Applied Thermal Engineering 102 (2016) 716–719

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research Paper

Effect of dehumidification drying environment on surface gloss of one component waterborne wood top coating

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HIGHLIGHTS

- Surface gloss is increasing with the increasing air temperature and relative humidity and the decreasing air velocity.
- Surface gloss is highly affected by the relative humidity.
- Significantly different amount of surface gloss is 2.2% and above, and highly significant different amount is 5.0% and above.

ARTICLE INFO

Article history:
Received 9 December 2015
Revised 5 April 2016
Accepted 7 April 2016
Available online 8 April 2016

Keywords:
Dehumidification drying
One component waterborne wood top coating
Surface gloss
Duncan's multiple range test analyses

ABSTRACT

One component waterborne wood top coating is dried by dehumidification drying method. An orthogonal experimental design is used to investigate the effect of the air temperature, relative humidity, and air velocity on the surface gloss. The Duncan's multiple range tests are used to analyze the difference between the means of a set of observations. Surface gloss increases as the air temperature and the relative humidity increase, whereas decreases as the air velocity decreases. Relative humidity has a more significant effect on surface gloss than the air velocity, which has a more significant than the air temperature. The difference in surface glosses is significant when the difference in the means is greater than or equal to 2.2%, and is highly significant when the difference is greater than or equal to 5.0%. The results can be used as practical standards to judge differences of surface gloss in different drying environments.

1. Introduction

China is a global leader in manufactured and exported furniture products with many solvent wood coatings being produced, and a huge amount of harmful volatile organic compounds (VOCs) being exhausted [1]. To cope with these problems, waterborne wood coatings are substituted for solvent coatings [2]. Drying of one component waterborne wood coatings is necessary to achieve a high quality coating, which affects the production cost and work efficiency and application of coating [3,4]. Coatings are dried with natural drying and hot air drying methods with the former using the atmosphere environment whereas the latter being heated with hot water vapor and electricity with convection. Natural drying does not consume industry energy; however, the drying rate is low and the quality of coating is inconsistent [5,6]. For hot air drying, the consumed energy is huge because of the high latent heat of water evaporation. The relative humidity cannot be controlled and the quality of coating is affected [7]. In the process of film formation, the relative humidity plays a more important role than the temperature on the coating quality. Therefore, dehumidification is more effective than heating up in improving the quality of the coating quality and accelerating the drying speed [8]. In the furniture manufacturing workshop where the air relative humidity is high, a dehumidifier can be used necessarily to avoid defects of the waterborne wood coating [9]. Dehumidification drying is an environment-friendly and energy-saving inprocess to drying one component waterborne coating [10].

The qualities and the drying processes of the coatings have been extensively studied. Adhesion was affected by various factors, such as: the cellar anatomy [11], sanding of wood [12], crosslinking agent, wetting agent and accelerator [13], the viscosity and amounts of the coating [11], penetration into the wood [14],

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http://dx.doi.org/10.1016/j.applthermaleng.2016.04.026
1359-4311/

relative humidity and temperature of air in the drying environment [15–17], the drying process and film formation [14]. The water resistance was enhanced by various methods, such as: core shell structure latex with polymerization process, introducing crosslinking monomers with double acetone and diplomatic agents, and adding silicone resin emulsion [18]. Moisture in the coating affects the roughness of the wood and the surface gloss of coating. As the moisture content increases, the hardness decreases, and the surface gloss increases [19]. Anti-ultraviolet material can increase the aging resistance property of the coating [20,21]. Results of the aging resistant performance of waterborne acrylic coating, polyurethane coating, acrylic modified polyurethane coating, and alkyd coating show that the waterborne polyurethane coating exhibited more favorable effects and the surface gloss quality remained unchanged throughout the testing process [22]. The chromatic value of one component polyurethane with the spraying method is the highest; however, one component acrylic-modified polyurethane, which is applied with brushing or roller coating, exhibits the lowest chromatic value [23].

The surface gloss can be used to judge the surface quality of coating, which is seriously affected by the drying conditions. The investigation is conducted to explore the effect of air temperature, relative humidity, and air velocity in dehumidification drying environment on surface gloss of one component waterborne wood top coating. The result of this research can provide insights into the use of dehumidification drying on one component waterborne wood top coating, which will prompt the application of waterborne wood coatings in the furniture industry.

2. Materials and methods

In order to investigate the interactions among air relative humidity, temperature, and velocity, an orthogonal experimental design ($L_9(3^4)$) is conducted (Table 1). Three variations in air relative humidity (50%, 55%, and 60%), air temperature (30 °C, 35 °C, and 40 °C), and air velocity (0.30 m/s, 0.60 m/s, and 0.90 m/s) are tested.

Sugar maple (*Acer saccharum*) veneered panels are cut into samples, which dimensions are 150 mm in length and 100 mm in width and 3 mm in thickness. The panels are 10–12% in moisture content and are 2.39–3.58 μm in surface roughness. The dimensions are measured with digital calipers (Model SF 2000 111-101B, Guanglu Co., Guilin, China), and the moisture content is tested using a wood moisture content meter (Model KT-50, Klortner Co., Italy). The surface roughness is measured with a small-sized surface roughness measure meter (Model Time TR 100, Times Top Science and Technology Co., Beijing, China). Ninety samples are prepared.

A constant temperature and relative humidity chamber (Model XL-BR-21S-A, Xin Lang Electrical Science and Technology Co., Shanghai, China) is used for the initial drying process. It is 23 °C in air temperature, 50% in relative humidity, and 0.3 m/s in air velocity. Top coating is dried in the dehumidification drying chamber (Model XL-BR-5P-A, Xin Lang Electrical Science and Technology Co., Shanghai, China). Air relative humidity and temperature are measured using a temperature and relative humidity electrical meter (Model 310 RS-232, Center Technology Co., Taiwan, China), and air velocity is measured using a thermo ball electrical wind velocity meter (Model QDF-3, Inspection Equipment Co., Beijing, China).

There are six layers of coatings on every panel, including two layers of sealer and two layers of primer and two layers of top coating. One component waterborne wood sealer with 43.90% total solids content is tested using a halogen moisture detector (Model JT-K6, Jingtai Co., Taizhou, China), and 60 g/m^2 of spray, which is measured using an electrical balance (Model JA21002, Shanghai Jingtian Electrical Instrument Co., Shanghai, China) with a precision of 0.01 g. The primer contains 36.63% total solids content and 100 g/m^2 of spray, and the top coating contains 36.63% total solids content and 120 g/m^2 of spray. The wood panels are painted using the air spraying method (Chaoren 2007).

After spraying, the samples with the first layer of sealer are dried for 4 h at a constant temperature (23 °C) and relative humidity (50%) in a chamber with an air velocity of 0.3 m/s. The dried sealer is sanded with 400 grit sandpaper. The second layer of sealer is sprayed and dried for 4 h in the same manner. After the sealer is dried, the wood is sanded with 400 grit sandpaper again. Then, the first layer of primer is sprayed and dried for 14 h. The first layer of dried primer is sanded with 400 grit sandpaper. Next, the second layer of primer is sprayed, dried for 4 h, and sanded with 600 grit sandpaper. Finally, the first layer of top coating is sprayed, dried for 15 h, and sanded with 800 grit sandpaper.

The drying parameters, such as air temperature, relative humidity, and air velocity in the dehumidification drying chamber are specified in Table 1. After painting, the samples with the second layer of top coating are dried for 4 h in the dehumidification drying chamber. The surface gloss at 60° of the dried coating is tested according to the standard which is "Paints and varnishes – determination of specular gloss of non-metallic paint films at 20°, 60°and 85°" (GB/T 9754-2007, China) [24]. The surface gloss is measured with a gloss meter (Model GZ-II, Shibo Weiye Glass Instrument, Tianjin, China). The test is repeated 10 times in every dehumidification drying condition.

Duncan's multiple range test analyses methods in Data Processing System (DPS) are used to study the differences in the mean values of the surface gloss between experiments.

Table 1
Orthogonal experimental design L_9 (3^4).

Experiment no.	Air temperature (°C)	Air relative humidity (%)	Air velocity (m/s)
1	30	50	0.3
2	30	55	0.6
3	30	60	0.9
4	35	50	0.6
5	35	55	0.9
6	35	60	0.3
7	40	50	0.9
8	40	55	0.3
9	40	60	0.6

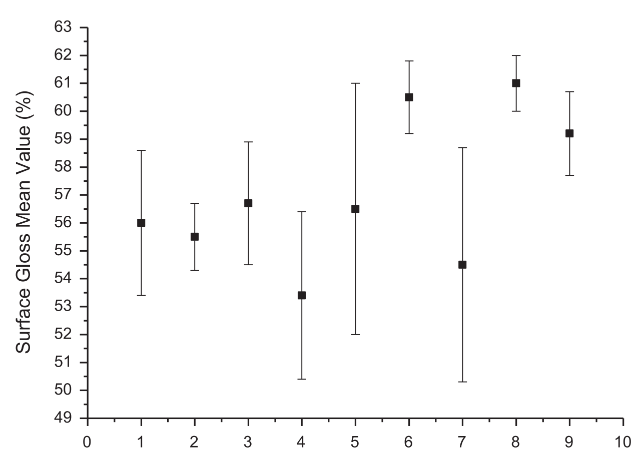

Fig. 1. Surface gloss of the second layer of top coating.