
		Radial	3.335	D	23.07	E	29.14	E
	9	Tangential	3.350	D	20.03	B	25.89	B
		Radial	3.982	F	24.70	G	31.37	F
	12	Tangential	3.577	E	22.06	D	28.09	D
		Radial	4.252	G	26.41	H	33.02	H

$\overline{X}$: Arithmetic means (µm); DH: Degree of homogeneity.

however, this study showed that feed direction was a significant factor on surface roughness. It is a known fact that the primary aim of commercial enterprises is to lower production costs by increasing the production amounts made in a unit time and consequently, to increase the ratio of profits. Thus, such enterprises seek different production processes in order to realize this goal. In conclusion, in addition to the information in the literatures, it can be said that benefits would result by feed wood in the direction of spindle rotation in planing, both from the aspect of decreasing the operating production costs and from the aspect of increasing the amount of work done in a unit time. Also, investigations will be made to determine the different planing conditions so as to obtain surface quality and to decrease energy consumption in the woodworking industry.

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