Journal of Applied Sciences

ISSN 1812-5654

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 9 (9): 1719-1725, 2009
ISSN 1812-5654

Effects of Impregnation with Timbercare Aqua to Surface Roughness of Some Varnishes

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Abstract: This study has been performed for determining the impacts of impregnation with Timbercare Aqua (TA) to surface roughness of some varnishes. For analysis, measurements were performed in the vertical direction of fibers by using Mitutoya Surftest-301 stylus scanner device. Roughness values were determined with ±0.01 μm sensitivity where scanning length (lt) was 12 mm and sampling length was (λc) 2.5 mm according to TS 971 and ISO 4288 standards. As a result, Surface roughness (Ra) mean value was measured as highest in oak (3.359 μm), in waterborne interior space varnish (2.465 μm) and TA and one layer application (3.320 μm). For the combination of wood, type of varnish and impregnation process, surface smoothness was lowest in combination of Scotch pine and polyurethane varnish and one layer impregnation (0.433 μm) and highest in combination oak and interior space varnish and one layer impregnation with TA (6.502 μm). Ra was measured highest on the surfaces impregnated with TA. So, it can be said that TA has an increasing effect on the surface roughness of woods.

Key words: Surfaces roughness, timbercare, wood, varnish, wood preservation

INTRODUCTION

Wood materials are impregnated for increasing resistance of wood materials to some environmental effects and for increasing their lifetime (Evans *et al*., 1992). Impregnation is the most effective condition for protecting wood against destructive effects (Miclasevics, 2004). The other preservative processes for wood materials is varnishing. Varnishing increases aesthetic and economical value and preserves wood material from environmental effects like water, oil, stain, contamination etc. Furnitures made with unimpregnated wood materials and coated only with paint and varnish have surface protection only for a short period (Evans *et al*., 1992).

Surface processes are applied for protecting furniture as final product, for beautifying wood and for increasing their economical value. Performance of this process depends on surface roughness of wood material. For surface roughness of massive wood materials, type of wood material, texture, cutting direction feed speed, cutting speed, cutting depth, number of knives during processing in machines are important (Richter, 1995).

Wood material has many cavities because of its porous structure. During processing with cutting instruments, various dents and protrusions are formed. Roughness because of wood material structure or formed during processing in machines affects upper surface processes directly. If the roughness of surface isn't appropriate, after painting and varnishing process, the surface defects become clearer which decreases the quality of product (Stumbo, 1960).

Many different chemicals are used for impregnation. Some of them can also reduce the strength of lumber or plywood and effect related to the nature of the chemicals (Terziev and Daniel, 2002; Winandy *et al*., 1988). Different solutions of CCA, tanalit-E, wolmanit-CX, ACQ impregnation materials decrease surface roughness value of Scotch pine wood (Temiz *et al*., 2005). After the impregnation of Uludağ fir, Oriental spruce, Scotch pine and oak wood with 5.5% solution of boric acid, borax, boric acid and borax by vacuum method, surface roughness values were determined. Boron compounds increased surface roughness (Örs *et al*., 2005).

Akaba wood (*Tetraberlinia bifoliolata*) was treated with borax, boric acid, monoammonium phosphate and

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diammonium phosphate, then experimental plywood panels were made from these veneer sheets. A stylus method was employed to evaluate the surface characteristics of the samples. Significant difference was determined ($p = 0.05$) between surface roughness parameters (R_a, R_z, R_{max}). Results revealed that the surface quality of the panels reduced with increasing chemical concentration (Ayrılmış *et al*., 2006). At the other study, some veneers were treated with borax, boric acid and ammonium acetate solutions. After these treatments, surface roughness and colour measurements were made on veneer surfaces. Considerable changes in surface roughness after preservative treatment did not occur on veneer surfaces. Generally, no clear changes were obtained or the values mean roughness profile (R_a) decreased slightly in R_a values after the natural inactivation process (Aydın and Çolakoğlu, 2005).

In the sanding process, structural features of the wood material the grain size and type of abrasive mineral are important for roughness. As the grain size of the sandpaper increases, the roughness also increases. To use silicon carbide abrasive mineral instead of aluminum oxide abrasive mineral decreases the roughness (Taylor *et al*., 1999).

In measuring the roughness values, systems like laser scatter/optical imaging and acoustic emission count rate are used, in addition to traditional stylus tracing system (Tanaka *et al*., 1994).

This study has been performed for determining impact of impregnation with timbercare aqua to surface roughness of some varnishes.

MATERIALS AND METHODS

All of the experimental applications were conducted from June 2005 to July 2008.

Wood materials: Uludağ fir (*Abies bornmülleriana* Lipsky), Oriental spruce (*Fagus orientalis* L.), Scotch pine (*Pinus sylvestris* L.), Oriental beech (*Fagus orientalis* L.) and oak (*Quercus petreae* L.) woods were chosen as test material because of their common usage in wood industry. The woods were chosen randomly from timber merchants of Ankara, Turkey. Special emphasis is given for the selection of the wood material. Accordingly, non-deficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages) wood materials were selected.

Impregnation material: TA used as an impregnation material in this study was supplied by Hickson Timber Products Ltd. Istanbul. TA is for using on door/window framing, wooden casings for metallic window frames, shutters, flooring blocks, roof caging systems, surface covers, eave-vault-balcony timbers, bearing components.

TA is a non-flammable, odorless, completely soluble in water, non-corrosive material with a pH value of 4 and a density of 1.02 g cm^{-3}. It is available as a ready-made solution. It contains 0.5% w/w tebuconazole, 0.5% w/w propiconazole, 1% w/w 3-Iodo-2-propynyl-butyl carbamate and 0.5% w/w cypermethrin. Before the application of TA on the wood material, all kinds of drilling, cutting, turning and milling operations should be completed and the relative humidity should be in equilibrium with the test environment. TA should be applied by the brush, 1 L of impregnation material for 4-5 m^2 of wood. Before the application of TA on the wood material, all kinds of drilling, cutting, turning and milling operations should be completed and the relative humidity should be in equilibrium with the test environment. The impregnated wood should be left for drying at least 24 h. The wood material can be painted, varnished or glued after it is fully dried (Hickson, 2000).

Varnishes: Sayerlack waterborne internal space varnish (AZ 5730), external space varnish (AZ 2360 85) and Sayerlack single component polyurethane varnish (TU 1190) were used. Technical specifications of those varnishes are given in Table 1.

Preparation of test specimens: The rough drafts for the preparation of test and control specimens were cut from the sapwood parts of massive woods with a dimension of 100×100×150 mm they were conditioned at a temperature of 20±2°C and 65±5% relative humidity for three months until reaching 12% humidity distribution according to (TS 2471, 1976).

TA was applied to the test specimens with a brush according to the producers definition. Brushing was performed twice with a period of 3-4 h. Impregnated specimens and control specimens were sanded with

Table 1: Technical specifications of varnishes

Type of varnish	Solid material rate (%)	Density (kg L^{-1})	Viscosity (sn)	Amount applied (g m^{-2})
Waterborne (AZ 5730-AZ 2360 85)	40±1	1.030±0.030	15±3 sec (Ford 4, 20°)	100-300
Polyurathane (TU 1190)	35±1	0.965±0.030	16±1 sec (DIN4, 20°C)	80-120

abrasive paper No. 280. To remove the fiber swellings and dusts were cleaned before varnishing. After sanding, test specimens were varnished according to ASTM D 3023. Varnishes was applied with spray gun according to the producers definition (ASTM D 3023, 1998).

Impregnated test specimens were kept under a temperature of 20±2°C and 65±5% relative humidity until they reached to a stable weight. Afterwards, specimens were weighed in an analytic scale of 0.01 g sensitivity. Retention of impregnation material (R) was calculated by the formula:

$$R = \frac{G.C}{V}.10^3 \quad G: T_2 - T_1$$

Where:

T_1 = The specimen weight after the impregnation
T_2 = The specimen weight before the impregnation
V = The volume of the specimens
C = The concentration (%) of the impregnation solution

Method of testing: The densities of wood materials, used for the preparation of test specimens were determined according to TS 2472 (TS 2472, 1976). For determining the air-dry density, the test specimens with a dimension of 20×30×30 mm were kept under the conditions of 20±2°C and 65±5% relative humidity until reaching to a stable weight. The weights were measured with an analytic scale of ±0.01 g sensitivity. Afterwards, the dimensions were measured with a digital compass of ±0.01 mm sensitivity. The air-dry densities of the specimens were calculated by the formula; $\delta_{12} = M_{12}/V_{12}$ (M_{12} = Air-dry weight of specimen, V_{12} = Air-dry volume of specimen) Roughness determinations were performed for each layer of varnished surfaces with control specimens which have varnished surfaces.

Surface roughness was determined with Mitutoyo Sj-301 stylus scanner device (Fig. 1) (Mituyoto). Producer's definition is taken into care during measurement. Accordingly, determination time was 10 mm min^{-1}, radius of needle was 5 μm, angle of needle tip was 90°, load of scanning arm was kept less than 10 g to avoid the scratch of the surface. Determinations were performed under 20±2°C temperature and 65±5% relative humidity conditions in a vibration free and silent environment.

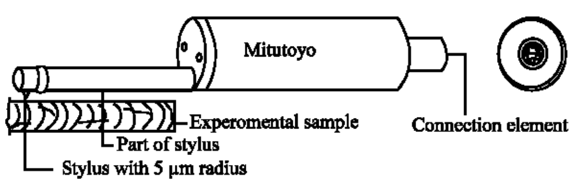

Fig. 1: The position of the stylus scanner device during the measurement

For analysis, measurements were performed in the vertical direction of fibers. When the tip of scanning needle arrived to cell cavities, measurements were repeated. Roughness values were determined with ±0.01 μm sensitivity where scanning length (lt) was 12 mm and sampling length was (λc) 2.5 mm. Surface roughness values were determined according to TS 971 and ISO 4288 standards (Fig. 1) (TS 971, 1988; ISO 4288,1996).

Evaluation of the data: By using 5 different types of wood and 3 types of varnish, a total of 30 specimens (2×5×3) were prepared with 3 specimens for each control specimen and surface with timbercare aqua. By using 5 different types of wood, 3 types of varnish and 5 types of surface processes a total of 750 measurements (5×3×5×10) were made with 10 measurements for each parameter. Multiple variance analysis was used to determine the differences between groups of specimens. Duncan Test was used to determine the significant difference between the groups.

RESULTS AND DISCUSSION

Oven-dry densities and retention amount of impregnation material of test specimens impregnated with timbercare aqua are given in Table 2.

Surface roughness mean values determined according to wood type, varnish type and number of varnish layers are given in Table 3. Accordingly, results of multiple variance analysis is given in Table 4.

Surface roughness mean value (Ra) for the combination wood type+varnish type+impregnation process is lowest (0.433 μm) in pine+polyurathane varnish+1st layer and highest (6.502 μm) in oak+interior space varnish+1st layer with TA. Ra is higher in surfaces processed with timbercare aqua. Accordingly, TA increases surface roughness before and after varnishing.

The differences between the groups have been found important for the effect of variance sources on the surface roughness (α = 0.05).

Duncan Test results are given in Table 5 to indicate the importance of differences between the groups. Histograms according to these are given in Fig. 2.

Surface roughness (Ra) has been found highest in oak, lowest in Uludağ fir and nearly equal for Scoth pine

Table 2: Oven-dry densities of wood materials

Type of wood	Oriental spruce	Scotch pine	Oak	Oriental beech	Uludag fir
Density (g cm^{-3})	0.524	0.531	0.784	0.583	0.461
Retention (kg m^{-3})	21.491	29.657	18.337	27.309	26.875

Table 3: Surface roughness mean values according to wood type, varnish type and surface process (µm)

		Varnish type														
		IS					ES					PP				
Wood type	Statistics	C	V1	V2	TA+V1	TA+V2	C	V1	V2	TA+V1	TA+V2	C	V1	V2	TA+V1	TA+V2
P	X	2.790	1.834	0.896	2.528	1.220	2.614	1.387	1.175	3.718	2.164	3.415	0.433	0.605	2.656	0.991
	V	0.108	0.088	0.123	0.160	6.003	0.115	0.082	0.202	0.949	0.428	0.112	0.017	0.184	0.801	0.213
	S	0.328	0.297	0.351	0.400	0.245	0.339	0.287	0.449	0.974	0.654	0.335	0.130	0.429	0.895	0.461
	Min	2.736	1.420	0.482	2.114	0.806	2.200	0.973	0.761	3.304	1.750	3.001	0.019	0.191	2.242	0.577
	Max	3.204	2.248	1.310	2.942	1.634	3.028	1.801	1.589	4.132	2.578	3.829	0.847	1.019	3.070	1.405
O	X	9.288	1.907	1.012	6.502	3.584	7.356	1.574	1.273	3.991	2.379	5.766	0.514	1.096	2.756	1.385
	V	1.248	0.085	0.056	2.952	1.447	1.024	0.182	0.135	0.968	0.618	2.123	0.020	0.085	1.378	0.949
	S	1.117	0.291	0.237	1.718	1.203	1.012	0.427	0.367	0.984	0.786	1.457	0.141	0.292	1.174	0.974
	Min	8.874	1.493	0.598	6.088	3.170	6.942	1.160	0.859	3.577	1.965	5.352	0.100	0.682	2.342	0.971
	Max	9.702	2.321	1.426	6.916	3.998	7.770	1.988	1.687	4.405	2.793	6.180	0.928	1.510	3.170	1.799
F	X	3.080	1.370	0.780	2.685	1.476	2.835	1.334	0.932	3.164	1.705	2.993	0.497	0.484	1.729	0.741
	V	0.593	0.208	0.085	0.317	0.312	0.058	0.152	0.073	0.920	0.238	0.049	0.018	0.071	0.462	0.048
	S	0.770	0.456	0.291	0.563	0.559	0.241	0.390	0.271	0.959	0.488	0.221	0.135	0.266	0.680	0.219
	Min	2.666	0.956	0.366	2.271	1.062	2.421	0.920	0.518	2.750	1.291	2.579	0.083	0.098	1.315	0.327
	Max	3.494	1.784	1.194	3.099	1.890	3.249	1.748	1.346	3.578	2.119	3.407	0.911	0.898	2.143	1.155
S	X	2.899	1.254	0.681	2.627	1.326	0.985	1.202	0.736	3.617	1.886	3.398	0.475	0.885	3.585	0.697
	V	0.056	0.181	0.026	0.601	0.261	0.106	0.118	0.037	1.279	0.575	0.104	0.005	0.078	4.393	0.118
	S	0.237	0.426	0.162	0.775	0.511	0.326	0.343	0.193	1.131	0.758	0.323	0.072	0.280	2.096	0.343
	Min	2.485	0.840	0.267	2.213	0.912	2.571	0.788	0.322	3.203	1.472	2.984	0.061	0.471	3.171	0.283
	Max	3.313	1.668	1.095	3.041	1.740	3.399	1.616	1.150	4.031	2.300	3.812	0.889	1.299	3.999	1.111
B	X	4.257	1.754	0.887	3.368	1.620	3.666	1.149	0.897	3.624	1.945	4.467	0.612	0.685	3.247	1.044
	V	0.325	0.194	0.061	0.781	0.686	0.121	0.086	0.065	0.916	0.637	0.238	0.028	0.049	1.177	0.119
	S	0.570	0.441	0.246	0.884	0.828	0.348	0.294	0.254	0.957	0.798	0.488	0.166	0.222	1.085	0.345
	Min	3.843	1.340	0.473	2.954	1.206	3.252	0.735	0.483	3.210	1.531	4.053	0.198	0.271	2.833	0.630
	Max	4.671	2.168	1.301	3.782	2.034	4.080	1.563	1.311	4.038	2.359	4.881	1.026	1.099	3.661	1.458

x: Mean; v: Variance; s: Standard deviation; Max: Maximum; Min: Minimum; (P) Pine; (O) Oak; (F) Fir; (S) Spruce; (B) Beech; (IS) Interior space; (ES) Exterior space; (PP) Polyurathane Parquet; (C) Control without varnish; (V1) Varnish 1st Layer; (V2) Varnish 2nd Layer; (TA+V1) Timbercare+Varnish 1st Layer; (TA+V2) Timbercare+Varnish 2nd Layer

Table 4: Results of multiple variance analysis according to wood type, varnish type and surface process

Source	df	Sum of squares	Mean square	F-value	p<0.05
Wood type (A)	4	264.801	66.200	148.783	0.000*
Varnish type (B)	2	63.584	31.792	71.452	0.000*
A×B	8	82.463	10.308	23.167	0.000*
Surface process type (C)	4	1223.737	305.934	687.579	0.000*
A×C	16	276.750	17.297	38.874	0.000*
B×C	8	32.924	4.116	9.250	0.000*
A×B×C	32	78.984	2.468	5.547	0.000*
Error	675	300.228	0.445	-	-
Total	750	6001.650	-	-	-

*: Significant with p<0.05

Table 5: Duncan test results

	Surface roughness mean value (Ra) µm	
Groups	X	HG
Wood type (LSD: ±0.323)		
P	1.895	AB
O	3.359	C
F	1.720	A
S	1.884	AB
B	2.215	B
Varnish type (LSD: ±0.2505)		
IS	2.465	B
ES	2.372	B
PP	1.806	A
Surface process type (LDS: ±0.5113)		
C	4.121	D
V1	1.153	AB
V2	0.868	A
TA+V1	3.320	C
TA+V2	1.611	B

X: Mean; HG: Homogeneity group

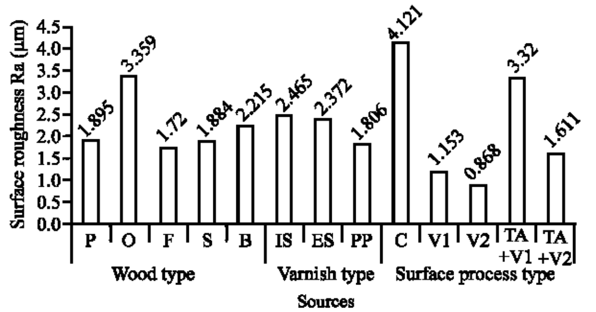

Fig. 2: Histogram of surface roughness values according to wood type, varnish type and surface process

and Oriental spruce. This case may be due to rough texture of oak wood. In this regard, difference between interior and exterior space varnishes has been found

Table 6: Duncan test double combination results

Wood type×varnish (LSD: ±0.2505)

Sources	X	HG
P		
IS	1.854	BCD
ES	2.212	EFG
PP	1.62	B
O		
IM	4.459	I
DM	3.315	H
PP	2.303	FG
F		
IM	1.878	BCD
DM	1.994	CDE
PP	1.289	A
S		
IM	1.757	BC
DM	2.085	DEF
PP	1.808	BCD
B		
IM	2.377	G
DM	2.256	EFG
PP	2.011	CDE

Wood type×surface (LSD: ±0.3234)

Sources	X	HG
P		
C	2.94	I
TA+V1	2.967	I
TA+V2	1.458	FG
V1	1.218	DEFG
V2	0.892	ABCD
C	7.47	L
O		
TA+V1	4.416	K
TA+V2	2.449	H
V1	1.332	EFG
V2	1.127	BCDEF
C	2.969	I
F		
TA+V1	2.526	H
TA+V2	1.307	EFG
V1	1.067	ABCDE
V2	0.732	A
C	3.094	IJ
S		
TA+V1	3.276	IJ
TA+V2	1.303	EFG
V1	0.977	ABCDE
V2	0.767	AB
C	4.13	K
B		
TA+V1	3.413	J
TA+V2	1.536	G
V1	1.172	CDEFG
V2	0.823	ABC

Varnish-Surface (LSD: ±0.2505)

Sources	X	HG
IS		
C	4.463	I
TA+V1	3.542	G
TA+V2	1.845	DE
V1	1.624	D
V2	0.851	B
EC		
C	3.891	H
TA+V1	3.623	G
TA+V2	2.016	E
V1	1.329	C
V2	1.003	B
PP		
C	4.008	H
TA+V1	2.795	F
TA+V2	0.972	B
V1	0.506	A
V2	0.751	AB

unimportant and parque varnish has been found important. In the regard of surface process, Ra is found highest in TA+V1 and lowest in V2. For this reason, it can be said that with the increase of number of varnish layers, surface roughness decreases.

Varnishing process has a decreasing effect on surface roughness. On the other side, TA application before varnishing has an increasing effect on surface roughness.

Double combinations of variance sources is given in Table 6. For combination of wood type+varnish type, most smooth surface was in Uludağ fir wood varnished with polyurathane varnish and highest roughness was in oak wood varnished with waterborne varnish.

For combination of wood type+surface process, the surface roughness was measured lowest in Uludağ fir wood with two layer varnish applied and highest in control specimens of oak wood. Except control specimens, the highest surface roughness was measured in oak and Oriental beech with TA+1 layer varnished.

For combination of varnish type+surface process, the surface roughness was measured lowest in one layer polyurathane varnish application and highest in interior and exterior varnishes with TA and one layer varnish application.

CONCLUSIONS

For surface roughness of wood material processed with TA, wood type, varnish type, surface process and combinations of these have been found important ($\alpha = 0.05$).

The most smooth surface was achieved in Uludağ fir with no process. The mean value of Ra, was lower than Scotch pine with 9.2% percentage, oak with 48.8% percentage, Oriental spruce with 8.7% and Oriental beech with 22.3% percentage. This case may be due to the anatomic structure of woods. Thus, for surface roughness of wood material, anatomic structure, growth characteristics, pre-applications (steaming, drying, impregnation, machine processes etc.) and spring, summer wood is affective (Aydın and Çolakoğlu, 2000).

Polyurathane varnish provided less rough surfaces than waterborne varnishes. According to control specimens, polyurathane varnish decreased roughness by 56.2%, waterborne varnishes decreased by 42.3%.

For the combination of wood type and varnish type, the roughness was highest in oak wood varnished with waterborne interior space varnish and lowest in Uludağ fir wood varnished with polyurathane varnish. Thus, varnishing has a positive effect on surface roughness and varnish type is important for this effect.

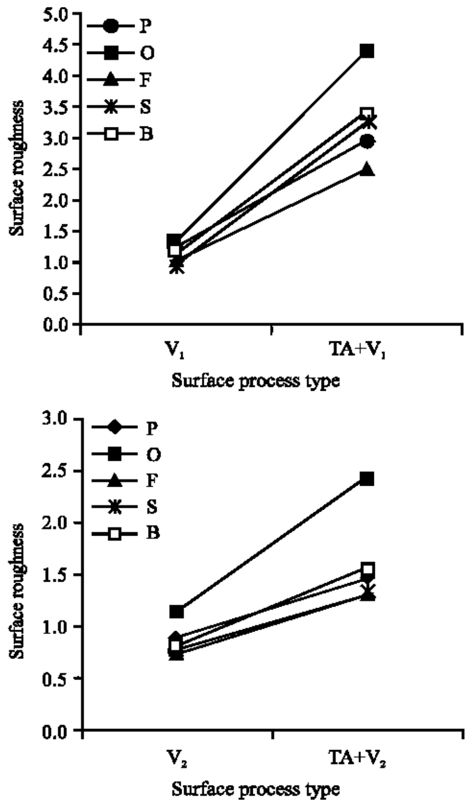

Fig. 3: Mean values of surface roughness with application V and TA and V according to wood type

For surface process, the highest roughness was in TA and one layer (V1) application and most smooth surface was in two layer (V2) application of TA. Surface roughness of varnished surfaces increased by 188% in the first layer and increased by 91.6% in the second layer of specimens with TA (Fig. 3).

Surface roughness values of the surfaces with TA and V1 applications were generally increased. This case may be due to the bloating up effect of TA on surfaces and difficulties during the sanding caused by tightening of fibers in bloated up surfaces. Bloated up and toughened fibers cause to rough surfaces even after sanding. Varnishes applied to these surfaces creates smooth surfaces after several applications.

For combination of wood type, varnish type and surface process, the most smooth surface was in Scotch pine varnished with polyurathane varnish and most rough surface was in oak with TA and one layer.

As a result, before the varnishing and because of the difficulties in sanding after the varnishing, That increased the surface roughness. Some more layer varnishing applications can be suggested for achieving smoother surfaces after the impregnation with TA. When the duration between varnishing layers and sanding applications are taken into account, this case may cause a longer process time and the use of more varnish.

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