Surface Properties of Oriented Strand Board Coated by Electrostatic Dry Powder Spray Deposition Technique

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Use of electrostatic powder coating technology for wood-based panels has considerably increased in the last decade. In this study, oriented strand boards (OSB; OSB/2 and OSB/3 grades) were coated with powder coatings using an electrostatic corona spray gun. Epoxy/polyester (hybrid:1/1) coating that is suitable for indoor applications was applied to the surface of OSB specimens (150 g/m^2) at three different curing temperatures, 120 °C for 15 min, 140 °C for 10 min, and 160 °C for 10 min using the electrostatic corona gun. The surface properties of the OSB specimens, roughness, wettability, scratch resistance, abrasion resistance, and film thickness were determined. The abrasion resistance and scratch resistance of the coated OSB specimens improved with increasing curing temperature from 120 to 160 °C. The highest mechanical surface strength was obtained from the OSB/3 specimens cured in the infrared oven at 160 °C for 10 min, while the lowest strength was found in the OSB/2 specimens cured in the infrared oven at 120 °C for 15 min. The contact angle values of the coated OSB specimens increased with increasing curing time, while the surface roughness decreased. The curing temperature of the electrostatic powder coating may be a useful indicator to users to obtain better surface quality on the substrate.

Keywords: Electrostatic powder coating; Oriented strand board; Surface properties; Wood

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INTRODUCTION

Oriented strand board (OSB) is one of the most commonly used structural wood-based panels in the construction industry used in places such as walls and roof siding. In addition to the construction industry, the furniture industry has recently become interested in OSB material as a substrate for indoor and outdoor furniture and home decor due to its significant advantages such as low price and low density, high mechanical properties, and good dimensional stability (Hiziroglu 2009).

Solvent-based paints, such as alkyd or oil-based paints, release considerable amounts of organic solvents that carry a sharp odor and are poisonous for humans in unventilated spaces (Piper 1965). The volatile organic compounds (VOCs) released from wood-based panels coated with solvent-based paints are harmful to human health because they contain toxic chemicals. For this reason, there is an increasing global interest in electrostatic powder coatings by panel-type furniture manufacturers due to their significant advantages such as a lower environmental impact, lower VOCs, low cost, design flexibility, toughness and durability, chemical and moisture resistance, seamless finish, and the ability to cut/drill without causing damage (Schmidt *et al.* 2013; Li and Zhang 2018). Unlike conventional liquid paints, the electrostatic thermosetting powder coating technology does not require a solvent with filler parts and binder in the liquid form (Okadaa *et al.* 1998; Schmidt *et al.* 2013). This alternative coating gives off significantly lower VOCs because it does not contain any carrier. The efficiency of this technique can be enhanced to 95 wt% material usage by collecting the powder (Ajer 2012). The most commonly used thermosetting powders are epoxy, polyester, epoxy/polyester hybrid, polyurethane, acrylic, and hybrid composition.

The application of powder coatings is different from the application of traditional wet coatings. The powder coatings are applied on the material surface using electrostatic forces. Coating application is performed using an electrostatic spray gun on the surface of the pre-heated substrate. The charged powder particles adhere to the surface of the pre-heated substrate until melted and cured into a uniform textured or smooth coating in an infrared oven (Jocham *et al.* 2011). The thermosetting powder coating melts and flows out on the surface of the substrate during cooking. After a while, the coating is cured on the surface, which results in a network structure of crosslinked polymers with a higher molecular weight. In the last decade, powder coating technology has gained great interest by furniture manufacturers due to its five significant advantages such as its efficiency, cost effectiveness, prvoides an excellent finish, potential energy savings, and usage of an environmentally friendly material.

Unlike natural woods, sanded OSB panels have a homogeneous surface and sufficient moisture content to provide conductivity of the powder coatings. Currently, there is no research on the surface properties of OSB painted by electrostatic powder coating technology. Polyester-epoxy powder coatings were used in the experiments because these powders are widely used for a variety of indoor applications (Wuzella *et al.* 2011, 2014). The OSB specimens coated with powder coatings can be an alternative to melamine paper overlaid MDF or particleboard for indoor furniture due to its high mechanical properties, especially its low deflection rate for bookcase shelves and countertops. The curing step is critical for the application of powder coatings. In this study, surface roughness and wettability of the OSB/2 and OSB/3 type panels coated with electrostatic powder painting by a corona gun were studied.

EXPERIMENTAL

OSB Panels

Two types (OSB/2 and OSB/3) of commercial OSB panels produced by Kronospan factory located in Kastamonu City, Turkey, were purchased from the local market. The technical specifications of the OSB/2 and OSB/3 are given in the EN 300 (2006) standard. The OSB panels were produced from a mixture of pine and aspen strands with a size of 125 mm × 240 mm and thickness of 11 mm and 10 mm, respectively. Prior to the powder coating process, the OSB panels were cut into samples with dimensions of 500 mm × 500 mm using a planar saw. The top and bottom sides of the OSB specimens were sanded with 60-grit sandpaper in a sanding machine (Makita Corporation, Aichi, Japan) to obtain a smooth surface before the paint application. A total of 12 test specimens, three replicates for each test group (three treatments: 120 °C, 140 °C, and 160 °C, and one control), were cut from the OSB/2 and OSB/3 panels. The test specimens were conditioned to a constant mass at a temperature of 20 °C and a relative humidity of 65%. The air dry density values of the OSB/2 and OSB/3 were 0.593 g/cm^3 and 0.643 g/cm^3, respectively.

Powder Coatings

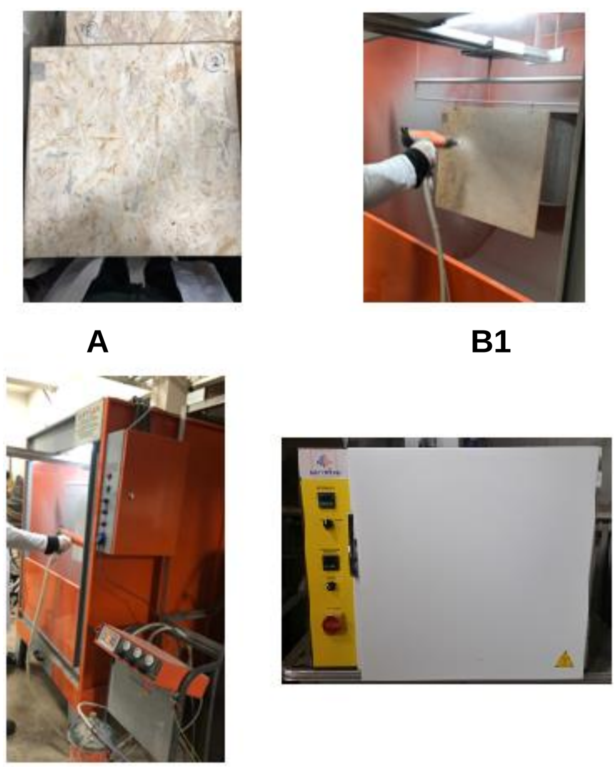
The electrostatic powder coatings (code: RAL 9016) for interior application were supplied by a commercial powder coatings company in Istanbul, Turkey. The technical properties of the powder coating (epoxy/polyester hybrid: 1/1) are given in Table 1.

Table 1. Properties of Powder Coatings (Epoxy/Polyester:1/1; Code: RAL 9016)

Test	Unit	Standard	Value
Physical Tests			
Gloss	(60°)	EN ISO 2813 (2014)	5 to 95
Impact resistance	kg.cm	EN ISO 6272-1 (2011)	80 to 100
Flexibility	mm	EN ISO 1520 (2006)	7 to 8
Buchholz indentation test	-	EN ISO 2815 (2003)	90 to 100
Cross-cut	Gt	EN ISO 2409 (2013)	0
Density	g/cm^3	EN ISO 8130-3 (2010)	1.30 to 1.70
Flow property	-	EN ISO 8130-5 (2010)	120 to 175
Chemical Tests			
Corrosion test (salt test)	h	EN ISO 9227 (2012)	1000+
UV-induced degradation	ΔE	300 W 48 h	< 2.80
Resistance to temperature	ΔE	200 °C to 120 min	< 2.80

Application of the Powder Coatings on the OSB Surface

The application of the powder coating to the surface of the OSB panels was performed using an electrostatic powder coating system (Boysan® Electrostatic Powder and Wet Coating Application Systems, Istanbul, Turkey) under laboratory conditions.



B2 **B3**

Fig. 1. A: OSB panel. B1 and B2: Application of powder coatings on the surface of OSB panels using the corona spray gun. B3: Infrared oven for curing of powder coating

The test specimens were pre-heated in an infrared oven for 5 min. The application of the powder coating on the sanded OSB surfaces was applied with a corona spray gun, which is the most common way of applying the powder coating to a material surface (Fig. 1). The OSB specimens were conditioned at 6 °C for 25 min to allow for dew to form on the surface of the OSB, which increased surface conductivity enough to attract the powder coating. Powder coatings were electrostatically applied by charging the powder particles at the tip of the corona spray gun (Electron® Powder Coating Company, Istanbul, Turkey). The gun imparted a negative electric charge to the powder, which was then sprayed towards the OSB specimens with compressed air and then accelerated toward the workpiece by the powerful electrostatic charge. The powder paint application on each specimen surface with dimensions of 500 mm × 500 mm was completed in 2 min. The power and air-velocity of the electrostatic corona gun were 50 kV and 80 µA, respectively. After the powder coating application by the corona gun, the OSB specimens were immediately placed in the infrared oven (Saramco®, Istanbul, Turkey) so that the powder coating was fully cured onto the substrate. The amount of the cured epoxy/polyester coating on the OSB surface was 150 g/m^2.

Determination of the Coating Thickness

Film thickness is one of the important indices of coating performance and appearance. Just like wood and wood-based panels have a complex structure, the values of film thickness measurement have a different variance. The layer thicknesses of the coatings of the OSB specimens were measured with PosiTector 6000 coating thickness gauge (DeFelsko® Corporation, Ogdensburg, NY, USA**)** between 20 µm and 300 µm. This was a non-destructive testing procedure.

Determination of Wettability and Surface Roughness

The contact angle values of the specimens were determined using the contact angle measuring instrument (KSV-CAM-101; KSV Instruments® Ltd., Helsinki, Finland) and image analysis software (CAM2008®; KSV Instruments® Ltd., Helsinki, Finland). The digital images of the the 5 µL droplet of the distilled water were recorded by a video camera at 1 s intervals up to 10 s. Five OSB specimens were used for each treatment. A total of 10 measurements for each treatment, two measurements for each specimen, at different points were taken from the specimens.

The surface roughness (µm) of the coated OSB panels was determined using a stylus method according to EN ISO 428 (1998)/A1 (2009) standards. The three main surface roughness parameters were R_a: arithmetic mean deviation of the measured profile, R_z: maximum height of the measured profile, and R_q: the root mean square deviation of the measured profile. Five specimens with dimensions of 100 mm × 100 mm were used for each OSB group. A total of 5 measurements for each specimen, for a total of 25 specimens for each OSB group, were taken from the Mitutoyo Surftest® (SJ-301, Mitutoyo® Inc. Kawasaki, Japan) equipment. The measurement points on the specimens were selected to represent all the surfaces of the OSB specimen.

Determination of Abrasion Resistance and Scratch Resistance

The abrasion test was conducted by fixing the specimen to a rotating table. The specimen was fixed on the rotating table of a Taber® rotary abraser (Model: 5131; Taber® Industries, North Tonawanda, NY, USA). The two abrasive wheels were coated with S-42 sandpaper and additional weights (500 g for each wheel) were fixed. The specimens were then rotated to cause abrasive friction between the wheels and the specimen surface. The number of cycles needed to wear out ¾ of the coated specimens was recorded as the abrasion resistance. The scratch resistance was measured with a motorised Taber® shear/scratch test equipment (Model: 551; Taber® Industries, North Tonawanda, NY,, USA). The abrasion resistance and scratch resistance of the specimens were determined according to EN 438-2 (2016) + A1 (2018) standards. Three specimens were used for each treatment.

RESULTS AND DISCUSSION

The contact angle values of the OSB specimens at different intervals (1 s, 5 s, and 10 s) are given in Table 2. For example, the lowest contact angle for 5 s (58.8°) was found in the OSB/2 specimens treated at 120 °C for 15 min in the infrared oven, while the highest contact angle (68.4°) for 5 s was found in the OSB/3 specimens coated at 160 °C for 10 min. A low contact angle (below 90°) is important to achieve a strong adhesion bond between coatings and substrate surface. Liquid coatings, such as paint, varnish, and adhesives, should be able to adequately wet the substrate surface to achieve proper physical adhesion. The contact angle values of coated OSB/3 specimens were higher than those of the OSB/2 specimens. The increase in the curing temperature decreased the wettability of the coated OSB specimens. The contact angle values of the coated OSB specimens decreased approximately from 3° to 4° with increasing wetting time (from 1 s to 10 s) (Table 2).

Table 2. Contact Angle Values of the Coated OSB Specimens

OSB Type	Infrared Oven Conditions		Contact Angle (°)		
	Curing Temperature (°C)	Curing Time (min)	1 s	5 s	10 s
OSB/2	120	15	59.7 (2.4)	58.8 (1.8)	56.2 (3.4)
OSB/2	140	10	62.2 (3.6)	61.4 (2.7)	59.1 (2.2)
OSB/2	160	10	65.7 (2.8)	64.4 (2.5)	61.6 (3.7)
OSB/3	120	15	62.8 (3.3)	61.0 (3.2)	60.2 (3.6)
OSB/3	140	10	66.4 (2.9)	64.1 (4.0)	63.4 (3.1)
OSB/3	160	10	70.7 (37)	68.4 (3.7)	67.3 (2.9)

* The values in the paranthesis are the standard deviations

The surface roughness graphs of the control and coated OSB/2 and OSB/3 specimens are presented in Figs. 2 and 3, respectively. For the OSB/2 specimens, the lowest surface roughness was obtained at the 160 °C curing temparature, followed by 140 °C and 120 °C. For example, the R_a value of the OSB/2 specimens cured at 160 °C specimens was measured as 3.62 µm while it was 6.20 µm at 160 °C (Fig. 2). When the curing temperature was increased from 120 °C to 160 °C, the surface became smoother. A similar trend was also observed for the OSB/3 specimens (Fig. 3). The results clearly showed that increasing the curing temperature in the infrared oven for powder coatings improved the surface smoothness of the coated OSB specimens. A similar result was reported by Barletta *et al.* (2007). In another study, Andrei *et al.* (2000) investigated an acrylic powder coating on metal surfaces, which showed an improvement in surface finishing as the curing temperature was increased in the oven. This may be due to fully curing the coating onto the OSB substrate, which works to make the surface more compact and reduce the micro voids on the surface. The surface roughness of the coated OSB specimens were higher than coated wood-plastic composites (WPCs). In a previous study, Ayrilmis *et al*. (2016) investigated the surface roughness of painted WPC produced from wood (60 wt%), polypropylene (37 wt%), and coupling agent (3 wt%). The cited authors found the average roughness values of the WPCs painted with solvent and water-based paints as 2.5 µm and 2.75 µm, respectively.

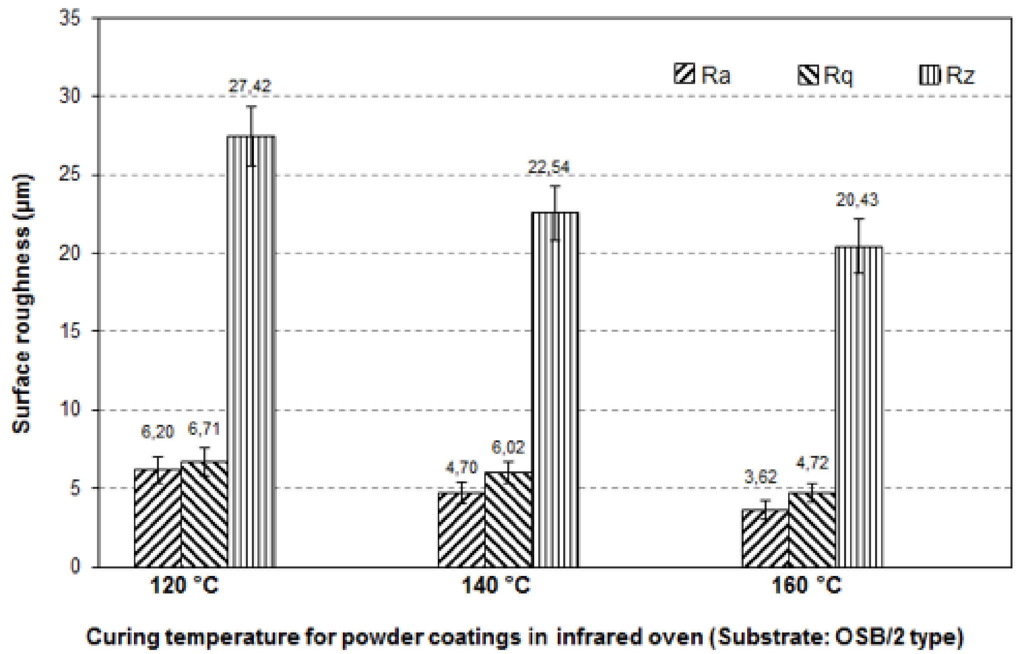


Fig. 2. Surface roughness of OSB/2 panels as a function of curing temperature of powder coatings

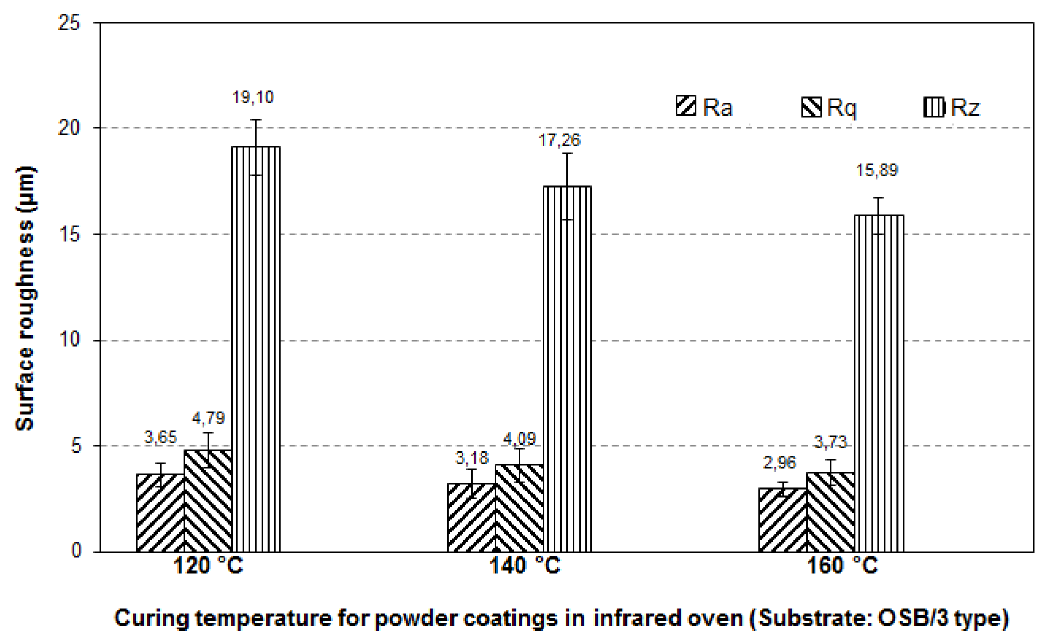


Fig. 3. Surface roughness of OSB/3 panels as a function of curing temperature of powder coatings

The coating should penetrate the substrate deeply to obtain a good bond performance, which requires that the polymeric material functions as a mechanical anchor. The wettability and surface roughness are two important parameters influencing the penetration depth of coatings and the mechanical interlocking between the substrate and coating. The contact angle values increased with increasing curing temperature (Table 2). This can be partly explained by the surface roughness values. The contact angle values decreased with increasing surface roughness, which enhanced the wettability. Surface roughness and capillary condensation improve the surface wettabiliy as a secondary effect (Fuji *et al.* 2000).

The dry film thickness of the coated OSB specimens changed from 146.1 µm to 150.6 µm. The abrasion resistance and scratch resistance of the coated OSB specimens are given in Table 3. The highest abrasion and scratch resistance were found in the OSB/3 specimens cured in the infrared oven at 160 °C for 10 min while the lowest surface resistance was found in the OSB/2 specimens cured in the infrared oven at 120 °C for 10 min.

The results showed that increasing curing temperature considerably improved the abrasion resistance and scratch resistance of the OSB panels coated with powder coatings. This may be due to the crosslinking mechanism in the powder coatings. The results showed the surface mechanical properties of the coated OSB were considerably affected by the degree of crosslinking of powder coatings during the curing process. A good surface strength for coatings, such as wear endurance and scratch resistance, can be obtained by higher curing temperature (Barletta *et al.* 2007).

Table 3. Film Thickness, Abrasion and Scratch Resistance of Coated OSB Panels Depending on the Curing Tempeature

OSB Type	Infrared Oven Conditions		Film Thickness (µm)	Abrasion Resistance (Rev.)	Scratch Resistance (N)
	Curing Temperature (°C)	Curing Time (min)			
OSB/2	120	15	150.6 (4.4)	185 (5.1)	1.95 (0.15)
OSB/2	140	10	147.3 (3.8)	215 (6.4)	2.02 (0.21)
OSB/2	160	10	146.1 (4.6)	220 (7.8)	2.21 (0.17)
OSB/3	120	15	149.5 (5.1)	195 (5.7)	2.16 (0.14)
OSB/3	140	10	146.0 (3.7)	241 (7.0)	2.32 (0.19)
OSB/3	160	10	148.8 (4.0)	258 (8.3)	2.45 (0.24)

Increasing the severity of curing conditions makes the coating film able to better resist the action of the indenter during the abrasion and scratch tests (Andrei *et al.* 2000). In a previous study, Akkuş *et al.* (2019) determined the scratch resistance of the particleboard and medium-density fibreboard coated with epoxy/polyester powder coatings was 2.80 N and 2.50 N, respectively. Barletta *et al.* (2007) observed a good visual appearance in the early phase of the curing of the coating while scratch resistance was still poor.

They concluded that increasing the curing temperature did not show a significant effect on the visiual appearance, but the adhesion of coating and abrasion resistance were strictly related to curing temperature and time. This is because a fully cured thermosetting coating shows its full potential regarding abrasion and scratch resistance.

CONCLUSIONS

1. The mechanical surface percormance of the oriented strand board (OSB) panels increased with increasing curing temperature of the powder coating. For example, the abrasion resistance and scratch resistance of the coated OSB/2 specimens increased from 185 to 220 Rev. and 1.95 to 2.21 N, respectively, as the curing temperature increased from 120 to 160 °C. The surface mechanical performance of the OSB/3 specimens was better than OSB/2 specimens.
2. The contact angle values of the coated OSB specimens increased with increasing curing temperature while the surface roughness decreased. The contact angle values of the coated OSB/2 specimens (58.8 to 64.4°) and OSB/3 specimens (61.0 to 68.4°) increased as the curing temperature of the powder coating increased from 120 to 160 °C. The average roughness of the OSB/2 specimens (6.20 to 3.62 µm) and OSB/3 specimens (3.65 to 2.96 µm) decreased as the curing temperature increased from 120 to 160 °C.
3. The film thicknesses (150.6 to 146.1 µm for OSB/2, and 149.5 to 148.8 µm for the OSB/3) of the OSB specimens was not considerably affected by the increased curing temperature (120 to 160 °C).
4. Based on the findings, it could be said that the optimum curing condition for epoxy/polyester coating was 160 °C and 10 min among the treatments tested.
5. The curing temperature of the electrostatic powder coating may be a useful indicator to users to obtain better surface quality on the OSB substrate.

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Article submitted: October 31, 2019; Peer review completed: December 31, 2019; Revised version received: January 8, 2020; Accepted: January 9, 2020; Published: January 14, 2020.
DOI: 10.15376/biores.15.1.1521-1530