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Effects of dehumidification drying environment on drying speed of one component waterborne wood top coating

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ABSTRACT

In this study, the effects of dehumidification drying environment including air temperature and relative humidity and velocity on drying speed of one component waterborne wood top coating are studied by Orthogonal experimental design and the results are analyzed creatively by Duncan analyses. It is found that during the dehumidification drying process, hard drying time is decreasing with the increasing air temperature and velocity and decreasing relative humidity. Air velocity is extremely significant to hard drying time, which is more significant than relative humidity, and relative humidity is more significant than air temperature. The difference of hard drying time is significant when the difference is 5 min and above, and it is extremely significant when the difference is 10 min and above, which are critical to judge the hard time in practice.

1. Introduction

More and more one component waterborne wood coatings are used in Chinese furniture industry because that they are environmental friendly [1–11]. Coatings are dried usually by natural drying and hot air drying [12–31]. In natural drying process, the drying speed is low and the quality of coating is unstable because that air temperature and relative humidity and velocity cannot be controlled [32,33]. Drying speed of coating is accelerated in furniture industry with hot air drying in order to meet the requirement of manufacturing efficiency [34–36]. However, the energy consume is big because that the latent heat of water evaporation is high. Relative humidity cannot be controlled and quality of coating is affected [37,38]. Relative humidity is more important than temperature in order to improve quality of coating and accelerate the drying speed, thus dehumidification is more effective than heating up [28–31].

Dehumidification drying coating is environmental friendly and energy-saving and fast speed [39–43]. Coating is dried in a closed chamber without gas exchanges between inside and outside room and no volatile organic compounds being exhausted. Heat pump dryer emerge from the ability of heat pumps to recover energy from the exhaust as well as their ability to control independently the drying air temperature and relative humidity [42]. In the range from 35 °C to 55 °C in air temperature and 50% to 70% in air relative humidity, drying speed is accelerated with the decreasing relative humidity, the effect of relative humidity to drying speed is greater than that of temperature [15–31].

Therefore, the objective of the project is to contribute to the understanding of dehumidification drying method to dry one component waterborne wood top coating by investigating the effects of air temperature and relative humidity and velocity on drying speed. The result of the research can provide the theory basis for dehumidification drying used to dry one component waterborne wood top coating, which is benefit to prompt the application of waterborne wood coatings in the furniture industry.

2. Materials and methods

Sugar maple (*Acer saccharum*) veneered panels which are bought in the market (150 mm × 100 mm × 3 mm, the dimensions are measured with three-keyboard digital calipers (Guanglu Co., Model SF

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2000 111-101B, Guilin, China)) are cut with 10–12% in moisture content which is tested with wood moisture content meter (Klortner Co., Model KT-50, Klortner, Italy), and 3.02–3.85 μm in surface roughness which is measured with small sized surface roughness measure meter (Beijing Time High Technology Co., Model TR 100, Beijing, China). 225 samples are made totally. Among these samples, 25 ones are used for drying time test of top coating in every dehumidification drying condition.

One component waterborne wood sealer and premier and top coating which belong to the acrylic and polyurethane and acrylate modified polyurethane binders are used in the study. The density of the liquid sealer is 1.08 g/cm^3, the one of the liquid premier is 1.05 g/cm^3, and the one of the liquid top coating is 1.05 g/cm^3. There are six layers of coating on every wood sample, including two layers of sealer and two layers of primer and two layers of top coating. One component waterborne wood sealer with 43.90% in solid content which is tested with halogen moisture detector (Jingtai Co., Model JT-K6, Taizhou, China), and 60 g/m^2 in spraying content which is measured with electrical balance (Shanghai Jingtian Electrical Instrument Co., Model JA21002, Shanghai, China) with precision of 0.01 g, primer with 36.63% in solid content and 100 g/m^2 in spraying content, top coating with 36.63% in solid content and 120 g/m^2 in spraying content, are painted on the wood panels with air spraying method.

After painting, the samples with the first layer of sealer are dried for 4 h in the constant temperature and relative humidity chamber (Xin Lang Electrical Science and Technology Co., Model XL-BR-21S-A, Shanghai, China) where temperature of air is 23 °C and relative humidity of air is 50% and air velocity is 0.3 m/s, shown in Fig. 1. The dried sealer is sanded with 400 grit sand paper. Then the second layer of sealer is sprayed and dried for 4 h in the environment as same as the first layer of sealer. The dried sealer is sanded with 400 grit sand paper also. Likewise, the first layer of primer is sprayed and dried for 14 h, and the second layer of primers are sprayed and dried for 4 h in the same environment. The first layer of dried primer is sanded with 400 grit sand paper. The second layer of dried primer is sanded with 600 grit sand paper. The first layer of top coating is sprayed and dried for 15 h in the same environment. The first layer of dried top coating is sanded with 800 grit sand paper.

In order to investigate the interaction among relative humidity of air and temperature and velocity to the drying speed of top coating, the orthogonal experimental design named by $L_9(3^4)$is planned, shown in Table 1. The relative humidities are divided into three levels at 50%, 55%, and 60%. Likewise, temperatures are divided into three levels at 30 °C, 35 °C, and 40 °C, velocities are divided into three levels at 0.30 m/s, 0.60 m/s, and 0.90 m/s.

Drying parameters in the dehumidification drying chamber (Xin Lang Electrical Science and Technology Co., Model XL-BR-5P-A, Shanghai, China) are set up to the designed condition in experiment number from 1 to 9 according to Table 1 separately, shown in Fig. 2. After painting, the samples with the second layer of top coating are dried in the dehumidification drying chamber. Temperature and relative humidity of air are measured with temperature humidification electrical meter (Center Technology Co., Model 310 RS-232, Taiwan, China) and air velocity is measured with thermo ball electrical wind velocity meter (Beijing Detecting Instrument Co., Model QDF-3, Beijing, China). Hard drying time is the moment when the coating is dried to hard drying degree. At this time, the coating is pressed by finger and there is not finger print on the coating. It is tested by A Method in Methods of Test for Drying Time of Coatings of Paints and Putties according to GB/T 1728 (1979) China standard [44]. Drying time meter (Biaogeda Co., BGD 263, GuangZhou, China) is used to test hard drying time of top coating.

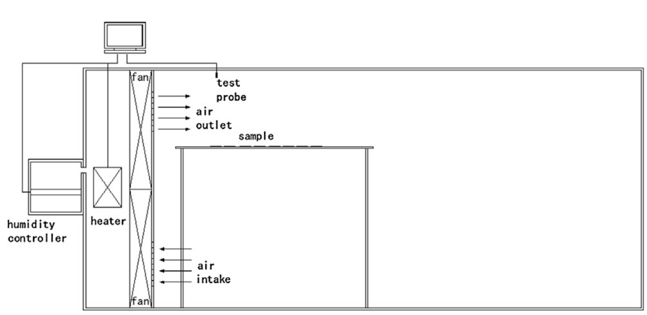

Fig. 1. Scheme on the constant temperature and humidity chamber.

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

Experiment no.	Air temperature (°C)	Relative humidity of air (%)	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

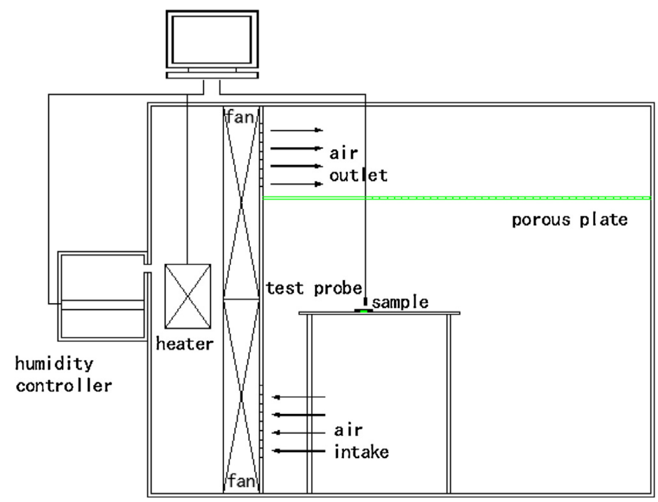

Fig. 2. Scheme on dehumidification drying chamber.

3. Results and discussion

3.1. Difference degree analysis of hard drying time

Drying speed of top coating is influenced by drying environment which can be proved by Table 2, the longest hard drying time is 40 min, the shortest one is 24 min, and the difference is 16 min.

In order to discuss the difference of hard drying time, the Duncan significance analysis method is used creatively to study the average values of hard drying time.

To the average values of hard drying time, Experiment No. 6, 1, and 9,as same as that 8, 2, 3 and 4, 4 and 5, 5 and 7 are not significantly different in hard drying time at the 5% significance level. However, Experiment No. 8 and 6, 2 and 6, 3 and 6, 4 and 9, 4 and 1, 4 and 6, 5 and 3, 5 and 2, 5 and 8, 5 and 9, 5 and 1, 5 and 6, 7 and 4, 7 and 3, 7 and 2, 7 and 8, 7 and 9, 7 and 1, 7 and 6 are