Effects of the Traditional Turkish Art of Marbling (Ebru) Techniques on the Adhesion, Hardness, and Gloss of Some Finishing Varnishes

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Abstract

The aim of this study was to determine the effects of ebru, a traditional Turkish art of marbling, on some physical properties of various varnishes. Scots pine (*Pinus sylvestris* L.), Turkish oriental beech (*Fagus orientalis* Lipsky), and medium-density fiberboard specimens were used as substrates. Each sample surface was first stained by ebru or a commercial wood stain (wood paint), dried, and then covered with one of a variety of varnishes. Nitrocellulose-based, alkyd-based synthetic, water-based, and polyurethane-based varnishes were applied as two consecutive topcoats. Adhesion, hardness, and gloss tests were performed. Results showed that, in general, there was not any statistically significant effect of ebru staining before coating with varnishes. In conclusion, the Turkish art of ebru can be utilized on wood and wood-based panels as an artistic and decorative staining technique.

Wood, as a natural organic material, possesses many superior properties but is susceptible to some treatments. Reasons for coating furniture are to keep it clean or to easily clean it, to make it scratch resistant, for appearance, to protect it from occasional wetting, etc. In order to overcome these disadvantages and to enhance the aesthetic appearance of wood materials, protective covers, such as dye and varnish, are applied to them (Kaygin and Akgun 2009).

Surface treatments increase the functional, aesthetic, and economic values of wood (Kaygin and Akgun 2009). Furniture, in particular, is influenced by fashion and art trends. Ebru, or marbling, is a traditional Turkish painting style that is applied on different materials, such as paper or fabric. However, marbling is not commonly applied as an aesthetic finishing for functional furniture and wooden artifacts. This study investigated the effect that marbling underneath varnish has on the finish properties. Figure 1 shows some boards treated with the ebru technique.

Ebru is an interesting art both technically and historically. Etymologically originating from the word *ebr*, meaning ‘‘cloud’’ in Persian, marbling can be defined as water facade painting (Hattat 2009). A mixture of ‘‘tragacanth’’ (a gummy substance derived from shrubs) and water is prepared in a large pan. Powdered dyes are sprinkled onto the surface of the water and tragacanth mixture and then transferred to a piece of raw and absorbing paper. As the name suggests, the method produces patterns similar to marble or other stone. Ebru is a kind of special nonfigurative, nonrepetitive art. Once you start marbling, it is impossible to return to the initial position on the work (Babaoglu 2009, Turkish Cultural Foundation 2009, Yilmaz 2009).

There is no certain knowledge about who invented this art or when. It was supposed that this art arose in Turkistan or China and then came through Iran and India to Anatolia by Silk Road migrations. It is said that the technique of marbling originally initiated from China, where a book from the Tang dynasty (618 to 907) mentions something about coloring paper on water (Kaya 2006). Later, it moved to the Anatolia, where it became very popular and developed tremendously under Ottoman rule. During the 16th century, travelers from Europe took the art back to their home, where it spread through Europe.

Ebru decorative materials have been used to cover a variety of surfaces for several centuries. They are often used as writing surfaces for calligraphy and especially as book

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Figure 1.—Application of various ebru techniques on wood samples.

covers and endpapers in bookbinding and stationery (Dundar 2009).

This study aimed to introduce the application of ebru as a new furniture and wood materials finishing style. Various wooden furniture items and wood samples were prepared and stained by ebru paint techniques and then coated with varnish. Adhesion, hardness, and gloss tests were performed on stained and varnished surfaces in order to determine the suitability of ebru art on wood and wood-based products.

Materials and Methods

Wood and wood-based materials

Commercially available Scots pine (*Pinus sylvestris* L.), Turkish oriental beech (*Fagus orientalis* Lipsky), and medium-density fiberboard (MDF) were used as substrates. Straight-grain specimens measuring 10 mm (radial) by 100 mm (tangential) by 100 mm (longitudinal) were cut and stored in the laboratory at 20 ± 2°C and 65 ± 5% relative humidity to reach equilibrium moisture content. The wood surfaces were sanded until a smooth flat surface was obtained; the wood dust was removed using a clean soft brush.

Marbling materials and application

For marbling, ready-to-use stains and thickening powder were obtained from a hardware store. For application, needles, combs, horsehair brushes, and water sinks with dimensions of 50 by 70 by 6, 70 by 100 by 6, and 100 by 200 by 10 cm were used.

For preparation of the ebru bath, 10 g of thickener was sprinkled into 1 liter of cold water, mixed vigorously with a beater, and then allowed to stand for at least 2 hours (Pebeo 2009). The gel was then spread 2 cm thick on a flat container larger than the objects to be stained.

Ebru colors were carefully placed on the surface of the bath with an eyedropper. For some patterns, paint was sprinkled on the surface of the gel with a brush. Drops were allowed to spread for a few seconds before working them with a wooden stick, needles, combs, and brushes to get various patterns.

Then the pattern in the gel was transferred to the wood surface by carefully laying the wood samples in the bath, where the design pattern on the gel surface was readily transferred to the samples. Each sample part was stained in this manner, dried for at least 2 days, and then covered with two coats of a polyurethane-based, nitrocellulose-based, alkyd-based synthetic or water-based varnish to enhance and protect the stain (Fig. 1).

Wood paint and application

For comparison purposes, a commercially available and commonly utilized ready-to-use nitrocellulose-based paint was applied to a number of samples. The manufacturer's instructions were followed for painting procedures.

Varnishes and application

Four commercially available varnishes-nitrocellulose, alkyd-based synthetic, two-component polyurethane, and waterborne-were used. The manufacturer's instructions were observed for preparation and conditioning of varnish mixtures. Two coats of varnish were applied to all marbling stained, painted, and unpainted samples. The spray nozzle distance and pressure were adjusted according to the manufacturer's instructions and moved in parallel to the specimen surface at a distance of approximately 20 cm. The air pressure of the spray gun was 3 bars, and the nozzle gap was 1.8 mm. The amount of surface application was approximately 120 to 125 g/m^2. After each coat, the specimens were left to dry for 24 hours on a dust-free platform under ambient temperature. Soft abrasive sandpaper was used to smooth the first varnish coat but not damage the marbling layer.

Adhesion test

After the varnish was applied, the samples were conditioned at 23 ± 2°C and 50 ± 5% relative humidity for 48 hours. The adhesion of the varnish layers was then determined according to ASTM D4541 as modified by Budakci (American Society for Testing and Materials [ASTM] 1995a, Budakci 2003).

For the adhesion tests, a 20-mm-diameter cylinder was glued to the varnish using epoxy resin. After curing for 24 hours, the varnish layer immediately surrounding the cylinder was cut, stopping at the substrate surface. The cylinder was then pulled perpendicular to the surface until failure.

The following equation was used to calculate the adhesion strength of the varnish:

$$X = 4F/\pi r^2$$

where

X = adhesion (MPa),

F = force at delamination (N), and

r = radius of sample cylinder (mm).

Surface hardness test

The surface hardness test was performed according to ASTM D4366-95 (ASTM 1995b) with an Erichsen Model 299/300 Pendulum Damping Tester. Specimens were placed on the panel table, and a pendulum was placed on the panel surface. Then the pendulum was deflected through 6° and released; at the same time, a stopwatch was started. The time for the amplitude to decrease from 6° to 3° was directly proportional to König hardness. Harder materials absorb less energy on impact and so take longer to dampen the pendulum motion.

Gloss test

Gloss is a measure of the amount of specular reflection from a surface, and it is an important coating property for aesthetic or decorative appearance. The gloss of wood specimens was determined according to ASTM 523 (ASTM 1970) by an Erichsen Model 507M reflectometer set at 60°. Results were based on a specular gloss value of 100, which relates to the perfect condition under identical illuminating and viewing conditions of a highly polished plane surface of black glass. Five panels for each varnish type and wood species were used in the experiments. One measurement was made parallel to and one vertical to the fiber on each sample.

Statistical analyses

Three different types of wood (Oriental beech, Scots pine, and MDF), three types of first-coat application (ebru stain, commercial wood paint, and unpainted [control]), four types of varnish (nitrocellulose based, polyurethane based, alkyd-based synthetic, and water based), three different set of tests (adhesion, hardness, and gloss), and five replications for each cell were prepared ($3 \times 3 \times 4 \times 3 \times 5 = 540$ specimens). A full factorial variance analysis was made in order to determine the effects of each dependent variable. In cases where the differences among the groups were statistically significant, a comparison was made with the Duncan test at the $\alpha = 0.05$ confidence level.

Results

The average values and standard deviations for all measured properties are given in Table 1. The multiple analyses of variance (ANOVAs) were used to determine the differences ($P < 0.05$) among the variables. The results of the ANOVA analysis for adhesion strength, hardness, and gloss are given in Table 2. The results of Duncan descriptive statistic tests done to determine the significance of effects of degree in wood material, painting material, and varnish type to surface adhesion strength, surface hardness, and gloss are given in Table 3.

Table 1.—Average surface adhesion, hardness, and gloss values.

			Tests[a]		
Material	First coat	Varnish	Adhesion (MPa)	Hardness	Gloss
Scots pine	Control	Cellulosic	2.54 (0.27)	29.8 (2.39)	86.7 (1.64)
		Synthetic	2.60 (0.29)	22.8 (8.58)	90.7 (4.01)
		Water based	3.74 (0.43)	10.8 (0.84)	46.0 (5.72)
		Polyurethane	2.62 (0.65)	89.0 (9.87)	96.1 (4.26)
	Ebru	Cellulosic	2.64 (0.86)	37.6 (10.97)	79.6 (7.46)
		Synthetic	2.86 (0.30)	19.4 (1.14)	89.4 (1.56)
		Water based	3.24 (0.09)	12.8 (1.30)	40.4 (3.73)
		Polyurethane	2.34 (0.34)	90.4 (1.82)	96.9 (0.63)
	Wood paint	Cellulosic	2.30 (0.36)	30.7 (0.43)	88.3 (2.72)
		Synthetic	2.48 (0.11)	31.0 (3.67)	92.4 (0.37)
		Water based	2.85 (0.22)	16.2 (2.38)	34.6 (9.24)
		Polyurethane	1.73 (0.40)	80.2 (2.59)	91.6 (7.33)
Beech	Control	Cellulosic	2.16 (0.76)	37.8 (1.92)	78.3 (3.90)
		Synthetic	3.96 (0.24)	26.2 (7.53)	89.8 (3.73)
		Water based	3.50 (0.38)	11.2 (1.92)	38.1 (5.52)
		Polyurethane	3.50 (0.68)	87.2 (11.30)	94.2 (2.49)
	Ebru	Cellulosic	2.76 (0.47)	33.0 (1.22)	85.0 (2.91)
		Synthetic	3.90 (0.57)	25.0 (3.16)	91.4 (3.22)
		Water based	3.18 (0.48)	11.0 (0.71)	46.0 (7.45)
		Polyurethane	3.54 (0.22)	95.4 (3.21)	95.6 (3.03)
	Wood paint	Cellulosic	3.20 (0.10)	32.2 (1.92)	85.1 (1.06)
		Synthetic	3.55 (0.36)	27.5 (2.18)	90.9 (1.10)
		Water based	3.20 (0.80)	15.5 (1.80)	41.8 (3.21)
		Polyurethane	3.01 (0.37)	83.2 (3.70)	94.0 (1.79)
MDF	Control	Cellulosic	2.42 (0.61)	13.6 (0.89)	77.3 (2.38)
		Synthetic	2.68 (0.18)	20.2 (0.84)	91.0 (1.27)
		Water based	2.48 (0.28)	10.0 (1.22)	43.4 (5.23)
		Polyurethane	2.64 (0.26)	90.2 (2.95)	96.6 (0.83)
	Ebru	Cellulosic	1.82 (0.56)	14.8 (0.84)	71.0 (1.46)
		Synthetic	2.74 (0.15)	23.0 (2.74)	89.7 (1.14)
		Water based	2.60 (0.07)	9.8 (0.45)	43.5 (8.91)
		Polyurethane	2.34 (0.57)	87.4 (7.80)	96.0 (0.70)
	Wood paint	Cellulosic	2.38 (0.29)	20.7 (0.43)	79.4 (1.70)
		Synthetic	2.73 (0.04)	26.5 (1.12)	88.5 (1.23)
		Water based	2.53 (0.08)	14.5 (1.12)	37.5 (2.86)
		Polyurethane	2.50 (0.43)	91.7 (0.83)	95.5 (0.79)

[a] Values are means (standard deviations).

Table 2.—Multiple variance analysis of the effects of substrate types, first-coat application type, and varnish type on surface adhesion, hardness, and gloss.[a]

Source	Dependent variable	SS	df	MS	*F* value	*P* value (α = 0.05)
Substrate	Adhesion	21.306	2	10.653	58.634	0.000
	Hardness	901.440	2	450.720	24.810	0.000
	Gloss	136.760	2	68.380	4.204	0.017
First coat	Adhesion	1.228	2	0.614	3.381	0.037
	Hardness	95.856	2	47.928	2.638	0.075
	Gloss	15.228	2	7.614	0.468	0.627
Varnish	Adhesion	10.879	3	3.626	19.959	0.000
	Hardness	156,060.929	3	52,020.310	2,863.449	0.000
	Gloss	81,242.142	3	27,080.714	1,665.099	0.000
Wood × paint	Adhesion	2.508	4	0.627	3.451	0.010
	Hardness	269.304	4	67.326	3.706	0.007
	Gloss	371.304	4	92.826	5.708	0.000
Wood × varnish	Adhesion	9.160	6	1.527	8.403	0.000
	Hardness	2,234.941	6	372.490	20.504	0.000
	Gloss	572.475	6	95.412	5.867	0.000
Paint × varnish	Adhesion	2.920	6	0.487	2.679	0.017
	Hardness	708.541	6	118.090	6.500	0.000
	Gloss	534.910	6	89.152	5.482	0.000
Wood × paint × varnish	Adhesion	3.922	12	0.327	1.799	0.053
	Hardness	762.124	12	63.510	3.496	0.000
	Gloss	367.306	12	30.609	1.882	0.041
Error	Adhesion	26.163	144	0.182		
	Hardness	2,616.050	144	18.167		
	Gloss	2,341.977	144	16.264		
Total	Adhesion	1,501.633	180			
	Hardness	42,7631.938	180			
	Gloss	1,154,120.749	180			

[a] SS = sum of squares; df = degrees of freedom; MS = mean square.

Adhesion

Among all mean adhesion values, the highest value (3.96 MPa) was obtained from Oriental beech control (unpainted) panels coated with synthetic varnish, and the lowest value (1.73 MPa) was obtained from painted Scots pine samples coated with polyurethane-based varnish (Table 1).

The average adhesion strength values of varnishes for each factor are given in Table 3. The highest average adhesion strength was obtained from beech samples (3.28 MPa) and the lowest from the MDF samples (2.48 MPa). The differences in adhesion among all three wood types were statistically significant. Among materials, the ranking from highest to lowest was beech, pine, and MDF. The good bonding to beech has been attributed to its low extractive content and open cell structure. In terms of wood coating, extractives in many wood species can retard the hardening of finishes and reduce the adhesion of finishes to the wood surface. In conifer wood, density differences between earlywood and latewood often lead to early finish failures because denser latewood generally shrinks and swells more than less dense earlywood, causing stresses in the finishes (Xie et al. 2006).

The effect of the paint type on adhesion was also significant. The highest average adhesion value (2.90 MPa) was obtained from control (unpainted) specimens and the lowest value (2.70 MPa) from specimens coated with commercial wood paint. Statistically, the average value for samples with ebru stain was between the values for painted and unpainted samples. The best adhesion with control (unpainted) samples might be the result of the adequate chemical bond between the varnish and wood surface. Meanwhile, ebru performs at least as well as commercial paint in adhesion to wood and varnish and also has film cohesion as good as commercial paint. In other words, it is not expected to cause adhesion problems. On the pine and beech samples, commercial paint and ebru stain stayed with wood. But on the MDF samples, commercial paint and ebru stain came off with varnish. The good bonding between paint and massive wood can be seen as an advantage of ebru stain because worn-out varnish film is reparable but ebru stain is not.

Table 3.—Duncan test results for main effects.

	Tests					
	Adhesion (MPa)		Hardness		Gloss	
	Mean	SG	Mean	SG	Mean	SG
Substrate						
Pine	2.66	B	39.2	A	77.7	A
Beech	3.28	A	40.4	A	77.5	A
MDF	2.48	C	35.2	B	75.8	B
First coat						
Control	2.90	A	37.4	B	77.3	—
Ebru	2.83	AB	38.3	AB	77.0	—
Wood paint	2.70	B	39.1	A	76.6	—
Varnish						
Cellulosic	2.46	C	27.8	B	81.2	C
Synthetic	3.05	A	24.6	C	90.4	B
Water based	3.03	A	12.4	D	41.2	D
Polyurethane	2.69	B	88.3	A	95.2	A

[a] SG = statistical group.

There are critical factors that must be met to obtain good adhesion of a coating to wood. One of them is that the coating should wet the wood cells properly and to a certain extent penetrate into the open pores in the wood (Ozdemir and Hiziroglu 2007). This factor may be a good advantage for marbling because it is designed on water and transferred onto wood in the wet position.

Among varnishes, the highest average adhesion strength value (3.05 MPa) was obtained from synthetic varnish and the lowest value (2.46 MPa) from cellulosic varnish. Statistically, there was no difference between the synthetic and water-based varnishes, which had higher strength than polyurethane, which in turn had higher strength than cellulosic varnish.

Hardness

Average surface hardness values are shown in Table 1. Among all hardness values, the highest (95.4) was obtained from ebru-stained Oriental beech panels covered with polyurethane-based varnish and the lowest (9.8) from ebru-stained MDF samples covered with water-based varnish.

The effect of wood type on hardness is summarized in Table 3. Of the three wood substrates, beech and pine were equivalent (40.4 and 39.2, respectively), while MDF was statistically lower at 35.2. The effect of the first coat on hardness was quite small, with the highest value (39.1) on painted and the lowest value (37.4) on the control (unpainted) samples. There was a significant difference between wood paint and control (unpainted) samples for hardness. Average hardness values of ebru-stained specimens was located between commercial wood paint and control samples.

Varnish type had the most dramatic impact on hardness of all the variables. The highest value (88.3) was obtained from polyurethane-based varnish and the lowest value (12.4) from water-based varnish (Table 3).

Statistically, there were significant differences in hardness among all varnish types. Polyurethane-based varnish was by far the hardest, followed by cellulosic, synthetic, and water-based varnish, respectively. It has been reported that hardness of finished wood products are determined by the varnish and paint layers rather than the wood substrate (Kaygin and Akgun 2009).

Gloss

Average surface gloss values are shown in Table 1. Among all samples, the highest gloss value (96.9) was obtained from ebru-stained Scots pine panels covered with polyurethane-based varnish, and the lowest value (34.6) was obtained from painted Scots pine panels covered with water-based varnish.

The effect of substrate on gloss was small, with the highest value (77.7) obtained from Scots pine and the lowest value (75.8) from MDF. Statistically, there was no significant difference between the Scots pine and beech. The lower gloss of MDF may be a result of the dark surface of MDF.

The effect of the first coat on gloss was statistically insignificant with the highest value (77.3) on unpainted (control) samples and the lowest (76.6) on painted samples. Among varnishes, the highest gloss value (95.2) was obtained with polyurethane and the lowest value (41.2) with the water-based varnish. Statistically, there were significant differences among all varnish types in gloss. Polyurethane varnish was followed by synthetic, cellulosic, and water-based varnish, respectively.

Discussion

This is the first study to determine the suitability of ebru staining under varnish on wood and wood-based materials. The adhesion strength, hardness, and gloss values obtained for ebru-treated wood were compared with unpainted wood and wood coated with commercial paint. By this comparison, we were able to see if there were decreases in the physical properties of ebru-stained samples. According to the Duncan test results for adhesion, hardness, and gloss, the ebru stain was located between and was indistinguishable from both the raw wood (unpainted) and the painted groups (Table 3). Despite the positive results of ebru shown here, it should be noted that this technique has some disadvantages. One disadvantage of the ebru technique is the necessity of treating all parts of furniture to be painted one by one before final assembly. For this reason, special care must be taken to ensure that furniture parts are not damaged during assembly. The other disadvantage of the ebru method is the risk of absorbing excessive moisture into the body of wood parts at the stage of sinking. This can be eliminated by processing parts quickly and by drying parts after painting. For enhancement of ebru stain and protection of the stained surface, the furniture should be coated with varnish.

Conclusions

Fashion, culture, and new materials are dynamic factors in the manufacturing and marketing of furniture and secondary wood products. Thus, there is always a need for the study and development of different materials and finishing styles.

In order to determine the usability of ebru staining for wood products and its compatibility with varnishes, adhesion, hardness, and gloss were measured. The results showed that the performance of the ebru-stained samples was as good as the performance of the control and painted samples. That is, there was no significant decline in varnish film properties when applied over ebru.

In conclusion, the traditional Turkish art of ebru-staining techniques can be used as a new and different finishing style for wood furniture and other secondary wood and wood-based products. Varnish should provide essentially the same adhesion, hardness, and gloss whether applied over ebru-stained or raw wood.

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