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Research Article

EFFECTS OF SANDING AND VARIOUS SURFACE SMOOTHING PROCESSES ON SURFACE ROUGHNESS AND VARNISH ADHESION OF BEECH, OAK AND PINE MASSIVE PARQUETS

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ABSTRACT

The objective of this study was to determine effects of sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets. First of all, the parquet samples were classified into four groups. Fifteen parquet samples were used for each group. Parquet samples in first group were processed on thickness machine, samples in second group were processed on plane machine, and samples in third group were sanded with 60 grit sandpaper while the parquets in fourth group were sanded with 180 grit sandpaper, parallel to grain direction. The surface roughness of the samples were determined according to DIN 4768. After surface roughness measurements, parquet samples were coated with cellulosic varnish by using a spray gun at a spread rate on 120 g/m^2. The adhesion of strength of the parquet samples were determined according to ASTM D 4541. According to the study results, the highest surface roughness values were obtained in oak, and there was no statistical difference between beech and pine. The adhesion strength values of beech parquets were higher than pine and oak parquets. Processing of sanding with lower grit sandpaper resulted in increased surface roughness while improved adhesion strength characteristics between the coating and the substrate.
Keywords: Surface roughness, adhesion strength, parquet, sanding, varnish.

1. INTRODUCTION

The primary function of any wood finish (paint, varnish, wax, stain, oil, etc.) is to protect the wood surface, help maintain a certain appearance, and provide a cleanable surface [1]. Finishing of wood material is one of the most important processes influencing overall quality of the final product. Physical characteristics in particular appearance of the finished product are affected by not only the type of finish but also the interaction between finish and the substrate. It is a well-known fact that species, wood density, and roughness of the substrate are considered major parameters to have an effective finishing process [2].

Wood coatings prolong service life by safeguarding the substrate from, in particular, outdoor conditions like UV light, high and/or changing humidity, mechanical damage, chemicals, living organisms like fungi, termites, etc. Coatings can also further improve aesthetics by providing

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colour or gloss [3]. Successful wood coating involves several stages including preparation of surfaces. Surf ace preparation is the most important factor in developing a successful coating system. The purpose of surface preparation is to remove all contaminants that can interfere with adhesion. Sanding or mechanical cleaning is then required to remove loose or deteriorated surface on wood to obtain the proper surface profile. The process of abrasive sanding is also essential in the manufacture of value-added wooden furniture, which demands quality surface finish [4].

Improperly prepared surfaces can lead to premature finish failure and poor performance [5]. Some mechanical pre-treatments such as sanding and planning can also be applied to get a fresh surface which eliminates bonding problems and improves glue bonding of wood [6]. Careful sanding to provide a smooth surface is essential for a good finish because any irregularities or roughness in the surface will be accentuated by the finish [1].

The wood surface texture can significantly affect the finishing requirements. New saw-textured surfaces may contain loose wood particles or protruding wood fibers. Loose wood material not removed prior to finishing or protruding fibers that are not thoroughly coated may lift. Therefore, it is essential that all foreign matter or loose material is removed prior to finishing [5]. The phenomenon of 'grain-raising' presents a major operational problem for high-quality wood finishing and will require sanding operations. Sanding can be considered as the last operation in the manufacturing process of the uncoated product. It is carried out to remove the first wood layers, producing a smooth and uniform surface and also eliminating blemishes due to previous operations such as gluing [7].

The objective of this work was to determine effects of sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets.

2. MATERIALS AND METHOD

Beech, pine and oak massive parquets with the dimensions of 30 cm x 5 cm x 1.8 cm were obtained from a commercial parquet plant located in Karadeniz Region in Turkey. First of all, parquet samples manufactured from beech, pine and oak wood were classified into four groups. Fifteen parquet samples were used for each group. Parquet samples in first group were processed on thickness machine, samples in second group were processed on plane machine, and samples in third group were sanded with 60 grit sandpaper while the parquets in fourth group were sanded with 180 grit sandpaper, parallel to grain direction.

Surface roughness values of parquets were determined after planning and sanding processes. Mitutoyo Surftest SJ-301 was employed for surface roughness measurements. Cut-off length was 2,5 mm, sampling length was 12,5 mm and detector tip radius was 5 μm in the surface roughness measurements. Fifteen measurements were taken from all parquet samples across the grain orientation. Three roughness parameters, average roughness (Ra), mean peak-to-valley height (Rz), and maximum roughness (Rmax) were used to evaluate surface roughness of the samples according to DIN 4768 [8]. Samples were conditioned to an equilibrium moisture content before the surface roughness measurements so that the moisture content could not alter the results of measurements.

After surface roughness measurements, parquet samples were coated with cellulosic varnish by using a spray gun at a spread rate on 120 g/m^2. The coating was applied to surface as 2 bases and 1 top layer. The mixture of cellulosic varnish for each layer had 100 parts varnish and 50 parts thinner by volume. Viscosity of varnish for the application was determined as 98,74 mpa.s (cup Ø = 4 mm).

Once parquet samples were dried in ambient temperature after coating process, dry film thickness of each samples were measured by using Erichsen P.I.G 445 measuring device at an accuracy of 1μm, according to ASTM D 4138 [9]. Average dry film thickness of cellulosic varnish was measured as 80 μm.

Pull-off test was used to evaluate adhesion of strength of the parquet samples according to ASTM D 4541 [10]. Fifteen replicate measurements with a contact area of 20 mm circles were taken from each side of the samples. Erichsen-525 MC Adhesion tester with a head glued to the surface of the samples was employed for the tests. The equipment runs at a constant speed and applies tension force to the surface layer by pulling the coating from the surface. Adhesion strength value of the coating is limiting value of the tension force applied which is registered on the display of the equipment in N/mm^2.

3. RESULTS AND DISCUSSION

It was showed in Table 1 that surface roughness test results of parquet samples after processing on thickness and plane machines and sanding.

Table 1. Surface roughness measurement results of parquet samples after processing on thickness and plane machines and sanding (values in parenthesis are standard deviations)

	Beech (µm)			**Pine (µm)**			**Oak (µm)**		
	Ra	**Rmax**	**Rz**	**Ra**	**Rmax**	**Rz**	**Ra**	**Rmax**	**Rz**
Processed on Thickness Machine	5.60 (1.02)	48,35 (9,01)	41,86 (8,16)	5,85 (0,81)	45,31 (10,66)	39,23 (5,74)	10,08 (1,30)	95,99 (10,35)	84,15 (6,80)
Processed on Plane Machine	4.85 (1.10)	44.68 (8.55)	38.04 (5.71)	5.23 (1.44)	43.97 (14.07)	35.46 (8.01)	9.52 (2.32)	101.38 (16.34)	80.49 (6.68)
Sanded with 60 Grit	6.81 (1.24)	53.71 (7.09)	45.69 (4.96)	6.73 (0.99)	56.80 (9.60)	50.57 (8.33)	11.36 (2.42)	120.46 (21.54)	93.83 (8.77)
Sanded with 180 Grit	3.69 (1.63)	37.28 (10.73)	30.38 (8.57)	3.97 (1.40)	41.52 (9.49)	32.47 (5.18)	5.66 (1.28)	75.27 (11.96)	61.76 (6.00)

In order to determine the effect of various surface treatments on the surface roughness values of beech, pine and oak massive parquet, multiple variance analysis was performed and the results are given in Table 2. Student-Newman-Keuls test results used to compare the mean values of variance sources were given in Table 3.

Table 2. Statistical analysis of the surface roughness test results

Source of Variation	**Sum of Squares**	**Degrees of Freedom**	**Mean Squares**	**F-value**	**Sig. level**
A: Wood Species	66734.5	2	33367.3	673.46	***
B: Surface Processing	11062.8	3	3687.6	74.43	***
Interaction: AB	1807.4	6	301.234	6.08	***
Error	8323.76	168	49.5462		
Total	87928.5	179			

Table 3. Student-Newman-Keuls test results of the samples (p<0.05).

Variance of Sources	**N**	**Surface Roughness Rz (µm)**	**Homogenous Group***
Effect of Wood Species			
Beech	60	38.99	a
Pine	60	39.45	a
Oak	60	80.06	b
Effects of Surface Processing			
Processing on thickness machine	45	55.08	b
Processing on plane machine	45	51.33	b
Sanding with 60 grit sandpaper	45	63.37	c
Sanding with 180 grit sandpaper	45	41.54	a

* Different letters indicate the statistically significant difference

According to the results of analysis of variance; both wood species and applied surface processing and their interaction with each other on the surface roughness values of parquets are significant with a probability of 0.1% error (Table 2).

Among the three wood species tested in Table 3, oak parquets gave the highest surface roughness mean values (Rz) due to the most porous anatomical structure having the roughest surface [11]. Normally diffuse porous woods with small pores tend to be the most evenly textured compared to the wood species such as oak, which has very large and open pores. Therefore, species with a finer texture (smooth and glassy) such as beech has a smoother surface roughness compared to species with a coarse texture (soft and rough) such as oak [12]. According to this statistical evaluation, the differences in surface roughness values for beech and pine were found not to be significant at 95% confidence level.

The smoothest samples were obtained after sanding with 180 grit sandpaper for all three parquet wood species while the highest surface roughness values were measured on parquets sanded with 60 grit sandpaper. Sanding operation could reduce the inhomogeneity of wood surfaces and make the wood surfaces more uniform. Therefore, sanding improved the surface roughness and application of higher grit of sanding reduced the surface roughness [13]. Hiziroglu et al. [14] sanded surface of oak, pine and nyatoh samples on 80, 180 and 240 grit sandpaper applying. As a result of the study, they found that 180 grit sandpaper gave the lowest surface roughness values among their groups. Sogutlu et al. [15] obtained same results from the oak, pine and cherry wood samples sanded on 80, 120 and 180 grit sandpaper. As a result of the study, they found that 180 grit sandpaper gave the lowest surface roughness values among their groups.

Pull-off strength adhesion test results of parquet samples after processing on thickness and plane machines and sanding were presented in Figure 1.

In order to determine the effect of various surface treatments on the adhesion strength values of beech, pine and oak massive parquet, multiple variance analysis was performed and the results are given in Table 4.

According to the results of analysis of variance; both wood species and applied surface processing and their interaction with each other on the adhesion strength values of parquets are significant with a probability of 0.1% error (Table 4).

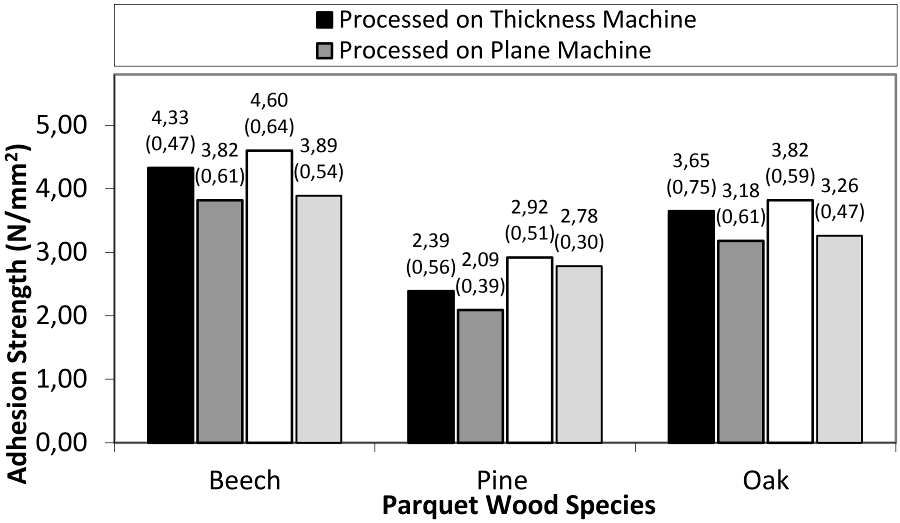

Figure 1. Pull-off strength adhesion test results of parquet samples after planning and sanding (Values in parenthesis are standard deviations)

Table 4. Statistical analysis of the adhesion strength test results

Source of Variation	Sum of Squares	Degreess of Freedom	Mean Squares	F-value	Sig. level
A: Wood Species	82.097	2	41.049	136.737	***
B: Surface Processing	11.756	3	3.919	13.053	***
Interaction: AB	3.956	6	0.659	2.196	*
Error	50.434	168	0.300		
Total	2237.961	180			

Student-Newman-Keuls test results used to compare the mean values of variance sources were given in Table 5.

Table 5. Student-Newman-Keuls test results of the samples ($p<0.05$).

Variance of Sources	N	Adhesion Strength (N/mm^2)	Homogenous Group*
Effect of Wood Species			
Beech	60	4.20	c
Pine	60	2.55	a
Oak	60	3.48	b
Effects of Surface Processing			
Processing on thickness machine	45	3.46	b
Processing on plane machine	45	3.08	a
Sanding with 60 grit sandpaper	45	3.78	c
Sanding with 180 grit sandpaper	45	3.31	b

* Different letters indicate the statistically significant difference

According to Figure 1 and the statistical evaluation (Table 5), adhesion strength values of beech parquets with cellulosic varnish were found higher than those of oak and pine parquets. The smooth surface quality of beech may be responsible for this finding. In the previous studies, adhesion strength of beech was also found to be better than that of oak [16-17]. The adhesion strength of varnish on wood surfaces has been reported to be higher in wood from angiosperm trees compared to gymnosperms [18]. The properties of the wood surface, its texture, anatomy and species all affect surface coating performance [19].

The highest adhesion strength values were obtained for the groups sanded with 60 grit sandpaper while the lowest adhesion strength values were obtained for planed groups without sanding. Because, the surface roughness of the groups sanded with 60 grit sandpaper were higher than the other groups. It has been reported that increased surface roughness leads to increased varnish layer adhesion strength resistance due to a mechanical and chemical bond between the wood sample and varnish liquid when applied to its surface. Such chemical adhesion occurs as the varnish liquid fills gaps on the wood surface and solidifies [15]. Similarly, the adhesion strength increased with increasing the area for the mechanical interlocking between coating and wood substrate [20].

4. CONCLUSIONS

The effects of the sanding and various surface smoothing processes on surface roughness and varnish adhesion of beech, oak and pine massive parquets was investigated in this study. The highest surface roughness values were obtained in oak, and there was no statistical difference between beech and pine. The adhesion strength values of beech parquets were higher than pine and oak parquets. Processing of sanding with lower grit sandpaper resulted in increased surface roughness while improved adhesion strength characteristics between the coating and the substrate. Therefore, it is recommended from this study that where high varnish adhesion strength is required, the wood surface should be sanded with low number grit sandpaper. The data obtained from this study will have potential to determine better finishing application for oak, pine and beech parquets.

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