Impact of Impregnation Chemical on Surface Glossiness of Synthetic, Acrylic, Polyurethane, and Water-Based Varnishes

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ABSTRACT: This study was performed to determine the effects of impregnation chemical on surface glossiness of some varnishes. For this purpose, the test samples prepared from Oriental beech, European oak, Scotch pine, Oriental spruce, and Uludag fir woods according to ASTM D 358 were impregnated with Imersol-Aqua according to ASTM D 1413 and producer's definition by short-term (S), medium-term (M), and long-term (L) of dipping methods and coated by synthetic (Sv), acrylic (Ac), water-based (Wb), and polyurethane (Pu) varnishes according to ASTM D 3023. After the varnishing process, the surface glossiness parallel to fibers was determined according to TS 4318. Consequently, among the nonimpregnated wood samples, surface glossiness parallel to fibers was found to be the highest in Oriental spruce and the lowest in European oak. As for the period of dipping, the highest surface glossiness was obtained in medium-term dipping and the lowest in long-term dipping. As for the varnish types, the surface glossiness was found to be the highest in polyurathane varnish and the lowest in water-based varnish. Considering the interaction of wood type, period of impregnation, and type of varnish, surface glossiness was the highest in Uludag fir, long-term dipping, and polyurathane varnish (103.9 gloss) and the lowest in Oriental beech, long-term dipping, and water-based varnish (67.78 gloss). In consequence, in the massive constructions and furniture elements the surface glossiness parallel to fibers after the impregnation with Imersol-Aqua is of great concern, long-term impregnation of Uludag fir materials could be recommended. © 2008 Wiley Periodicals, Inc. J Appl Polym Sci 108: 3361–3369, 2008

Key words: coating; surface glossiness; Imersol-Aqua; wood materials

INTRODUCTION

Preserving wood material from environmental effects and providing a long usage period is economically important. Preserving and beautifying covering materials like paint, polish, and varnish are used for this reason. Technical surface processes also increase technical, esthetic, and economic value of wood.[1]

Furnitures coated only with paint and varnish have surface protection only for 2 years.[2] So, after the impregnation with materials having appropriate water-repellent, biotic and abiotic effects, varnishing and painting applications are important for long-term utilization against photochemical degradation, dimensional changes, biological factors, and fire.[3]

In painting and varnishing applications with water-repellent materials, wood materials impregnated with boron are more resistant to environmental conditions.[4]

Some processes affect the wood structure and specifications such as hardness, color, brightness, and surface adhesion strength to some extent. The surface glossiness is one of the most important parameters for limiting the usage of varnishes. The surface glossiness is determinative in this sense.[5]

Impregnated and unimpregnated woods of oriental beech, scotch pine, chestnut, and oak were applied with different bleaching solutions. The bleaching solutions were ineffective for the surface glossiness. Varnish type and wood material type were the main effective factors, but Imersol-WR 2000 showed an increasing effect on the surface glossiness.[6]

For Scotch pine and chestnut varnished after impregnation with Tanalith-CBC, adhesion strength of varnishes was the lowest in polyurathane varnish used in Scotch pine.[7]

Mahogany and Douglas woods loose their surface glossiness in the early months, but after 6 months their surface glossiness increased again. Then, the surface glossiness decreases again.[8]

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Scotch pine, Oriental beech, and oak wood were bleached with NaOH + H_2O, NaOH + $Ca(OH)_2$ + H_2O_2, hypochlorite, and hydrochloric acid and then varnished with synthetic, polyurathane, acid hardening varnishes. Adhesion strength and surface glossiness values of these wood samples were determined. Chemicals were ineffective on the surface glossiness, and generally wood material type and varnish type were effective on the surface glossiness. Most glossy surfaces were obtained with acrylic varnish and least glossy surfaces were obtained with acid hardening varnish.[9]

Eucalyptus woods were bleached with caustic soda, hydrogen peroxide, and alkalies. The surface glossiness was increased in these woods. The pH values of those chemical materials were effective in this increment.[10]

After exposure of test samples of Scotch pine (*Pinus sylvestris* Lipsky) wood to outdoor conditions for 12 months and bleaching with 18% NaOH + H_2O_2, $NaSiO_3$ + H_2O_2, and $Ca(OH)_2$ + H_2O_2 solution groups, the surface glossiness values were determined. The surface glossiness values of Scotch pine were decreased by outdoor conditions but bleaching applications decreased these negative effects, providing results similar to values of natural samples.[11]

Synthetic, polyurethane, and acrylic varnishes were applied to Scotch pine, Oriental beech, and oak at different thickness values and effect of these applications on the surface glossiness were determined. The surface glossiness depends on wood material type and varnish type and increased by the layer thickness.[12]

The aim of this study was to determine the impact of impregnation of Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petrea* Liebl.), Scotch pine (*Pinus sylvestris* Lipsky), Oriental spruce (*Picea orientalis* Lipsky), and Uludag fir (*Abies Bornmülleriana* Mattf.) woods, used for production of massive and panel furniture, with Imersol-Aqua on the surface glossiness of some varnishes.

MATERIAL AND METHODS

Material

Wood materials

The woods of Oriental beech (*Fagus orientalis* Lipsky), European oak (*Quercus petrea* Liebl.), Scotch pine (*Pinus sylvestris* Lipsky), Oriental spruce (*Picea orientalis* Lipsky), and Uludag fir (*Abies Bornmülleriana* Mattf.) were chosen randomly from timber merchants of Ankara, Turkey. Special emphasis is given for the selection of the wood material. Accordingly, nondeficient, proper, knotless, normally grown (without zone line, without reaction wood and without decay, insect mushroom damages) woods were selected according to TS 1476.[13]

Varnishes

Synthetic (Sn), acrylic (Ac), water-based (Wb), and polyurethane (Pu) varnishes are supplied by merchants in Ankara and used according to the producer's technical specifications given in Table I.[14]

Impregnation chemical

Imersol-Aqua used as an impregnation chemical in this study was supplied from Hemel Hickson Timber Products, Istanbul. Imersol-Aqua is nonflammable, odorless, fluent, water-based, and completely soluble in water, noncorrosive material with a pH value of 7 and a density of 1.03 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 carbonate, and 0.5% w/w cypermethrin. Before the application of Imersol-Aqua 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. In the impregnation process, dipping duration should be at

TABLE I
Some Properties of the Varnishes

Type of varnish	pH	Density (g cm^{-3})	Viscosity (snDINCup/4 mm)	Amount applied (g m^{-2})	Nozzle gap (mm)	Air pressure (bar)
Pu (filler)	5.94	0.98	18	160	1.8	2
Pu (finishing)	4.01	0.99	18	160	1.8	2
Sn	–	0.94	18	120	–	–
Wb (primer)[a]	9.17	1.014	18	150	1.3	1
Wb (filler)[b]	9.30	1.015	18	80	1.3	1
Wb (finishing)[c]	8.71	1.031	18	80	1.3	1
Ac (filler)	4.30	0.95	18	120	1.8	2
Ac (finishing)	4.60	0.97	18	120	1.8	2

[a] ASTM D 17.
[b] ASTM D 65.
[c] ASTM D 45.

least 6 min and the impregnation pool must contain at least 15 L of impregnation material for 1 m^3 of wood. The impregnated wood should be left for drying at least 24 h in the 20°C ± 2°C temperature and 65% ± 3% relative humidity conditions. The wood material can be painted, varnished, or glued after it is fully dried.[15]

Methods

Determination of densities

The densities of wood materials used for the preparation of test samples were determined according to TS 2472.[16] For determining the air-dry density, the test samples with a dimension of 20 mm × 30 mm × 30 mm were kept under the conditions of 20°C ± 2°C temperature and 65% ± 5% relative humidity until they reach 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 (δ_{12}) of the samples were calculated by the formula,

$$\delta_{12} = \frac{M_{12}}{V_{12}} \mathrm{g\,cm^{-3}} \tag{1}$$

where, M_{12} is the air-dry weight (g) and V_{12} is the volume (cm^3) at air-dry conditions.

The samples were kept at a temperature of 103°C ± 2°C in the drying oven till they reach a stable weight for the assessment of oven-dry density. Afterwards, oven-dried samples were cooled in the desiccators containing P_2O_5 (phosphorus pentoxide) and weighed with an analytic scale of 0.01 g sensitivity. The volumes of the samples were determined by stereometric method and the oven-dry densities (δ_o) calculated by the formula,

$$\delta_o = \frac{M_o}{V_o} \mathrm{g\,cm^{-3}} \tag{2}$$

where, M_o is the oven-dry weight (g) and V_o is the oven-dry volume (cm^3) of the wood material.

Determination of humidity

The humidity of test samples before and after the impregnation process was determined according to TS 2471.[17] Thus, the samples with a dimension of 20 mm × 20 mm × 20 mm were weighed and then oven dried at 103°C ± 2°C temperature till they reach a constant weight. Then, the samples were cooled in desiccators containing P_2O_5 and weighed with an analytic scale of 0.01 g sensitivity. The humidity of the samples (h) was calculated by the formula;

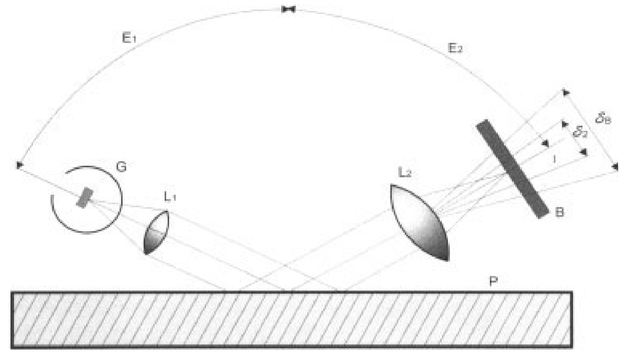

Figure 1 60° glossmeter. G = lamp; L_1, L_2 = lenses; B = receiver window; P = paint film; $E_1 = E_2 = 60° \pm 0.2°$; δ_B = receiver gap = 4.4° ± 0.1°; δ_2 = source image angle = 0.75° ± 0.24°; 1 = filament image.

$$h = \frac{M_r - M_o}{M_o} \times 100 \tag{3}$$

where, M_r is the initial weight of the samples (g) and M_o is the oven-dry weight of the samples (g).

Preparation of test samples

The rough drafts for the preparation of test and control samples were cut from the sapwood parts of massive woods with a dimension of 190 mm × 140 mm × 15 mm and conditioned at a temperature of 20°C ± 2°C and 65% ± 3% relative humidity till they reach 12% humidity distribution according to ASTM D 358.[18] The air-dry samples with a dimension of 150 mm × 100 mm × 10 mm were cut from the drafts for impregnation and varnishing.

The test samples were impregnated according to ASTM D 1413.[19] The samples were dipped in the impregnation pool immersing 1 cm below the upper surface for 10 min in short-term dipping, 2 h for medium-term dipping, and 5 days for long-term dipping. The specifications of the impregnation solution were determined before and after the process. The processes were carried out at a temperature of 20°C ± 2°C. Retention of impregnation material (R) was calculated by the formula;

$$R = \frac{GC}{V} 10^3 \mathrm{kg\,m^{-3}} \quad (G = T_2 - T_1) \tag{4}$$

where, G is the amount of impregnation solution absorbed by the specimen, T_2 is the specimen weight after the impregnation, T_1 is the specimen weight before the impregnation, C is the concentration (%) of the impregnation solution, and V is the volume of the samples. Impregnated test samples were kept under

TABLE II
Oven-Dry Densities of Wood Materials (g cm^{-3})

Methods	Statistical values	Oriental beech	European oak	Scotch pine	Oriental spruce	Uludag fir
Control (C)	x	0.657	0.652	0.537	0.405	0.380
	Min.	0.605	0.596	0.512	0.388	0.349
	Max.	0.679	0.572	0.572	0.435	0.406
	SD	0.019641	0.020627	0.01668	0.015460	0.019220
	v	0.000382	0.000278	0.00027	0.000239	0.000369
Short-term dipping (S)	x	0.658	0.655	0.543	0.408	0.382
	Min.	0.638	0.606	0.524	0.393	0.352
	Max.	0.685	0.698	0.566	0.425	0.426
	SD	0.013690	0.026607	0.01175	0.010539	0.022818
	v	0.000187	0.000708	0.00013	0.000111	0.000520
Medium-term dipping (M)	x	0.661	0.659	0.561	0.409	0.389
	Min.	0.642	0.625	0.525	0.398	0.355
	Max.	0.692	0.705	0.582	0.427	0.431
	SD	0.01439	0.022872	0.01739	0.009104	0.021468
	v	0.00020	0.000523	0.00030	0.000082	0.000460
Long-term dipping (L)	x	0.666	0.665	0.568	0.414	0.396
	Min.	0.644	0.631	0.542	0.401	0.365
	Max.	0.698	0.708	0.596	0.438	0.444
	SD	0.01512	0.020360	0.01476	0.011162	0.022375
	v	0.00022	0.000414	0.0002	0.000124	0.000500

x, mean; Min, minimum; Max, maximum; SD, standard deviation; v, variance.

20°C ± 2°C temperature and 65% ± 3% relative humidity condition until they reach a stable weight.

Varnishing

Test samples were varnished according to ASTM D 3023.[20] The surfaces of samples were sanded with abrasive papers to remove the fiber swellings and dusts are leaned before varnishing. Producer's definition is taken into care for the composition of solvent and hardener ratio and one or two finishing layers were applied after the filling layer. Spray nozzle distance and pressure are adjusted according to the producer's definition and moved in parallel to the specimen surface at a distance of 20 cm. Varnishing was done under 20°C ± 2°C temperature and 65% ± 3% humidity conditions. Synthetic varnish was applied with a hard and strong brush.

TABLE III
Air-Dry Densities of Wood Materials (g cm^{-3})

Methods	Statistical values	Oriental beech	European oak	Scotch pine	Oriental spruce	Uludag fir
C	x	0.679	0.672	0.577	0.420	0.401
	Min.	0.655	0.655	0.555	0.401	0.385
	Max.	0.705	0.699	0.592	0.441	0.412
	SD	0.01678101	0.01382290	0.0121909	0.01435143	0.00922841
	v	0.00028202	0.00014860	0.0001486	0.00020596	0.00008546
S	x	0.682	0.676	0.579	0.428	0.407
	Min.	0.662	0.658	0.558	0.407	0.392
	Max.	0.708	0.702	0.600	0.455	0.415
	SD	0.01669811	0.01422672	0.0002416	0.01238621	0.00700391
	v	0.00027920	0.00020241	0.0002416	0.00012340	0.00004905
M	x	0.689	0.678	0.592	0.437	0.410
	Min.	0.668	0.664	0.578	0.412	0.399
	Max.	0.716	0.704	0.605	0.460	0.422
	SD	0.01648220	0.01297760	0.0076324	0.01568961	0.00607379
	v	0.00027200	0.00016840	0.0000582	0.00024616	0.00003689
L	x	0.695	0.683	0.597	0.440	0.419
	Min.	0.669	0.667	0.579	0.422	0.408
	Max.	0.722	0.709	0.612	0.462	0.444
	SD	0.01485321	0.01312320	0.0098322	0.01436029	0.01106592
	v	0.00022120	0.00017221	0.0000966	0.00020621	0.00012245

x, mean; Min, minimum; Max, maximum; SD, standard deviation; v, variance; C, control; S, short-term dipping; M, medium-term dipping; L, long-term dipping.

TABLE IV
Retention Amounts of Wood Materials (kg m^{-3})

Methods	Statistical values	Oriental beech	European oak	Scotch pine	Oriental spruce	Uludag fir
S	x	79.228	22.861	40.585	32.785	38.745
	Min.	40.70	20.06	38.21	29.88	31.79
	Max.	158.25	25.06	51.64	36.10	43.90
	SD	48.246184	2.0463577	5.1824926	2.4615706	4.4595706
	v	1862.1554	3.350064	21.486584	4.847464	15.910216
M	x	149.298	31.575	77.891	51.285	57.593
	Min.	59.90	23.84	65.44	37.37	52.22
	Max.	270.09	42.01	88.95	59.93	71.13
	SD	101.18734	8.1801815	9.1136628	8.6209048	8.037884
	v	8191.1022	53.532296	66.44708	59.456	51.686064
L	x	388.143	204.822	176.471	156.915	177.996
	Min.	293.82	120.09	165.04	151.3	160.20
	Max.	532.65	265.39	197.15	159.49	206.45
	SD	89.297891	54.820866	13.613663	3.132566	17.98909
	v	6379.2907	2404.2619	148.26546	7.850376	258.88588

S, short-term dipping; M, medium-term dipping; L, long-term dipping.

Determination of surface glossiness

Determination of surface glossiness values were performed with glossmeter using light reflection property of varnished surfaces. Glossmeter consists of a lens photocell receiver and a source directing parallel or convergent light-bundle to test area (Fig. 1).

Determination of surface glossiness was made according to TS 4318.[21] Accordingly, for determination of surface glossiness values of paint and varnish layers 20° angle of reflection was used for matt layers, 60° for both matt and bright layers, and 85° for very bright layers. Samples were prepared at a temperature of 20°C ± 2°C and 50% ± 5% relative humidity and tested at 60° ± 2° glossiness level. Results were determined according to black calibration panel which has an accepted surface glossiness value of 100.

Statistical analyses

By using 5 different types of wood, 3 methods of impregnation + 1 control specimen, 4 types of varnish, 5 samples for each parameter a total of 400 samples (5 × 4 × 4 × 5) were prepared. Multiple variance analysis was used to determine the differences in surface glossiness values of samples. Duncan Test was used to determine the significant difference between the groups.

RESULTS AND DISCUSSION

Oven-dry density

Statistical values for oven-dry densities of test samples impregnated with Imersol-Aqua are given in Table II.

Oven-dry densities changed by the type of wood and impregnation periods and increased with the increase of impregnation period.

Air-dry density

Statistical values for the air-dry densities of wood materials impregnated with Imersol-Aqua are given in Table III.

Air-dry densities were found different depending on the type of wood and duration of impregnation. Air-dry densities of impregnated woods are increased by dipping duration.

TABLE V
Surface Glossiness Average Values According to Wood Material Type, Varnish Type, and Impregnation Material (Gloss)

Types of material	x	HG
Wood materials[a]		
Oriental beech (I)	90.60	C
European oak (II)	88.09	D
Scotch pine (III)	93.44	B
Oriental spruce (IV)	94.49	A
Uludağ fir (V)	93.62	B
Varnishes[b]		
Synthetic (Sn)	94.98	B
Acrylic (Ac)	95.46	B
Water-based (Wb)	77.72	C
Polyurethane (Pu)	100.028	A
Impregnation methods[c]		
Control (C)	91.77	BC
Short-term dipping (S)	92.39	AB
Medium-term dipping (M)	92.65	A
Long-term dipping (L)	91.38	C

x, mean; HG, degrees of homogeneity.
[a] LSD: 0.7157.
[b] LSD: 0.6402.
[c] LSD: 0.6402.

TABLE VI
Average Values According to Wood Material Type + Impregnation Period and Impregnation Period + Varnish Type

Types of material	x	HG
Wood materials + varnishes[a]		
I + Ac	93.5	FG
I + Sn	94.01	FG
I + Wb	75.68	K
I + Pu	99.14	CD
II + Ac	91.97	H
II + Sn	92.58	GH
II + Wb	70.44	L
II + Pu	97.37	E
III + Ac	97.79	DE
III + Sn	96.55	E
III + Wb	79.33	J
III + Pu	100.1	BC
IV + Ac	97.18	E
IV + Sn	97.42	E
IV + Wb	81.87	I
IV + Pu	101.5	AB
V + Ac	94.50	F
V + Sn	96.66	E
V + Wb	81.29	I
V + Pu	102.0	A
Wood materials + dipping periods[b]		
I	94.32	ABC
I + S	90.39	GH
I + M	89.91	GH
I + L	87.76	IJ
II	87.53	J
II + S	87.45	J
II + M	88.21	IJ
II + L	89.18	HI
III	93.08	CDE
III + S	93.88	ABCD
III + M	94.81	AB
III + L	92.00	EF
IV	92.71	DE
IV + S	95.43	A
IV + M	95.44	A
IV + L	94.38	ABC
V	91.18	FG
V + S	94.82	AB
V + M	94.89	AB
V + L	93.60	BCD

x, mean; HG, degrees of homogeneity; I, oriental beech; II, oak; III, scotch pine; IV, oriental spruce; V, Uludağ fir; Sn, synthetic; Ac, acrylic; Wb, water-based; Pu, polyurethane; C, control; S, short-term dipping; M, medium-term dipping; L, long-term dipping.
[a] LSD: 1.431.
[b] LSD: 1.431.

Retention quantities

Retention amounts of woods for different impregnation periods are given in Table IV.

Amounts of retention were found different depending on wood type and impregnation period. Retention is the highest in Oriental beech and the lowest in oak. As dipping period increases, amount of retention increased.

Surface glossiness

Surface glossiness average values according to wood material type, varnish type, and impregnation material are given in Table V.

Surface glossiness was the highest in beech and the lowest in oak. According to varnish type, surface glossiness was the highest in polyurathane varnish and the lowest in water-based varnish. According to impregnation period, surface glossiness was the highest in medium-term dipping and the lowest in long-term dipping. So, varnish type was the first, wood material type was the second, and impregnation process was the third degree effective on surface glossiness. This might be due to the texture of wood materials, layer properties of varnishes, and dipping period of impregnation process. As a matter of fact, different results were obtained depending on the impregnation periods. Average values according to wood type + impregnation period and impregnation period + varnish type are given in Table VI.

Surface glossiness values according to wood type + varnish type was the highest in fir + polyurathane varnish and the lowest in pine + water-based varnish. Surface glossiness values according to wood type + impregnation period was the highest in spruce + medium-term dipping and the lowest in oak + short-term dipping. Properties of varnish layer structure and surface properties of wood material were important for surface glossiness values.

Average values of surface glossiness according to varnish type + impregnation period are given in Table VII.

Surface glossiness values was found different according to impregnation period + varnish type. Impregnation process showed a decreasing effect in

TABLE VII
Average Values of Surface Glossiness According to Varnish Type + Impregnation Period

Types of material	x	HG
Dipping periods + varnishes		
Sn	94.70	DE
S + Sn	95.41	CDE
M + Sn	95.52	CD
L + Sn	94.33	DE
Ac	95.52	CD
S + Ac	94.06	E
M + Ac	95.64	CD
L + Ac	96.60	C
Wb	75.76	G
S + Wb	80.36	F
M + Wb	79.85	F
L + Wb	74.92	G
Pu	101.1	A
S + Pu	99.75	B
M + Pu	99.60	B
L + Pu	99.67	B

LSD: 0.08617.

TABLE VIII
Multiple Variance Analysis for Impact of Wood Material Type, Varnish Type, and Impregnation Material for Surface Glossiness

Source	Degrees of freedom	Sum of squares	Mean square	*F* Value	Probably % 5 (Sig)
Factor A	4	2,252.027	563.007	106.1936	0.0000
Factor B	3	28,914.316	9638.105	1817.9271	0.0000
AB	12	639.490	53.291	10.0516	0.0000
Factor C	3	100.907	33.636	6.3443	0.0000
AC	12	751.535	62.628	11.8128	0.0000
BC	9	623.848	69.316	13.0744	0.0000
ABC	36	1,551.854	43.107	8.1308	0.0000
Total	399	36,530.52			

Factor A, wood material type; Factor B, varnish type; Factor C, impregnation period.

TABLE IX
Duncan Test Results (Gloss)

Materials	x	HG	Materials	x	HG
V + L + Pu	103.9	A	I + L + Ac	95.68	KLMN0PQRSTU
III + Pu	102.6	AB	V + M + Ac	95.60	KLMN0PQRSTU
V + M + Pu	102.1	ABC	II + M + Pu	94.94	LMN0PQRSTUV
IV + Pu	102.0	ABCD	II + L + Ac	94.74	MN0PQRSTUV
IV + M + Pu	101.7	ABCDE	I + Ac	94.68	MN0PQRSTUV
I + Pu	101.7	ABCDE	IV + M + Sn	94.66	MN0PQRSTUV
V + Pu	101.4	ABCDE	I + Sv	94.60	N0PQRSTUV
IV + L + Pu	101.3	ABCDEF	I + M + Ac	93.90	0PQRSTUVW
IV + S + Pu	100.9	ABCDEFG	II + M + Ac	93.78	PQRSTUVW
V + S + Pu	100.8	ABCDEFG	II + Sn	93.12	QRSTUVWX
III + M + Pu	100.6	ABCDEFGH	V + Sn	92.96	QRSTUVWX
III + S + Pu	99.84	BCDEFGHI	V + L + Sn	92.78	RSTUVWX
I + S + Pu	99.70	BCDEFGHIJ	II + S + Sn	92.46	STUVWX
II + L + Pu	99.20	BCDEFGHIJK	I + S + Sn	92.34	TUVWX
III + L + Sn	99.00	CDEFGHIJK	I + S + Ac	92.02	UVWX
IV + S + Sn	98.72	CDEFGHIJK	II + M + Sn	92.00	VWX
I + M + Pu	98.62	CDEFGHIJK	II + Ac	91.60	VWX
III + M + Sn	98.58	CDEFGHIJK	I + L + Sn	91.02	VWX
IV + L + Sn	98.54	DEFGHIJKL	II + L + Sn	90.32	WX
IV + M + Ac	98.26	EFGHIJKLM	II + S + Ac	90.20	X
IV + L + Ac	98.22	EFGHIJKLMN	IV + M + Wb	87.10	X
V + Ac	97.84	FGHIJKLMN	V + S + Wb	86.52	Y
II + Pu	97.82	GHIJKLMN	I + Wb	86.36	YZ
III + S + Sn	97.56	GHIJKLMN	IV + S + Wb	86.00	YZ
II + S + Pu	97.52	GHIJKLMN	V + M + Wb	85.54	YZ
III + L + Pu	97.40	GHIJKLMN0	III + M + Wb	83.38	Za
V + L + Ac	97.20	HIJKLMN0P	III + S + Wb	82.20	ab
III + L + Ac	97.14	HIJKLMN0P	V + L + Wb	80.54	ab
IV + Ac	97.04	IJKLMN0P	IV + L + Wb	79.42	bc
IV + Sn	96.80	IJKLMN0P	I + S + Wb	77.48	cd
III + M + Ac	96.68	IKLMN0PQ	III + Wb	77.32	cd
I + L + Pu	96.56	IJKLMN0PQ	IV + Wb	74.96	d
III + Ac	96.46	IJKLMN0PQR	III + L + Wb	74.44	de
V + M + Sn	96.32	IJKLMN0PQRS	V + Wb	72.56	ef
IV + S + Ac	96.14	JKLMN0PQRS	II + L + Wb	72.44	fg
I + M + Sn	96.04	KLMN0PQRS	II + M + Wb	72.14	g
III + Sn	96.00	KLMN0PQRS	I + M + Wb	71.08	gh
V + S + Ac	96.00	KLMN0PQRS	II + S + Wb	69.62	hı
V + S + Sn	95.96	KLMN0PQRST	I + L + Wb	67.78	ı
III + S + Ac	95.92	KLMN0PQRST	II + Wb	67.58	ı

LSD: 0.1723.

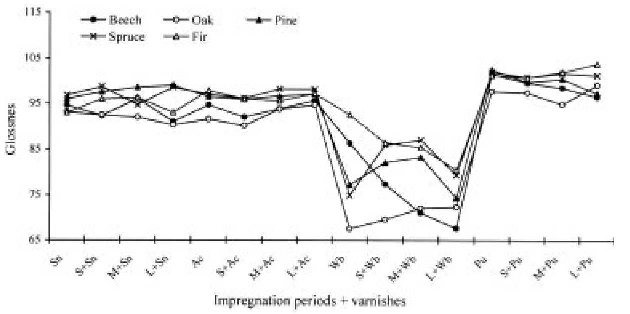

Figure 2 Change of glossiness according to wood type, impregnation periods, and varnishes.

polyurathane varnish but an increasing effect in other varnishes. Long-term dipping process showed negative effect according to synthetic, water-based, and polyurathane varnish. Results of multiple variance analysis for the impact of wood material type, varnish type, and impregnation material for surface glossiness is given in Table VIII.

The differences between the groups have been found important of surface glossiness parallel to fibers (α: 0.05). Duncan Test results are given in Table IX to indicate the importance of differences between the groups.

Surface glossiness value was the highest in Scotch pine + polyurathane varnish and the lowest in oak + water-based varnish for wood material without impregnation. For samples varnished after impregnation, surface glossiness was the highest in Uludag fir varnished with polyurathane after long-term dipping impregnation and the lowest in Uludag fir varnished with water-based varnish after long-term dipping impregnation. Change of glossiness according to wood species impregnation periods and varnishes are given in Figure 2.

CONCLUSIONS

Air-dry and oven-dry densities of impregnated samples were increased proportional to impregnation periods. This case might be due to the increase of penetrated impregnation material by the increase of impregnation period. Thus, retention quantities were found higher in long-term dipping than short-term dipping. In a similar study, retention quantity was increased with the increase of dipping period during impregnation of Scotch pine and Oriental beech with Imersol-WR.[22] Impregnation with long-term dipping methods provides advantages for applications requiring high retention quantity. On the other hand, retention was found low in oak, Oriental spruce, and Uludag fir. This case may be due to pit aspiration in Oriental spruce and Uludag fir and tyloses in Oak woods.

Surface glossiness value was the highest in Oriental spruce, polyurathane varnish, and medium-term dipping and the lowest in oak, water-based varnish, and long-term dipping. In oak, surface glossiness was found 3% lower than Oriental beech, 6% lower than Scotch pine, 7% lower than Oriental spruce, and 6% lower than Uludag fir. This case might be due to structural differences of wood types.

Surface glossiness value in impregnation treatment was 1% higher in short-term and medium-term dipping, 0.5% lower in long-term dipping according to control samples. Accordingly, impregnation materials have an increasing effect on surface glossiness values for short-term dipping.

Surface glossiness values of varnishes were found highest in polyurathane varnish and lowest in water-based varnish. Surface glossiness of water-based varnish was found 13% less than synthetic varnish, 19% less than acrylic varnish, and 23% less than polyurathane varnish. This case might be due to structural and layer properties of varnishes.

Surface glossiness value for wood material + impregnation period was the highest in IV + M (95.44) and the lowest in II + S (87.45). Impregnation materials affect surface glossiness values of Oriental beech, oak, Oriental spruce, and Uludag fir at a rate of 4% negatively, 0.3, 1, 3, 4% positively in short-term dipping, 5% negatively, 1, 2, 3, 4% positively in medium-term dipping and 7% positively, 2% negatively, 2, 3% positively in long-term dipping orderly.

Surface glossiness value for impregnation period - varnish type was the highest in S + Pu (99.75) and the lowest in L + Wb de (74.92). Impregnation materials affect surface glossiness values of synthetic, acrylic, water-based, and polyurathane at a rate of 1% positively, 2% negatively, 6% positively, 2% negatively in short-term dipping, 1, 0.2, 5% positively, 2% negatively, in medium-term dipping and 0.4% negatively, 2, 5% positively, 2% negatively in long-term dipping orderly.

Considering the interaction of wood type, period of impregnation, and type of varnish, surface glossiness was the highest in Uludag fir, long-term dipping, and polyurathane varnish (103.9 gloss) and the lowest in Oriental beech, long-term dipping, and water-based varnish (67.78 gloss). Consequently, in the massive constructions and furniture elements the surface glossiness parallel to fibers after the impregnation with Imersol-Aqua is of great concern, long-term impregnation of Uludag fir materials could be recommended.

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