THE EFFECT OF DÉCOR PAPER AND RESIN TYPE ON THE PHYSICAL, MECHANICAL, AND SURFACE QUALITY PROPERTIES OF PARTICLEBOARDS COATED WITH IMPREGNATED DÉCOR PAPERS

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The objective of this study is to evaluate the effect of décor paper and resin type on physical properties, mechanic properties, and surface quality properties of particleboards coated with décor papers impregnated by using different resin. White oak, New wenge and common maple pattern decor papers impregnated with urea formaldehyde (UF), melamine formaldehyde (MF) and urea-melamine formaldehyde (UF+MF) were used as coating materials. Particleboard surface was laminated with these coating materials by hydraulic press. As a result, specimens coated with MF-impregnated papers showed better performance than those coated with UF and UF+MF-impregnated papers. Resin type and paper pattern affected the physical, mechanical (with exception of tension strength), and surface properties (especially cigarette burn and abrasion) of coated particleboards. Physical and mechanical properties of coated particleboard were significantly improved compared to non-laminated particleboards. It was found that paper pattern affected the surface properties, such as impact, scratch, and abrasion, resistance to staining and cigarette burn. However, it did not change the cracking and steaming properties of the coated samples. After the coating process, it was determined that cigarette burn, abrasion, impact, and scratch performances were among 1 to 3 grade, Ip:10-35, Fp:210-340/100-150, and 2 to 5 grade, respectively.

Keywords: Composite materials; Coatings; Surface treatments; Resin type

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INTRODUCTION

The use of wood-based panels, without improvement of the surface appearance and the physical–mechanical characteristics, is gradually disappearing (with the exception of panels used for packing). Surface quality of wood composites such as particleboard is an important physical property influencing different processes, including their finishing. Although particleboard panels are used for interior applications, their hygroscopic nature plays an important role on their performance due to long-term changes in relative humidity (Hiziroglu 1999; Kilic et al. 2009). For outside use of particleboard the surface of boards is coated by different processes. Nowadays, particleboard panel products are coated by impregnated papers, paint, print, varnish, veneers, laminates, foils, etc. Lamination is a process that imparts a pleasing appearance in addition to improving the physical, mechanical, and optical properties, and it also imparts a pleasing appearance. The main surface characteristics obtained by the lamination process are resistance to scratching, abrasion, moisture, heat, and to some household chemicals. The purposes of these applications are to increase physical, mechanical, and surface properties, to suppress the absorption of water and humidity, and to eliminate the release of formaldehyde emission (Nemli and Colakoglu 2005; Nemli and Hiziroglu 2009; Ozdemir et al. 2009, Nemli et al. 2004, 2007). Surface improvement by the lamination depends on the materials used in laminating and the system used for lamination (Ahonen 1977; Ozdemir et al. 2009). In addition, the resin type used in the production of substrate and coating materials affects the final product's properties. As a rule, urea and melamine formaldehyde resins (synthetic resins) are extensively used as binder adhesives in the production of panel and coating materials (Seller 1996). For coating of the particleboards widely different materials such as décor paper and synthetic resins have been used.

Décor paper is a high-quality special paper that is bonded to a suitable substrate, e.g. wood composites, using special synthetic resins. Papers impregnated with a resin have gained wide acceptance as facing materials for industrial grade particleboard. Alpha-cellulose papers are used exclusively as the base papers for the decorative films. For impregnating, papers must have a high moisture resistance and the right porosity to accept the proper amount of resin. The surface print quality of the décor paper is essential, so that decorative designs can be created using gravure printing processes. It must also be possible to impregnate the paper with the appropriate synthetic resins that can include urea formaldehyde, melamine formaldehyde, acrylic, phenolic resins, and mixtures thereof. The coating is laminated under high pressure and heat with particleboards or other substrates. Cauls are used for a typical laminating process. The quality of cauls, cleanliness, and temperature are key factors that influence laminating quality (Hiziroglu 1996).

Resin-impregnated paper is a preprinted or solid-color decorative paper that has been saturated with a melamine, phenol, or polyester resins. These papers bond to particleboard without a resin while simultaneously providing a resin-rich finish on the surface under heat and pressure (Nemli 2008). Resin-saturated papers are self-bonding overlays having a typical weight ranging from 60 g/m^2 to 130 g/m^2 (Barret 1993; Sparkes 1993). These papers are saturated with reactive resins and partially cured at the point of manufacture. Final curing is completed at the time of hot-pressing during the lamination process when the resins form a hard cross linked thermo-set material (Nemli and Usta 2004).

The resin in the paper flows into the surface of the substrate during the laminating process. In a typical application the resin is introduced into the paper using an impregnation process followed by drying of impregnated paper in an oven. Polyester resins are fully cured at a pressure of 12.5-14.0 MPa and at a temperature of 120-160^{o}C (Soine 1991).

The type of resin used for impregnation of melamine paper influences the quality of décor papers (Nemli and Usta 2004; Nemli and Hiziroglu 2009). It was reported in another study that the varnish type plays a very important role in the end use applications (Aksu 2009). Polyurethane-based varnish is more resistant to the scratching, abrasion, and cigarette burns compared to cellulosic varnish (Nemli 2008). Nemli and Colakoglu (2005) stated that surface coating processes improved the bending strength, modulus of elasticity, and thickness swelling, and that they reduced the formaldehyde emission from the particleboard as well. Norvydas and Minelga (2006) reported that modulus of elasticity and bending strength of particleboard panels increased, depending on the type and thickness of the coatings. In the other study, it was reported that phenolic-impregnated paper overlays resist weathering better than do overlays impregnated with urea or melamine (Fahey and Pierce 1971).

In this study, it was aimed to evaluate the influence of resin type and décor paper on some physical, mechanical and surface quality properties of the particleboards coated with décor papers impregnated with different resins. Thereafter, it was determined how the physical, mechanical, and surface properties had been changed.

MATERIALS AND METHODS

Particleboards were laminated or coated with décor papers having the patterns new wenge (*Milettia laurentii* De Wild), white oak (*Quercus alba*), and common maple (*Acer campestre*) applied to them. Impregnated papers at 70 g/m^2 (*New wenge and White oak*) and 80 g/m^2 (*Common maple*) were used as coating materials, and the particleboards used were obtained as a substrate from a commercial particleboard plant in Turkey. Three-layered particleboard panels were manufactured by using 40% softwood and 60% hardwood. Base décor papers were impregnated with 100% urea formaldehyde (UF), 100% melamine formaldehyde (MF), and 55% urea formaldehyde plus 45% melamine formaldehyde. Décor papers were purchased from MADES AS and then a press paper pattern was applied to the décor paper. Papers having different pattern (new wenge, white oak and common maple) were impregnated by using UF, MF, and UF+MF. The properties of the impregnated décor paper used in this study are shown in Table 1.

Table 1. Properties of Décor Paper impregnated with UF, MF, and UF + MF

Décor papers (pattern)	Urea Formaldehyde			Melamine Formaldehyde			Urea + Melamine Formaldehyde		
	Moisture content (%)	Resin fluidity (%)	Resin leaching rate (%)	Moisture content (%)	Resin fluidity (%)	Resin leaching rate (%)	Moisture content (%)	Resin fluidity (%)	Resin leaching rate (%)
New Wenge	7.94	4.39	22.09	5.94	1.79	28.44	5.85	2.25	46.94
White Oak	8.2	4.1	22.0	6.0	2.1	30.4	6.0	2.2	44.79
Common maple	7.9	3.9	23.8	6.0	1.8	29.0	5.7	1.6	48.4

The conditions for the lamination operation were as follows: press temperature 140-145 °C, pressure 2.5 N/mm^2, and press time 30 s. Those operations were carried out in a commercial plant production line in Turkey. Thirty samples were prepared for each test to determine the physical and mechanical properties. Furthermore, five samples were prepared for each test to determine the surface properties. All the tests were done at

Bartin University, Forest Products Laboratory. Each test sample was conditioned at 20±2 °C and 65±5 RH for 2 weeks before testing according to TS 612 (1997).

Physical, mechanical, and surface properties of laminated particleboard were determined according to relevant standards. Namely, test specimens and their dimensions were prepared in accordance with TS EN 325 (1999) and TS EN 326-1 (1999). Physical properties of laminated particleboard such as water absorption (WA) (TS EN 317, 1999), thickness swelling (TS) (TS EN 317, 1999), and from the mechanical properties such as modulus of elasticity (MOE) (TS EN 310, 1999), bending strength (BS) (TS EN 310, 1999), and internal bonding strength (IB) (TS EN 319, 1999) were tested. In addition, surface properties of laminated particleboard such as crack test, steam test, scratch test, abrasion test, resistance to staining, and resistance to cigarette burn were measured in accordance with the corresponding standard (TS 14323, 2006). Data for physical and mechanical tests were statistically analyzed, and ANOVA was performed ($p<0.05$) to determine the significance of differences among factors. Results were assessed by a DUNCAN test of whether there is a meaningful difference among the groups.

RESULTS AND DISCUSSION

The average, standard deviation, and coefficient of variation of physical properties such as density (g/cm^3), moisture content (%), thickness swelling (%), and water absorption (%) of the particleboards laminated with different impregnated décor papers are given Table 2. As can be seen from Table 2, the tests done after the lamination process showed some changes of physical properties of the particleboards. The highest and lowest values of density were obtained in the particleboards laminated with white-oak-UF and wenge-UF papers. According to the average moisture content of the particleboards laminated with different impregnated décor paper, it found that the highest and lowest moisture content was 8.8% in white oak-UF versus 8.46% in wenge-UF.

After the lamination process, the highest values of thickness swelling and water absorption of the particleboards was obtained in control samples (un-laminated particleboards). The water absorption and thickness swelling of the particleboards were decreased after laminating with different impregnated décor paper. The minimum values of water absorption and thickness swelling at 2 and 96 hours were obtained as 56.68% and 81.41% in white oak-UF, 11.08% in common maple-UF, and 14.84% white oak-UF. The data of water absorption and thickness swelling were obtained in this study were found suitable according to TS EN 312 (1992). Water absorption and thickness swelling ratios of laminated samples decreased as compared to the control samples.

Improvements in WA and TS values of laminated particleboard with décor paper impregnated with MF resin were higher than those of décor paper impregnated with UF resin. However, improvements of the physical properties of laminated samples depended on resin type, as well as the type of décor paper. The average values of mechanical properties such as bending strength, modulus of elasticity, and tension strength parallel to grain are given Figs. 1, 2, and 3.

Table 2. Physical Properties of the Particleboards coated with Impregnated Décor Papers

Samples	SV	d (g/cm³)	MC (%)	Thickness Swelling				Water Absorption			
				2 hours	24 hours	48 hours	96 hours	2 hours	24 hours	48 hours	96 hours
Wenge ÜF	x	0.66A	8.46A	11.61CD	14.04A	16.98D	17.15B	64.27CD	70.52AB	84.30B	84.59AB
	±s	±0.01	±0.23	±0.42	±0.63	±0.48	±0.68	±3.58	±1.58	±2.53	±1.33
	%v	1.80	2.71	3.58	4.47	2.81	4.22	5.58	2.24	3.00	1.57
Wenge ÜF/MF	x	0.69AB	8.58B	12.25BC	16.84D	16.68CD	17.17BC	58.58AB	73.06BCD	78.93A	83.55AB
	±s	±0.01	±0.25	±0.35	±0.75	±0.63	±0.50	±0.94	±2.68	±2.67	±1.42
	%v	1.58	2.96	2,83	4.46	3.79	2.90	1.60	3.67	3.38	1.69
White Oak ÜF/MF	x	0.70AB	8.60BC	11.42D	16.85D	16.28CD	18.50C	56.68A	71.34ABC	79.15A	81.41A
	±s	±0.01	±0.66	±0.38	±0.59	±1.39	±0.94	±4.15	±1.28	±1.76	±3.68
	%v	1.28	7.74	3.28	3.49	8.55	5.09	7.32	1.80	2.22	4.52
Common maple ÜF/MF	x	0.71AB	8.61BC	12.95AB	15.39B	16.62CD	16.98BC	63.75C	69.18A	77.47A	82.37AB
	±s	±0.01	±0.45	±0.28	±1,01	±1.15	±0.75	±3.20	±2.92	±2.93	±4.56
	%v	0.99	5.29	2.13	6.54	6.89	4.44	5.03	4.23	3.78	5.53
Wenge MF	x	0.71AB	8.66C	12.38B	16.16CD	16.99D	17.29BC	59.54AB	74.73CDE	77.68A	84.97AB
	±s	±0.01	±0.66	±0.45	±0.60	±0.41	±0.82	±0.98	±2.50	±1.37	±1.99
	%v	1.40	7.69	3.60	3.73	2.42	4.77	1.64	3.34	1.76	2.34
Control	x	0.71AB	8.66C	13.65A	15.22BC	16.66CD	17.06BC	65.14CD	77.21EF	85.51B	90.90C
	±s	±0.02	±0.32	±1.14	±0.87	±0.80	±1.37	±2.13	±3.23	±2.09	±4.18
	%v	3.23	3.70	8.36	5.69	4.81	8.05	3.28	4.18	2.44	4.60
Common maple ÜF	x	0.71AB	8.83D	11.08D	15.99CD	16.49CD	17.17BC	59.52AB	75.02CDE	76.77A	84.90AB
	±s	±0.02	±0.65	±0.14	±0.90	±0.62	±1.00	±1.63	±3.40	±2.41	±3.49
	%v	3.07	7.39	1.28	5.63	3.78	5.80	2.73	4.53	3.13	4.11
Common maple MF	x	0.72AB	8.83D	12.58D	15.25BC	15.62BC	16.44B	67.12D	76.41DEF	84.75B	84.78AB
	±s	±0.01	±0.52	±0.52	±0.65	±0.28	±0.51	±1.42	±2.57	±1.87	±3.96
	%v	1.81	5.94	4.13	4.29	1.81	3.13	2.12	3.36	2.21	4.68
White Oak MF	x	0.74B	8.88DE	11.17D	14.20A	14.29A	14.84A	58.21AB	75.76DEF	82.82B	83.40AB
	±s	±0.01	±0.77	±0.61	±1.01	±1.69	±1.93	±1.18	±2.69	±1.75	±1.56
	%v	1.48	8.68	5.42	7.10	11.82	13.94	2.03	3.55	2.11	1.87
White Oak ÜF	x	0.75B	8.90E	11.38D	14.29AB	15.01AB	15.94B	60.67B	79.47F	83.1B	86.61B
	±s	±0.02	±0.33	±0.66	±0.71	±0.45	±1.43	±1.75	±3.74	±3.09	±2.98
	%v	2.94	3.76	5.79	4.94	2.97	8.94	2.88	4.71	3.71	3.44

(*sv means statistical values, d and MC shows density and moisture content)

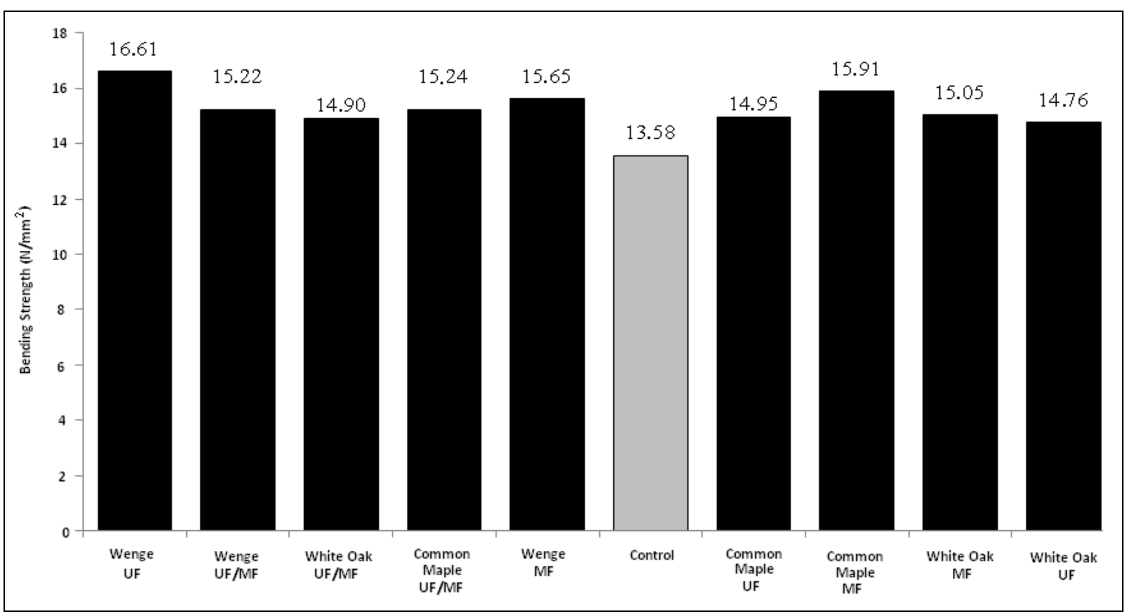

Figure 1. Bending strength of the particleboards laminated with impregnated décor papers

After the lamination process, the mechanical properties of the particleboards laminated with impregnated décor papers were increased. It was determined that the highest bending strength was 16.61 N/mm^2 in wenge-UF. The bending strength of laminated particleboards ranged from 13.58 N/mm^2 to 16.61 N/mm^2.

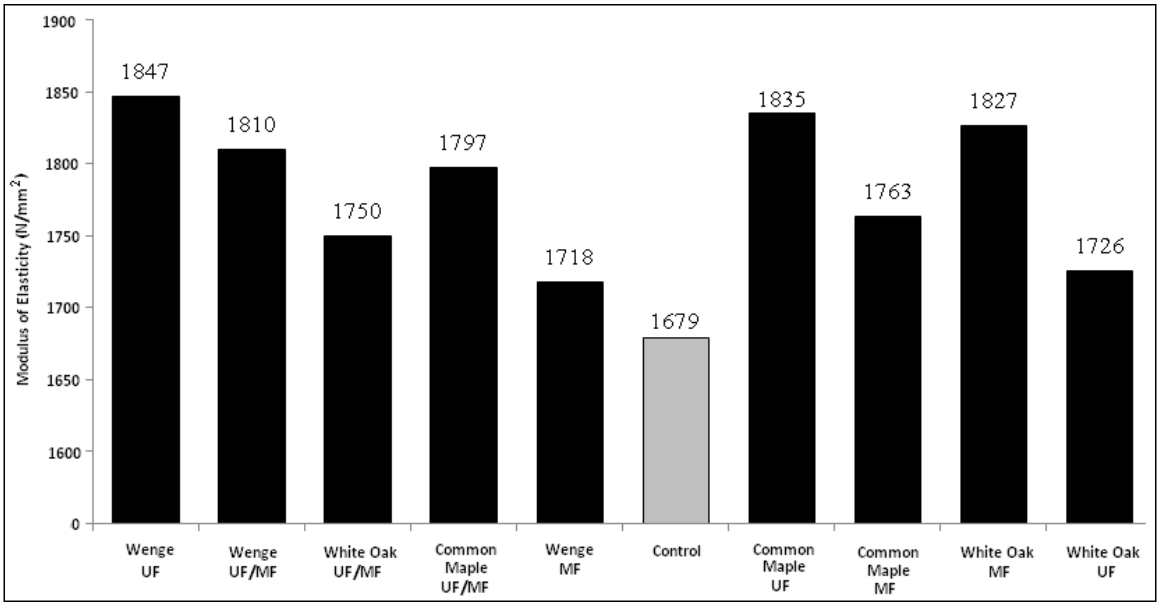

Figure 2. Modulus of elasticity of the particleboards laminated with impregnated décor papers

As can be seen in Fig. 2, the highest and lowest values of modulus of elasticity were 1847 N/mm^2 in wenge-UF and 1679 N/mm^2 in control samples. According to Figs. 1 and 2, it was found that the effect of the lamination process on modulus of elasticity was higher than that on bending strength.

MOE and BS of coated particleboards increased by statistically significant amounts compared to un-coated particleboards. On the other hand, resin type and décor paper pattern did not affect covered particleboard samples. MOE and BS of coated particleboard with décor paper impregnated with MF resin gave higher values than those of UF and UF + MF resins.

According to results of variance analysis and ANOVA tests, tensile strength parallel to grain values of the particleboards laminated with different impregnated décor paper was not found to be statistically significant compared to non-laminated particleboards. Similarly, previous authors showed that physical and mechanical properties (except for IB value) of coated panel can be improved with different coatings (Norvydas and Minelga 2006; Nemli and Çolakoglu 2004; Nemli and Kalaycioglu 2001). As seen in Fig. 3, the values of tension strength ranged from 0.31 N/mm^2 to 0.36 N/mm^2, with the highest value of 0.36 N/mm^2 occurring in wenge-MF.

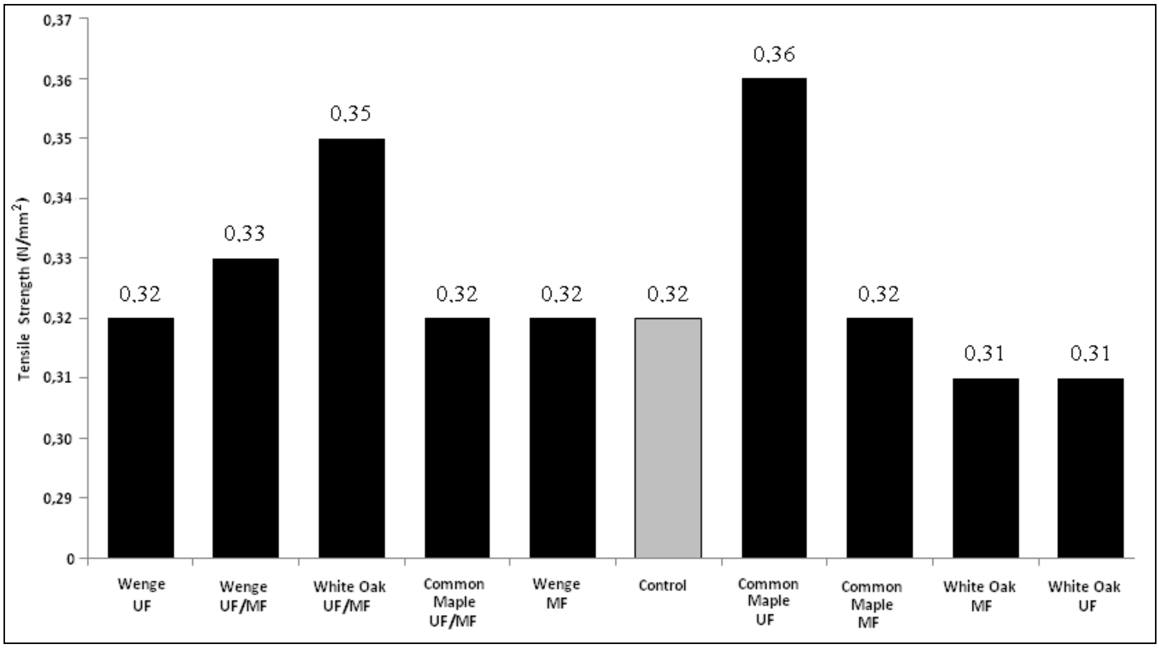

Figure 3. Tensile strength of the particleboards laminated with impregnated décor papers

The average values of surface properties such as resistance to cracking, water vapour, cigarette burn, staining, abrasion, impact, and scratch are given Table 3.

Table 3. Surface Quality Properties of the Particleboards Laminated with Impregnated Décor Papers

Surface Properties	New Wenge Décor Paper			Common Maple Décor Paper			White Oak Décor Paper		
	UF	MF	UF-MF	UF	MF	UF-MF	UF	MF	UF-MF
Cracking	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade
Water Vapour	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5.Grade	5. Grade	5.Grade	5.Grade
Cigarette burn	1.Grade	2.Grade	2.Grade	1.Grade	3. Grade	2. Grade	1. Grade	3. Grade	2. Grade
Staining	4.Grade	5.Grade	5.Grade	4.Grade	5.Grade	5.Grade	4.Grade	5.Grade	5.Grade
Abrasion	Ip=10 Fp=210	Ip= 35 Fp= 340	Ip=25 Fp=310	Ip=20 Fp= 270	Ip=35 Fp=360	Ip= 25 Fp= 320	Ip= 20 Fp= 260	Ip=30 Fp=340	Ip= 25 Fp=305
Impact	130 cm	150 cm	140 cm	100 cm	130 cm	100 cm	100 cm	130 cm	100 cm
Scratch	2.Grade	4.Grade	3.Grade	2.Grade	4. Grade	3. Grade	3. Grade	5. Grade	3. Grade

The abbreviations (UF, MF, UF-MF) were given in materials and methods.

As shown in Table 3, all the crack tests and water vapour tests results were in accordance with the fifth class; hence, no cracks or steam hazard occurred on the surface. Thus, it was found that the cracking and steaming properties of the laminated particleboard did not depend on resin type and the nature of the décor paper. In general, the crack test is used to assess the quality of a laminated décor paper with respect of small cracks in the surface. The properties of resin, the quality of resin applied, the swelling and shrinkage of the particleboard, and the pressing process all have a considerable influence on cracking (Nemli 2008). As hot steam imposes a very severe stress on the laminate, this can be regarded as an endurance test to simulate the effect of the influence of steam. If resin impregnation is insufficient before pressing, the hot steam can cause blisters to form on the final product.

While scratch values of particleboard laminated with paper impregnated with UF resin were rated as third class, other samples were rated as fourth class. Test samples coated with MF resin showed higher resistance against the scratch properties than those of UF resin. The linkage of the MF resin provides a stable bond that is not susceptible to hydrolysis due to hot pressing of the layers (Pizzi 1994). The abrasion properties of samples coated with MF resin were found to be better than those coated with UF resin. It was found that the abrasion properties were changed depending on resin type and décor paper. The abrasion test is used to determine the resistance of material surfaces to abrasive stress.

As the décor paper on the top layer of CPL was impregnated with only MF resin and UF resin, they are used for the finish foil manufacturing. MF resins are noted for their scratch and abrasion resistances. The UF used for finish foils manufacturing hydrolysizes during the hot pressing due to weak amino-methylene linkages (Barret 1993; Dunky 1995). Nemli reported that a resin mixture was found to be effective for abrasion resistance. Because an acrylic and urea containing layer is below the top surface, they do not play important role during scratching (Nemli 2008).

It was found that the resistance to stain by MF-white oak overlaid samples was higher than those of other specimens. While resin type affected resistance to cigarette burn, décor paper did not affect the samples. Increasing the amount of UF resin in the mixture of FF and MF negatively affected the resistance to the cigarette burn, especially above a 50% level. However, UF usage up to 50% in the mixture caused considerable discoloration, blister, and formation of cracks after cigarette burn testing (Nemli 2008). It was determined that impact test results ranged from 100 cm (common maple and white oak papers laminated with UF and UF/MF) to 150 cm (new wenge papers laminated with MF).

CONCLUSION

Success of finished fiberboard products depended on the resin type and surface coating material. It was determined that resin type and décor paper pattern influenced the properties of the substrate. Resin type affected physical, mechanical, and surface properties of laminated particleboard. In particular, mechanical and surface properties of coated specimens were higher than those of uncoated samples. Also, different décor paper samples impregnated with UF, MF and UF + MF resins significantly affected the properties of coated panels. Coated particleboard with MF resin showed better performance than those coated with UF, MF and UF + MF resins. Moreover, it was determined that the properties of décor paper impregnated with UF resin met the requirements of related standards. Particleboard coated with décor paper impregnated with MF resin gave better surface properties than those of décor paper impregnated with UF and UF + MF resins. As a result, décor paper affected the surface properties such as crack, steam, scratch, abrasion, resistance to staining, and resistance to cigarette burn affected. However, this did not affect the cracking and steaming properties of laminated samples.

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