Effect of Single Modification of Talcum Powder on Mechanical Properties and Optical Properties of Waterborne UV Curing Coatings

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Abstract. The talcum powder was employed for the single modification of waterborne ultraviolet (UV) curing wood coatings, through optimizing process parameters to prepare the waterborne UV curing wood coatings. It was found that when talcum powder content in Waterborne UV curing wood coatings was at 2.0%, the waterborne UV curing wood coatings was dried firstly in 50°C oven for 30 min and then under UV light irradiation for 3 min, the obtained waterborne UV curing wood coating had good hardness, adhesion and impact strength. But when the content of talcum powder was more than 2.0%, the mechanical properties of waterborne UV curing wood decreased. The gloss measurement showed that waterborne UV curing wood coating gloss decreased with the increased talcum powder content, and when the talcum powder contents were more than 2.0%, waterborne UV curing wood coating showed low gloss.

Introduction

Wood coatings are used for wood products and wooden furniture surface decoration and protective coatings [1]. Traditional wood coatings contain a large amount of harmful materials, seriously impacting on human health and the quality of the environment [2]. Therefore, it was gradually abandoned by people [3]. In recent years, waterborne UV curing wood coatings have the advantages of environmental protection, energy saving and fast curing, so it is widely used in the field of wood industry [4]. However, successful coating formulations have an important component that is gloss [5]. High gloss coating will cause some damage to eyesight, now sub light coating of low gloss products is favored more and more people [6]. Therefore, sub light coating of low gloss products in the field of wood coatings has great application space [7]. There are many factors which will affect wood coatings gloss, such as composition, curing conditions, construction and extinction agent [8]. However, waterborne UV curing coatings have the defects of poor mechanical properties and high gloss, which seriously affects its application in the surface of the wood [9]. Therefore, it will need to modify waterborne UV curing coatings to improve its mechanical properties and reduce gloss.

Talcum powder has the property of low hardness, low corrosion resistance, easy to disperse and easy to suspend. In the coating, talcum powder as a promoter action will be added to the coating which can reduce manufacturing costs and improve the coating hardness [10]. In this paper, the talcum powder was added to waterborne UV curing wood coating, through orthogonal experiment to achieve the composition and curing conditions of process parameters optimization, trying to improve the mechanical properties of waterborne UV curing wood coating and achieve the sub gloss.

Experimental

Materials

All reagents in the present experiment were pure and they have not been pre-treated. Waterborne UV curing wood coating was provided by the Guangdong Yihua Timber Industry Co. Talcum powder was provided by Shanghai Chemical Reagent Co., used as modifier.

Coating Preparation

A certain amount of waterborne UV curing coating was firstly poured out to the disposable cups, in order to facilitate the modification of the experiment. Then balance the pre-designed amount waterborne UV curing coatings and talcum powder, respectively. The pre-designed amount talcum powder was added to waterborne UV curing coatings, stirred with a glass rod. Finally, waterborne UV curing coatings were painted on the wood substrates which were coated the pre-treatment primer. The finished wood substrates were firstly put in the oven drying for 30 min, and the oven temperature was set at 40°C-50°C. Then the finished wood substrates were put in the UV curing machine for radiation curing with the medium pressure mercury UV lamp, and the lamp distance of 30 cm, UV lamp number of two and curing time of 1min-3min were controlled.

Testing and Characterization

The determination of GB6739-86 coating hardness pencil was used for determination of the hardness of waterborne UV curing wood coatings. According to GB 9286-1998, scribe adhesion test standard was used for measuring coating adhesion. According to GB/T1732-93, the impact strength of coating hammer was used for measuring the impact strength of waterborne UV curing wood coatings. The gloss of coating was tested by the gloss meter.

Results and Discussion

Orthogonal Experimental Analysis

The results of orthogonal experiments indicated the talcum powder content, oven temperature and UV irradiation time were to some extent influenced the gloss and mechanical properties such as adhesion, impact strength and hardness of waterborne UV curing wood coating. Comparatively speaking, the effect of talcum powder content on the gloss of waterborne UV curing wood coating is more obvious. Therefore, in the orthogonal experiment, the influence of the modification conditions on the gloss was mainly analyzed, then process parameters were further optimized and the influence of the modification on the mechanical properties was discussed. Table 1 shows the effect of the three factors (talcum powder content, oven temperature and UV irradiation time) on the waterborne UV curing coatings gloss. In this orthogonal experiment, the amount of three components was in the following range of experiments: talcum powder content (A): 1.0%-5.0%, oven temperature (B): 40°C-50°C, UV radiation time (C): 1min-3min. Two levels were selected in each factor. The first level of the factor A is the talcum powder content 1.0%, the second level of the factor A is the talcum powder content 5.0%. The first level of factor B is the oven temperature 40°C, the second level of factor B is the oven temperature 50°C. The first level of factor C is UV radiation time 3 min, the second level of factor C is UV radiation time 1 min. In the same column, the range (R) and the variance of the maximum average gloss and the minimum average gloss which corresponds to the same factor were calculated, listed in the last two rows in Table 1. The greater R and variance implied the more significant effect of factors.

As can be seen from Table 1, through compared their range R and variance values it can be found that talcum powder content had the most obvious effect on the modification of gloss of waterborne UV curing wood coating, and followed by the oven temperature and UV irradiation time. In addition, from Table 1 it can be clearly seen sample 4# of waterborne UV curing wood coatings has the minimum gloss value, compared to the sample 1#-3#, so in the independent test oven temperature was fixed at 50°C, UV radiation time was fixed for 3 min.

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Table 1 Talcum powder modified table of orthogonal experiment

Sample	Talcum powder content (%)	Oven temperature (ºC)	UV radiation time (min)	Gloss (%)
1#	1.0	40	3	70
2#	1.0	50	1	59
3#	5.0	40	1	41
4#	5.0	50	3	35
I	64.5	55.5	52.5	
II	38.0	47.0	50.0	
R	26.5	8.5	2.5	
Variance	702.25	72.25	6.25	

Effect of Talcum Powder on the Mechanical Properties of Waterborne UV Curing Wood Coatings

For the key role of talcum powder, on the basis of orthogonal experiment, a series of independent experiments were designed as follows: the oven temperature was fixed at 50°C, UV irradiation time was fixed for 3 min and the content of talcum powder were change to 0, 0.5%, 1.0%, 2.0%,3.0%, 4.0% and 5.0%, respectively. It was found that the content of talcum powder has a certain role on the hardness property of waterborne UV curing wood coatings. Figure 1 shows the changing trend of the effect of talcum powder content on the hardness of waterborne UV curing wood coatings. It can be seen that when talcum powder content increased from 0 to 0.5%, the hardness of waterborne UV curing wood coating increased from H to 2H. Continued to increase the content of talcum powder to 2.0%, the coating hardness still maintained 2H. This is because the good suspension and dispersion of talcum powder can be uniformly dispersed in waterborne UV curing wood coating. Therefore, talcum powder could improve the hardness of waterborne UV curing wood coating. But when the talcum powder content was more than 2.0%, the hardness decreased. This is because the talcum powder has a special layered structure and large ratio of diameter to thickness. With the increase of talcum powder content, the particles in the matrix dispersion will be worse, even occur reunion, therefore, the combination of waterborne UV curing wood coating to talcum power will be decreased which resulted in the decrease in hardness.

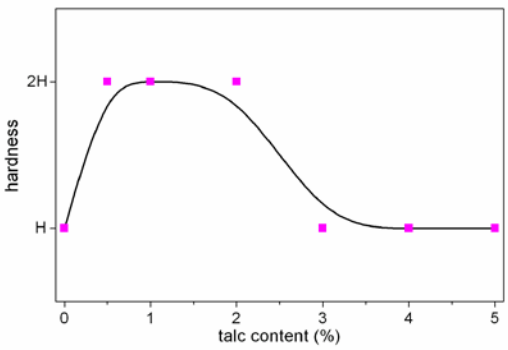

Fig. 1 Changing trend of the effect of talcum powder content on the hardness of waterborne UV curing wood coatings

The adhesion of the waterborne UV curing wood coatings shows the extent to which the coating is attached to the substrate under specified load. Figure 2 shows the changing trend of the effect of talcum powder content on the adhesion of waterborne UV curing wood coatings, and with the increased content of talcum powder the adhesion of the waterborne UV curing wood coatings showed "U" curve. As can be seen from Figure 2, with the talcum powder content increased from 0 to 0.5%, the adhesion varied greatly and increased from the third level to the first level. With the further increase of talcum powder content to 2.0%, the coating adhesion was better, was the first level. This is because with the increase of talcum powder particles, coating cohesion and mechanical interlock will increase, resulting in increased adhesion [11]. However, when the talcum powder content increased from 2.0% to 5.0%, the adhesion of waterborne UV curing wood coatings decreased, reached the second level. This is because the talcum powder is gathered in high content, and can not be uniformly dispersed [12].

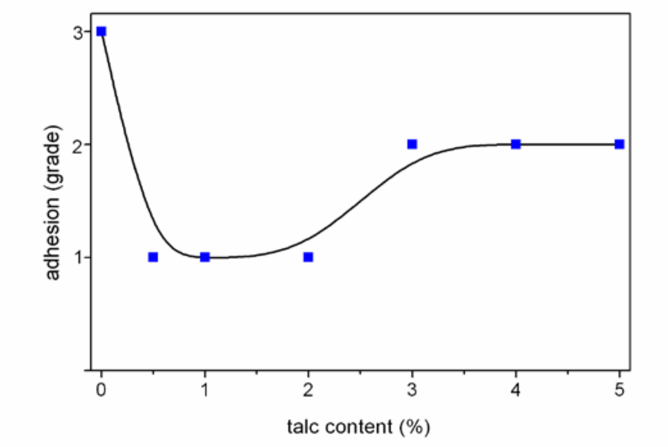

Fig. 2 Changing trend of the effect of talcum powder content on the adhesion of waterborne UV curing wood coatings

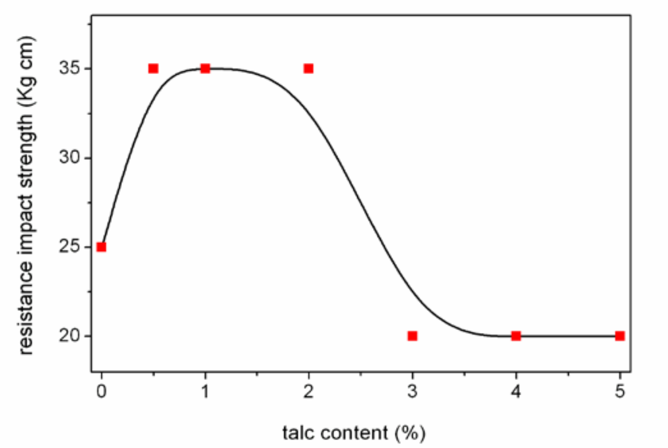

Fig. 3 Changing trend of the effect of talcum powder content on the impact strength of waterborne UV curing wood coatings

After the adhesion test, in order to further investigate the fatigue behavior of the waterborne UV curing wood coatings, the impact resistance of the coating was studied, as shown in Figure 3. Impact test is to test the dynamic loading capacity of the waterborne UV curing wood coating. As can be seen from Figure 3, when the talcum powder content increased from 0 to 0.5%, the impact strength from 25 Kg·cm increased to 35Kg·cm, and when the content of talcum powder further increased from 0.5%

to 2.0% impact strength of waterborne UV curing wood coatings maintained in 35Kg·cm. With the content of talcum powder continued to increase, impact properties of waterborne UV curing wood coating decreased. The change trend of adhesion trend is consistent with the dynamic impact experiments, implying that good adhesion of waterborne UV curing wood coatings ensured the good impact performance [13].

Effect of Talcum Powder on the Optical Properties of Waterborne UV Curing Wood Coatings

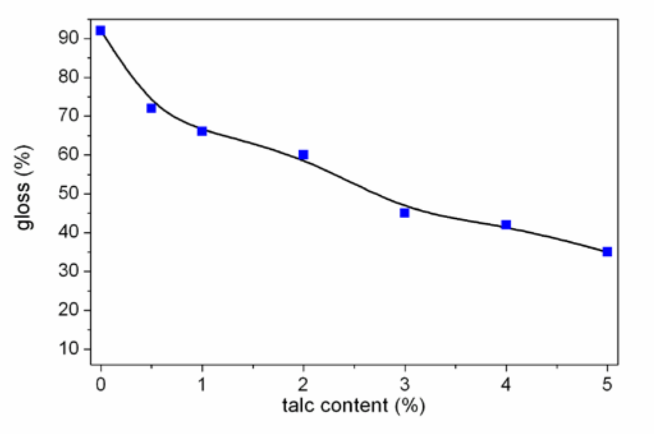

Fig. 4 Changing trend of the effect of talcum powder content on the gloss of waterborne UV curing wood coatings

The influence of talcum powder content on gloss of waterborne UV curing wood coatings is shown in Figure 4. From Figure 4 it can be seen that the gloss of the waterborne UV curing wood coating decreases with increase of the content of talcum powder. When the talcum powder content increased from 0 to 2.0%, the gloss of waterborne UV curing wood coating reduced from 92.0% to 60.0%. As the talcum powder content continued increasing from 2.0% to 5.0%, the gloss of waterborne UV curing wood coating continued to slowly decline from 60.0% to 35.0%, which had always maintained a lower value. Because the talcum powder in waterborne UV curing wood coatings is insoluble, volume concentration in the surface layer of waterborne UV curing wood coatings will continuously increased with talcum powder content, leading to the formation of micro roughness of surface. Scattering occurs when light is incident on the surface, thereby reducing the gloss of waterborne UV curing wood coating. When the talcum powder content increases to a certain value, the talcum powder will gather in the high content and it is difficult for the talcum powder to be dispersed, and the gloss of waterborne UV curing wood coating will decrease slowly.

Conclusion

The orthogonal experiment showed that the content of the mechanical properties of waterborne UV curing wood coatings depended largely on the content of talcum powder. Effect of content of talcum powder on the mechanical properties of the waterborne UV curing wood coating results showed that when the oven temperature was fixed at 50 °C, UV irradiation time was fixed for 3min and talcum powder content from 0 to 2.0%, the hardness of waterborne UV curing wood coating increased to 2H, adhesion increased from level 3 to level 1, impact strength increased from 25 Kg·cm increased to 35 Kg·cm. But when the talcum powder content was more than 2.0%, the hardness, adhesion and impact resistance performance of waterborne UV curing wood coatings decreased. Gloss results showed that the gloss of waterborne UV curing wood coating decreased with the increase of the content of talcum powder. When the talcum powder content was more than 2.0%, the waterborne UV curing wood coating exhibited low gloss.

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