Gloss and Oscillatory Hardness Test Effects of Varnishes with Different Ratios of Marble Powder Additives on Wood Materials

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Increasing global problems and stricter regulation of industrial waste management necessitate a more detailed examination of waste materials. In addition, because of problems such as surface cracking and discoloration of surface-treated materials during use, increasing varnish durability is a popular topic today. In this study, to increase the surface treatment performance, different proportions (2.5%, 5%) of waste marble powder were added into varnishes (water-based and polyurethane varnish) and their effect on surface treatment was evaluated in terms of gloss and oscillatory hardness test. The highest gloss and oscillatory hardness was found in specimens where the marble powder was at a 2.5% level. As the proportion of marble powder in the mixture increased, it had a matting effect. Oscillatory hardness was found to be higher in polyurethane varnish in the radial section. Among the wood species, beech wood exhibited the highest hardness value with polyurethane varnish.

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INTRODUCTION

Researching new advances to enhance the development and popularization of wood materials is one of the most important areas of progress in wood material science. The durability of wood depends on the conditions of use. Unsuitable climate and humidity conditions lead to the loss of the desired physical and mechanical properties of wood, often even permanent deterioration. Various problems encountered in the use of surface-treated wood materials, which are becoming widespread each day, limit the service life of these materials. Although the usage areas of these materials are increasing in the world, various difficulties are encountered. Additives are used in the production recipes to solve these problems encountered in surface-treated wood materials. However, despite these additions, the adhesion on the surface weakens over time, and problems, such as varnish breaks, cracks, or color changes in the materials, continue. Re-varnishing such materials is difficult and costly. Therefore, it is important to determine the mechanism to increase the bond strength between the varnish and the wood material in the first application, or the additive material to be mixed with the varnish, and the interaction of the additive material and varnish. To overcome these limitations, it was aimed to add marble powder to the varnish to improve the performance of the surface and to reuse the waste material.

Recycling is of great importance in terms of protecting the environment, using resources efficiently, and ensuring a sustainable future. Recycling marble dust has many economic advantages, such as waste reduction, conservation of natural resources, energy saving, economic advantages, production of innovative and sustainable products, reduction of environmental pollution, social responsibility, and environmental awareness, *etc*. It provides both significant benefits in terms of sustainability and economic efficiency. This process, which contributes to natural conservation, environmental protection, and energy saving, plays a critical role especially for the dissemination of environmentally friendly products and markets. Marble powder has a wide range of uses. It is used in construction and building materials (cement and mortar, concrete products, ceramic and tile production); paint and coating industry (filler); glass and ceramic industry (glass production, ceramics and porcelain); paper industry, plastics industry, chemical and cosmetic industry (cosmetics, cleaning products); and the sculpture and art industries. There are many studies on the use of marble powder as a filler in the wood industry, usually in board making or in the paper industry (El-Sherbiny *et al*. 2015; Erdogan and Eken 2017; Lu *et al*. 2018; Balçık *et al*. 2024).

Marble is defined as limestone that has been altered under high temperature and pressure. The scientific definition of marble is a stone formed by the recrystallization of limestone ($CaCO_3$) and dolomitic limestone ($CaMg(CO_3)_2$) under heat and pressure by undergoing metamorphosis. In industrial terms, all natural stones that can be processed, polished, shined, sized, and used for decorative purposes are called marble. Calcium carbonate ($CaCO_3$) in the structure of marble powder is a filling material. The properties that calcium carbonate can add to paints and varnishes can be listed as gloss, opacity, and mechanical properties (Karakaş and Çelik 2012).

Gloss is a property that expresses how much the surface reflects light in the manner of a mirror. It depends on the type of wood, the roughness of the surface, the type of varnish used, the number of layers, and the quality of application (Sönmez *et al*. 2004; Ged *et al*. 2010; Vardi *et al*. 2010; Çakıcıer *et al*. 2011; Salca *et al*. 2016; Slabejová *et al*. 2016). Studies to determine the gloss level of coatings on wood surfaces have been conducted depending on factors such as application methods, type of varnish used, substrate properties, and aging. Among the studies, it was determined that the gloss level of coatings applied to black alder (*Alnus glutinosa* L.) wood was affected by the type of varnish used. Higher gloss values were obtained in samples coated with UV varnish compared to water-based products (Salca *et al*. 2021). There are also differences in gloss in measurements taken perpendicular to the application method or parallel to the fibers (Salca *et al*. 2016; Salca *et al*. 2021).

An oscillatory hardness test is performed to evaluate the surface performance and durability of the material. Varnish is applied to protect the wood surface against mechanical abrasion, scratches, and impacts. It helps to understand how well the varnish surface resists such mechanical stresses. Wood products are usually designed to be used for a long time. Oscillatory hardness is measured to determine how resistant the varnish is to abrasion and deformation (Gurleyen 2021; Kılıç and Söğütlü 2022).

Marble powder is used in various fields such as paper, construction, paint, glass, ceramics, and chemistry (Erdem and Öztürk 2012; El-Sherbiny *et al.* 2015; Erdogan and Eken 2017; Aykaç and Sofuoğlu 2020). In this study, marble powder was mixed with varnishes (water-based and polyurethane varnishes) at different ratios (2.5% and 5%) and applied by spraying method on different wood species (chestnut, beech, yellow pine, spruce). Its effects on wood surface treatments were examined in terms of gloss and oscillatory hardness. The use of marble dust at 2.5% and 5% ratios was preferred to ensure a homogeneous mixture with the varnish and to ensure that the spraying process can be used smoothly, as stated in the literature. Top with the addition of additives quality increase and improvement in the properties of the material used in surface treatments is expected. The novelty of this study is that gloss and hardness tests are investigated in many aspects (wood type, cross-sectional shape, fiber direction, additive ratio, varnish type).

EXPERIMENTAL

Materials

The wood materials used in the study were preferred according to their durability classes. Wood species have different durability levels, and their durability was determined according to their resistance to rot, insect, and fungal attacks, especially in wood materials. Among these species, Anatolian chestnut (*Castanea sativa* Miller), Eastern beech (*Fagus orientalis* Lipsky), Yellow pine (*Pinus sylvestris* L.), and Eastern spruce (*Picea orientalis* L. (Link.)) can be listed in terms of durability. Eastern beech (*Fagus orientalis* Lipsky) has dense, hard, and heavy wood that produces smooth surfaces when machined. Anatolian chestnut (*Castanea sativa* Miller) has hard, medium weight, is difficult to dry, and has low bending resistance. Yellow pine (*Pinus sylvestris* L.); wood has moderately soft and medium weight. It has a moderately high bending resistance. Eastern Spruce (*Picea orientalis* L. (Link.)); has soft, medium weight and splits easily. It has low working capacity. It has difficult impregnation and is less durable (Berkel 1970). The specimens were kept at 20 ± 2 °C and 65 ± 5% relative humidity for 4 weeks to stabilize the moisture levels between approximately 6% to 8%. Firstly, their thicknesses were adjusted with a sidelining machine, and then their widths and thicknesses were brought to the specified dimensions in four processing machines. As a result of these processes, 2-m- to 2.5-m-long materials were obtained. Then, the materials were cut on a circular saw machine and smoothed with sandpaper 80 and 120 grit, and then 180 grit sandpaper on a calibrated sanding machine in accordance with industrial applications. After the surface finishing processes were completed, the materials were kept at 20 ± 2 °C temperature and 65 ± 5% relative humidity until reaching the equilibrium moisture content (6% to 8%) according to TS 642 ISO 554 (1997) standard and then varnished by adding marble powder (2.5%, 5%) in two different varnish types, polyurethane and water-based, in accordance with industrial applications. Polyurethane varnishes are generally preferred for wood materials due to their durability, aesthetic appearance, water and moisture resistance, chemical resistance, easy application and suitability for outdoor use. Water-based varnishes dry faster than solvent-based ones, which speeds up the application process and saves time. They are easy to clean and apply, moisture and abrasion resistance, ideal for indoor use. Water-based varnish has a density of 1.15 (g/cm^3), whereas polyurethane varnish is 1.2 (g/cm^3).

The properties of marble powder are 99.9% purity, 20 µm size, density 2.7 g/cm^3. Marble powder was added to the thinner part of the varnishes and mixed using an ultrasonic mixer, then added to the varnish and mixed again with an ultrasonic mixer after manual mixing. The varnishing of the sample parts was carried out in accordance with industrial standards, with 2 coats of base varnish and one coat of final varnish per unit area of 120 ± 5 g/m^2. Varnishes were applied to the surface of the material with a pneumatic top tank spray gun. After both filler varnishing applications, the sample parts were dried and sanded with a vibrating hand sander using aluminum oxide paper sanding belts. The prepared varnish additive mixtures were applied using an overhead tank spray gun. For each sample, 120 m^2 of varnish was sprayed. The samples were first sanded with sandpaper number 180 grit. Wood residues remaining on the samples were removed with compressed air. Then, the first coat of filler varnish was applied and left to dry. After sanding with 220 grit sandpaper, the residues were removed again with compressed air and the second layer of filler varnish was applied. It was then left to dry again. For the topcoat varnish, it was sanded with sandpaper number 320 grit and the third coat of topcoat varnish was applied.

Solid Matter Amount

The amount of solids allows determination of the layering properties of the varnish to make layers in equal proportions. According to ASTM D1644-01 (2006), the varnishes were dropped with a dropper of 2 ± 0.2 g on a tared Ø 75 ± 5 mm concave watch glass, and then kept in an oven at 60 °C until the weight became constant. At the end of this process, after complete evaporation of the solvents added into the varnish, the weighings were repeated on a digital balance with a precision of 0.001 g. The amount of solid was calculated using Eq. 1,

$$K_m = [(V_u - Ç_b) / V_u] \times 100 \qquad (1)$$

where V_u is applied varnish (g), $Ç_b$ denotes evaporated solvent (g), K_m is solid matter (%), $V_u = G - D$, $Ç_b = G - E$, G is wet weight (g), D is tare (g), and E denotes dry weight (g).

Dry Film Thickness

The dry film layer on the surface of the material was determined in accordance with ASTM D6132 (2008). For this purpose, a dry film thickness measuring instrument Erichsen P.I.G. 455 PosiTector 200 dry film layer thickness meter was used, and the dry film thickness was determined with a sensitivity of ± 5 µm.

Oscillatory Hardness Test

The oscillatory hardness device Ericksen GmbH / co.KG Germany model 299/300 was used on samples conditioned according to the Köning method for 16 h at 23 ± 2 °C and 50 ± 5% relative humidity. After the samples were placed in the device, the layer hardness on the sample surface was determined by pendulum oscillations performed with two balls with a hardness of 63 ± 3.3 HRC and a diameter of 5 ± 0.0005 mm. The higher the number read on the screen of the device, the harder the surface, while the lower the number read on the screen, the lower the hardness (Sönmez 1989). The oscillatory hardness was made in accordance with the principles specified in ANS/ISO 1522 (1988). For oscillatory hardness, a total of 384 measurements were made with 4 wood species*2 varnish types*2 additive ratio+1 control group (3), 2 cross-sectional shapes* 8 measurements. The sample dimensions used were 8.2*32*1.5 cm.

Gloss

A gloss meter (PCE-GM 100) was used. After varnish application, the test specimens were conditioned for 16 h at 23 ± 2 °C and 50 ± 5% relative humidity in accordance with ISO 2813 (2014) standards and made ready for measurements. The tests were performed using a gloss-meter, the unit of measurement is expressed as gloss units (GU), perpendicular and parallel to the fibers. The tester is constructed using a lens that directs a parallel or converging beam of light from the light source to the test area and a photocell receiving window that receives the light from this lens. When determining the gloss of paint and varnish layers, 20° was used to determine the surface gloss of matt layers, 60° for both matt and glossy layers, and 85° for high gloss layers. In this study, the analysis was based on 60° measurements. The reasons for this can be listed as suitability for medium gloss level, compliance with industrial standards, versatility, practicality, and proximity to human perception. For the gloss test, a total of 480 measurements were made with 4 wood species*2 varnish types*2 additive ratio+1 control group (3), 2 cross-sectional shapes* 2 fiber directions *5 measurements. The sample dimensions used were 8.2*32*1.5 cm. Abbreviations used in tables and graphs are given in Table 1.

Table 1. Abbreviations Used

Expansions	Abbreviations
Control	C
Marble powder 1(2.5%)	MP1
Marble powder 2 (5%)	MP2
Radial section	RS
Tangent cross section	TCS
Parallel to the fibers	//
Perpendicular to the fibers	⊥

Data Analysis

Analyses were performed using the IBM SPSS (2022, New York, ABD) program. Statistical methods were used to calculate the arithmetic mean (X), standard deviation (S), and percentage coefficient of variation (V). Analysis of variance were used to determine whether there is a difference in the comparison of varnish + additives properties. In cases where there was a difference, homogeneity groups were determined by Duncan-test. In the analysis of variance, the values of the F-measure and F-table were determined, and if the F-measure values were greater than 5% (N.S.), between 5% and 1% (*), between 1% and 0. 1% (**), and less than 0.1% (***) will be explained with signs. Samples that did not fit the normal distribution were evaluated by t-test.

RESULTS

Solid Matter Amount

The solids content of the additive varnishes used in the study are given in Table 2.

Table 2. Solids Content of Varnishes with Additives Used (%)

	Additives	Control	Marble Powder 1 (2.5%)	Marble Powder 2 (5%)
Varnish types	Water based varnısh	43	47.1	48.2
	Polyurethane varnish	4.9	49.8	50.9

Dry Film Thickness

The arithmetic mean values of the dry film layer thicknesses of the varnish types used in the experiments were 100 (µm).

Oscillatory Hardness

The arithmetic mean and standard deviation values of oscillatory hardness are given in Table 3.

Table 3. Arithmetic Mean and Standard Deviation Values of Oscillatory Hardness

	Water-based Varnısh					
Additive	C		MP1		MP2	
Sectıon shape	RS	TCS	RS	TCS	RS	TCS
Beech	36.62 (1.84)*	35 (2.5)	46.12 (2.23)	44.87 (1.72)	34.12 (3.13)	33.62 (1.99)
Chest-nut	29 (2.97)	39.62 (0.91)	38.25 (3.65)	41 (4.59)	30.37 (2.44)	31.12 (2.41)
Yellow Pine	25.62 (3.2)	28 (2)	35.25 (3.37)	41.5 (2.2)	24.25 (2.05)	29.62 (2.66)
Spruce	25 (1.85)	30.62 (1.92)	39.37 (4.06)	39.87 (1.8)	26.87 (3.13)	30.5 (2.72)
	Polyurethane Varnish					
Beech	105.37 (4.59)	107.25 (5.36)	129.62 (6.73)	128.87 (4.91)	99.62 (3.5)	111.37 (7.68)
Chest-nut	89.37 (7.17)	107.62 (4.17)	100.87 (7.58)	116.62 (7.81)	89.37 (6.65)	119.87 (9.34)
Yellow Pine	93.12 (3.35)	111.75 (2.76)	109.5 (8.22)	119.12 (4.29)	94.12 (8.3)	100.62 (12.7)
Spruce	86 (5.31)	109.87 (3.44)	103.5 (7.42)	111.25 (7.53)	92.75 (1.83)	97.87 (3.6)

*: Standard deviation

According to the results of the statistical analysis. The effect of wood species, cross-sectional shape, and additives on oscillatory hardness was found to be significant with a probability of error of 0.1%. Statistical analysis of oscillatory hardness is given in Table 4.

Table 4. Statistical Analysis of Oscillatory Hardness

Water-based Varnish						
Source	T III Sos	df	MS	F	Sig.	PES
CM	7278.563[a]	23	316.459	43.766	0.000	0.857
I	219916.688	1	219916.688	30414.491	0.000	0.995
TS	1405.521	3	468.507	64.795	0.000	0.536
A	4632.875	2	2316.437	320.363	0.000	0.792
CSS	494.083	1	494.083	68.332	0.000	0.289
A * TS	251.792	6	41.965	5.804	0.000	0.172
CSS * TS	160.542	3	53.514	7.401	0.000	0.117
A * CSS	100.542	2	50.271	6.952	0.001	0.076
A * CSS * TS	233.208	6	38.868	5.375	0.000	0.161
Polyurethane Varnish						
CM	26244.328[a]	23	1141.058	27.015	0.000	0.787
I	2142708.797	1	2142708.797	50730.189	0.000	0.997

TS	4702.141	3	1567.380	37.109	0.000	0.399
A	8280.875	2	4140.438	98.028	0.000	0.539
CSS	7387.922	1	7387.922	174.914	0.000	0.510
A * TS	2094.750	6	349.125	8.266	0.000	0.228
CSS * TS	1790.932	3	596.977	14.134	0.000	0.202
A * CSS	484.625	2	242.313	5.737	0.004	0.064
A * CSS * TS	1503.083	6	250.514	5.931	0.000	0.175

Type III Sum of Squares: T III Sos; Mean Square: MS; Partial Eta Squared: PES; Corrected Model: CM; Intercept: I; Tree species: TS; Additives: A; Cross-Sectional Shape: CSS

The arithmetic mean and standard deviation values of gloss are given in Table 5.

Table 5. Arithmetic Mean and Standard Deviation Values of Gloss

Water-based Varnısh						
Additives	C		MP1		MP2	
Sectıon shape	RS	TCS	RS	TCS	RS	TCS
Beech (//)	63.04 (4.57)*	64.6 (7.29)	63.6 (2.02)	59.72 (4.28)	60.98 (4.9)	53.12 (7.19)
Beech (┴)	58.24 (5.91)	58.6 (8.1)	58.98 (7.75)	55.22 (5.12)	56.86 (4.87)	49.46 (3.32)
Chestnut (//)	60.42 (7.05)	61.44 (3.2)	48.16 (4.25)	60.02 (5.58)	48.62 (2.85)	46.62 (2.33)
Chestnut (┴)	51.14 (10.62)	55.84 (10.07)	38.88 (5.9)	57.9 (3.72)	40.22 (4.32)	38.22 (3.35)
Yellow pine (//)	69.28 (7.84)	76.56 (3.52)	63.1 (6.52)	64.06 (2.17)	47.02 (4.27)	53.34 (4.53)
Yellow pine (┴)	66.2 (5.07)	70.16 (6.05)	45.86 (10.03)	59.5 (2.8)	47.4 (1.81)	46.28 (5.69)
Spruce (//)	76.82 (3.72)	75.6 (2.09)	66.96 (6.55)	66.52 (9.25)	55.68 (3.13)	58.36 (5.89)
Spruce (┴)	72.1 (7.02)	71.94 (3.03)	66.66 (3.92)	69.32 (2.77)	36.88 (3.04)	46.62 (6.46)
Polyurethane Varnish						
Beech (//)	68.54 (3.48)	65.86 (1.31)	79.48 (2.84)	85.5 (3.18)	73.66 (1.39)	79.6 (2.54)
Beech (┴)	70.14 (0.53)	63.46 (5.03)	77.46 (6.81)	78.06 (5.95)	90.56 (1.52)	87.74 (2.15)
Chestnut (//)	68 (5.04)	67.42 (1.84)	66 (5.76)	80.88 (6.08)	79.92 (5.67)	90.62 (5.06)
Chestnut (┴)	58.28 (1.1)	63.62 (1.32)	57.38 (9.84)	81.48 (9.63)	71.82 (8.34)	88.82 (5.41)
Yellow pine (//)	68.36 (5.03)	69.38 (1.72)	84.32 (1.24)	89.6 (1.55)	87.18 (8.35)	79.92 (2.41)
Yellow pine (┴)	63.74 (9.98)	65.44 (1.5)	78.66 (3.3)	85.96 (2.17)	86.78 (6.75)	87.32 (0.28)
Spruce (//)	68.46 (3.19)	65.2 (0.44)	83.46 (4.1)	80.86 (2.71)	90.84 (3.38)	88.22 (0.48)
Spruce (┴)	66.64 (0.62)	64.08 (3.31)	85.76 (5.82)	82.02 (5.8)	86.7 (9.65)	84.72 (1.24)

According to the statistical analysis, the effect of wood type, cross-sectional shape, and additives on gloss were significant with a probability of error of 0.1% (Table 6).

Table 6. Statistical Analysis of Gloss

Water-based Varnish						
Source	T III Sos	df	MS	F	Sig.	PES
CM	24826.760[a]	47	528.229	16.887	0.000	0.805
I	806269.968	1	806269.968	25776.186	0.000	0.993
TS	5245.747	3	1748.582	55.902	0.000	0.466
A	11217.430	2	5608.715	179.309	0.000	0.651
CSS	325.734	1	325.734	10.414	0.001	0.051
FD	2194.940	1	2194.940	70.172	0.000	0.268
A * TS	2498.697	6	416.449	13.314	0.000	0.294
CSS* TS	775.195	3	258.398	8.261	0.000	0.114
TS * FD	51.124	3	17.041	0.545	0.652	0.008
A * CSS	272.311	2	136.155	4.353	0.014	0.043
A * FD	86.499	2	43.249	1.383	0.253	0.014
CSS * FD	56.843	1	56.843	1.817	0.179	0.009
A * CSS * TS	907.814	6	151.302	4.837	0.000	0.131
A * TS * FD	808.507	6	134.751	4.308	0.000	0.119
CSS * TS * FD	46.268	3	15.423	0.493	0.688	0.008
A * CSS * FD	109.351	2	54.675	1.748	0.177	0.018
A * CSS * TS * FD	230.301	6	38.384	1.227	0.294	0.037
Polyurethane Varnish						
CM	23708.303[a]	47	504.432	17.646	0.000	0.812
I	1429018.635	1	1429018.635	49988.700	0.000	0.996
TS	1532.292	3	510.764	17.867	0.000	0.218
A	16217.267	2	8108.634	283.649	0.000	0.747
CSS	231.870	1	231.870	8.111	0.005	0.041
FD	272.001	1	272.001	9.515	0.002	0.047
A * TS	915.214	6	152.536	5.336	0.000	0.143
CSS* TS	2131.204	3	710.401	24.851	0.000	0.280
TS * FD	217.807	3	72.602	2.540	0.058	0.038
A * CSS	629.354	2	314.677	11.008	0.000	0.103
A * FD	107.479	2	53.740	1.880	0.155	0.019
CSS * FD	93.126	1	93.126	3.258	0.073	0.017
A * CSS * TS	637.088	6	106.181	3.714	0.002	0.104
A * TS * FD	410.665	6	68.444	2.394	0.030	0.070
CSS * TS * FD	141.375	3	47.125	1.648	0.180	0.025
A * CSS * FD	67.274	2	33.637	1.177	0.311	0.012
A * CSS * TS * FD	104.286	6	17.381	0.608	0.724	0.019

Type III Sum of Squares: T III Sos; Mean Square: MS; Partial Eta Squared: PES; Corrected Model: CM; Intercept: I; Tree species: TS; Additives: A; Cross-Sectional Shape: CSS; Fiber Direction: FD

DISCUSSION

Oscillatory Hardness

Figure 1 shows the oscillatory hardness graph. It compares the oscillatory hardness values of water-based and polyurethane varnishes applied to different wood species (beech, chestnut, yellow pine, and spruce) and fiber directions. The results of the samples with 2.5% and 5% marble dust added to the varnishes and the control groups are presented side by side.

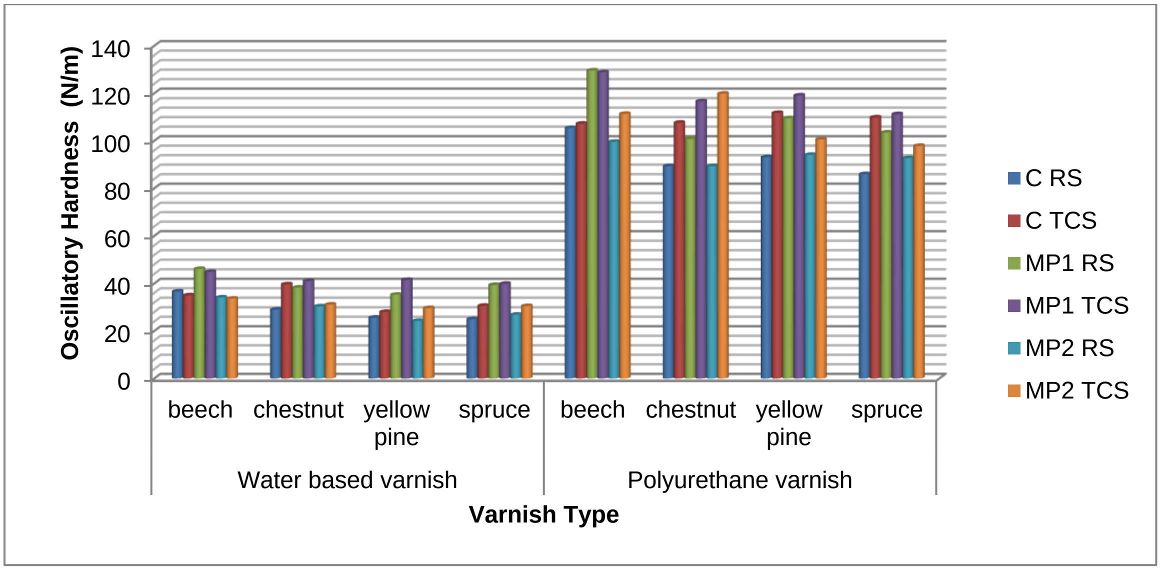

Fig. 1. Oscillatory hardness of water-based and polyurethane varnishes applied to different wood species and fiber directions

Among the varnish types, polyurethane varnish has a higher hardness value than water-based varnish. This shows that polyurethane varnish is superior in terms of structural durability. Among the studies conducted, water-based varnish forms a very thin film on the surface, since the amount of solids in the water-based varnish is very low. Since its molecule size is small, it has the effect of reducing hardness (Sönmez *et al.* 2004; Budakçı and Sönmez 2010). The effect of marble powder was observed in both water-based and polyurethane varnishes, and the addition of marble powder at the rates of 2.5% and 5% affected the hardness. 2.5% marble powder has a high hardness value in wood species. This may indicate that a high proportion of marble powder reduces the flexibility of the varnish and therefore reduces the hardness. Hardness value varies according to the area of use. It is desirable to increase the hardness to increase resistance to mechanical effects.

The effect of cross-sectional shape shows significant differences between radial and tangential cross-sections in the same wood species. Especially in polyurethane varnish, it was observed that the hardness was higher in radial cross-section applications. Beech shows the highest hardness value with polyurethane varnish, while wood species such as yellow pine and spruce generally have lower hardness values. These differences may be due to the different internal structure of each wood and its interaction with the varnish.

Gloss

Figure 2 shows the gloss results. It compares the gloss values of water-based and polyurethane varnishes applied to different wood species (beech, chestnut, yellow pine, and spruce) and fiber directions. The gloss values of varnishes with 2.5% and 5% marble dust added to the varnishes and the control group are also shown.

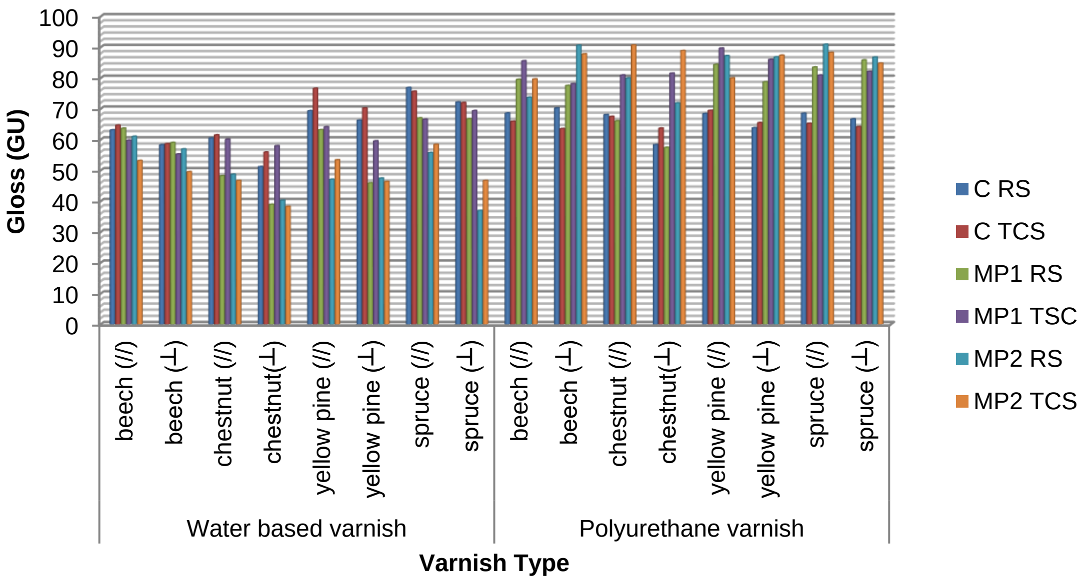

Fig. 2. Gloss values of water-based and polyurethane varnishes applied to different wood species and fiber directions

Differences between varnish types indicate that polyurethane varnishes gave higher brightness values compared to water-based varnishes, indicating that polyurethane varnishes generally provide a glossier coating. In one study, polyurethane varnish was said to be glossier than water-based varnish (Slabejová *et al*. 2016). In another study, it was stated that differences in the structure and application methods of varnishes can affect the gloss (Pelit *et al*. 2015). In a study, travertine and marble powder used as additives to red pine (*Pinus brutia* ten) and black poplar (*Populus nigra* L.) wood species were added to the samples of synthetic varnishes, cellulosic varnishes and cellulosic paints at 0%, 2.5% and 5% rates and examined in terms of gloss and roughness. When the gloss values for red pine were examined, there was a linear decrease in the gloss values for cellulosic varnish with the addition of additives, an increase in the gloss values for paint with the addition of 2.5% additive, and a decrease with the addition of 5% additive. However, in the surface treatment applied without the addition of additives, the gloss was at its lowest, and the gloss values for paint decreased linearly with the addition of additives. For poplar, there was a decrease in gloss values for cellulosic varnish with the addition of additives. Although the decrease in the gloss value obtained with the addition of 2.5% additive was very small, the decrease in the gloss value measured with 5% additional additive was much higher, and the gloss values for 72 synthetic varnish decreased with the addition of additive. Although the decrease in the gloss value obtained with the addition of 2.5% additive is very small, the decrease in the gloss value measured with 5% additional additive is much higher (Sofuoğlu *et al.* 2013). In the light of this information, the effect of marble powder, the addition of marble powder at 2.5% and 5% changed the brightness value in both water-based and polyurethane varnishes. It can be observed that varnishes with 5% marble powder added mostly had lower gloss values. This indicates that the marble powder produces a dulling effect. The study is consistent with the literature. Regarding the effect of fiber direction, Fig. 2 shows the gloss variation of the same wood species according to parallel and perpendicular fiber directions. Generally, higher gloss values were obtained in applications parallel to the fibers. This indicates that fiber orientation affects the light reflectivity of the surface. Gloss changes according to wood species, differences in brightness values are observed between wood species. Especially beech and chestnut have higher gloss values than others. This difference can be explained by the diverse surface structure of each wood and its interaction with varnish.

CONCLUSIONS

In this study, marble powder was mixed with varnishes (water-based and polyurethane varnishes) at various ratios and applied on different wood species (chestnut, beech, yellow pine, and spruce). The effect on wood surface treatments was evaluated.

1. Polyurethane varnish was found to provide higher hardness. Specimens treated with polyurethane varnish were generally more durable than those with water-based varnish.
2. The addition of marble powder affected the hardness: 2.5% addition of marble dust increased hardness, while 5% addition of marble dust caused a slight decrease. Higher hardness was obtained in radial cross-section applications. Therefore, the type of varnish, the proportion of marble dust and the fiber orientation should be carefully selected to ensure durability properties suitable for the intended use of the wood surfaces. The reason why marble dust reduced the gloss is that marble dust makes both physical and chemical changes in the varnish. It adds microscopic roughness to the varnish mixture, thus causing deviations from mirror-like reflection. This causes light to scatter in different directions, so it is thought to reduce the optical transparency of the varnish. Applications parallel to the fibers were generally glossier than applications perpendicular to the fibers. These results indicate that the varnish type, marble dust ratio, and fiber orientation should be carefully selected depending on the desired gloss level on wood surfaces.

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