The Effect of Pretreatment Method on the Decorative Effect of the Wax Furniture

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Abstract. In this study, the authors used hot wax selected from beeswax and insect wax. These two types of wax are blended with a 1: 1 ratio. Then use three methods of surface treatment before wax coating on the Ash wood surface including hydrothermal method, compound lye method, and plasma method. Through comparative analysis of 4 properties: color, adhesion, hardness and surface properties of the hydrophobic coating. The results show that the hot wax coating on the ash surface can maintain the original color of the wood. Comparison of three methods of wood treatment shows that: plasma method for the coating surface has the best adhesion, hydrothermal method for best surface hardness of the coating, and the hydrophobicity of hot wax after hydrothermal pretreatment is the best.

1. Introduction

With the improvement of people's living standards, the requirements for natural environmental protection are increasing with the desire to maintain the nature of materials, specifically the quality of surface decoration and performance of wood products [1-3]. China's natural wax hot wax wood decoration technology has a history of more than 2,000 years, it can not only highlight the natural texture and color of wood, but also green, moisture-proof and anti-mite, in this context, and the waxing process has begun to receive people's attention [2-7]. Natural waxes are derived from a variety of minerals, plants and animals, and are sold in liquid, paste and solid sticks, usually in a variety of colors [8-11]. The natural wax is clear in color, such as amber, and the color is a series of wood tones or even white. Some waxes are softer and some are harder, but the hardest waxes are also softer than paints and varnishes [9-14]. The wax used in the conventional waxing process is generally beeswax and insect wax, and the pretreatment method used is hydrothermal pretreatment [15-18].

In this article we use a mixture of beeswax and insect wax combined in the ratio of 1:1. Then use three methods of surface treatment before wax coating on the Ash wood of surface including hydrothermal method, compound lye method, and plasma method, then evaluate the quality of wood
surface coating by hot wax through 4 factors: color, adhesion, hardness and surface properties of the hydrophobic coating.

2. Materials and methods

2.1. Materials
Ash veneer wood samples without defects or impurities were provided by Maoershan Experimental Forest of Harbin. Wood blocks measuring 500 × 500 × 10 mm in the longitudinal, radial, and tangential directions, respectively, oven-dried at 103°C (approximately 48 h) before treatment. Then the Ash veneer wood was conditioned at 30 ± 1°C and a relative humidity (RH) of 65% ± 1%.

The hot wax material is selected from the beeswax of Guangzhou Shantou and the insect wax of Jieyang of Guangdong according to the mass ratio of 1:1.

2.2. Hot wax method
The surface of the test piece is first hand polished. For rough grinding, 180 mesh sandpaper is selected to be sanded and run along the grain direction. The grinding time of each test piece is 120s. Then, the surface of the test piece is cleaned with a pneumatic spray gun and wiped with a cotton cloth. For fine grinding, dry sanding is carried out in the direction of wood texture with 800 mesh sandpaper. The grinding time is 30s. The sanding is performed by pre-treatment with a pneumatic spray gun. After the pretreatment, the test materials are dried and bear the weight.

The beeswax and the insect wax were weighed according to the mass ratio of 1:1 and the total mass was 30 g, and then placed in 4 beakers to be heated in a water bath to melt them. The surface of the test piece is heated by a hair dryer, and then the wax liquid is firstly coated with a paint brush and then coated with the grain, then uniformly coated and heated by a horizontal temperature hot air gun, and the temperature is controlled at 70 °C. After the waxing is completed, the test piece is allowed to stand still. After 240 minutes, the residual wax on the surface of the test piece is scraped off, and the white cotton cloth is used to wipe hard in order to make the surface wax layer evenly distributed. The control of the amount of hot wax is mainly obtained by weighing the test piece before and after ironing with an electronic balance.

2.3. Pretreatment method
1) Hydrothermal treatment
Hydrothermal treatment is a simple and easy pretreatment method in the current production process. This method is conducted through the analysis and comparison of wood material before and after the pretreatment. The polished experimental specimens are put into hot water at 80 °C under normal temperature and normal pressure, and the specimens are heated for 30 minutes. After that, the specimens are taken out from the hot water and put into the oven, the temperature is adjusted to 60 °C. The test piece is removed after being dried for 48 hours.

2) Compound lye treatment
The compound lye is mainly composed of NaOH and a modifier. The mass fraction of NaOH is 5%-10%, and the mass fraction of modifier is 11%-15%. The polished test specimens are placed in the compound lye at normal temperature and pressure for 30 minutes, and then taken out from the compound lye. The test piece was then dried in an oven at 60 °C for 48 hours before being taken out.

3) Plasma treatment

The plasma treatment was carried out in GSL-1100X-PJF-A equipment provided by Milliren Technologies, Inc. (Figure 3) [19].

The surface of the test material is subjected to plasma treatment in order to increase the surface polarity, so that in the waxing process, the wood test piece can be chemically combined with the wax very easily, and the interface bonding strength of the waxed wood is enhanced. Put the polished test sample into the sample stage of the vacuum chamber, reduce the pressure of the vacuum chamber to 1.0×10^{-3} Pa, pass air, adjust the gas flow meter, control the pressure of the vacuum chamber, and sputter the surface of the wood sample. The wood specimen was taken out after 20s.

![Figure 3. Schematic diagram of plasma treatment device.](image)

2.4. Detection method

1) Color measurement

The measurements of the surface color were performed with a CM-2300d spectrophotometer (D5003908, Konica Minolta Sensing, Inc., Osaka, Japan). Measurements were made within an 8 mm diameter spot. According to the CIE \( L^* a^* b^* \) color system there are three important parameters: \( L^* \), \( a^* \), and \( b^* \) (Figure 4) [20, 21]. The overall color change \( \Delta E^* \) was measured using the CIE \( L^* a^* b^* \) color measuring system according to CIE 1976 \( L^* a^* b^* \) color space. The overall color change \( \Delta E^* \) was calculated using the following formulae:

\[
\Delta L^* = L^{*1} - L^{*0} \tag{1}
\]

\[
\Delta a^* = a^{*1} - a^{*0} \tag{2}
\]

\[
\Delta b^* = b^{*1} - b^{*0} \tag{3}
\]

\[
\Delta E = \sqrt{\Delta L^*^2 + \Delta a^*^2 + \Delta b^*^2} \tag{4}
\]

Where \( \Delta L^* \), \( \Delta a^* \), and \( \Delta b^* \) are the changes in value between before and after heat treatment.
2) Cross-cut test
The adhesion test of the wax film was carried out according to the national standard GB/T9286-1998 "cross-cut test of color paint and varnish film". According to the standard, a cross-cutting tool is used to cut the vertical cross-parallel line with a spacing of 2mm on the waxing test material, then a piece of tape on the grid is cut and rubbed with the tip of the finger, then the paper tape is gently peeled off. A magnifier is used to inspect the cut area of the test piece under good illumination.

3) Film hardness pencil test standard
The film hardness was measured according to the national standard GB/T6739-1996 "paint film hardness determination method". In accordance with national standards, firstly prepare a group of Zhonghua brand advanced drawing pencils (9H-6B), use the wallpaper knife to repair the pen part, so that the lead core is exposed 3cm, and then the lead core is vertically placed on the sandpaper to draw a circle until the edge is sharp. The hot wax test piece is placed horizontally and measured by a pencil scratch tester at a moving speed of 0.5 mm/s. If two or more paint films are not scratched or scratched, the previous one is replaced. The pencil with the hardness number was subjected to repeated experiments.

4) Hydrophobic
The hydrophobicity was measured by the German OCA20 video optical contact angle measuring instrument (Figure 5) to measure the surface contact angle of the test piece after hot waxing, the untreated pre-tested test piece, the three sets of pre-treated test pieces and the three sets of pre-treatment hot wax. The surface of the test material was tested for hydrophobicity. The test liquid used was distilled water. The volume of the drop was measured to be 5 μL, and the maximum contact angle was measured. The three different points on the flat side of the hot wax test piece were selected and the average value was taken.
3. Results and discussion

3.1. Color measurement

It can be seen from Table 1 that the blanching test materials treated by the three pretreatment methods have lower brightness L* than the materials, and the hot wax test materials after plasma pretreatment have the highest brightness L*, hydrothermal pretreatment. After the hot wax test material, the lightness L* is the lowest, indicating that the color of the hot wax test material after the plasma treatment is darker than that of the hot wax test material after the hydrothermal treatment. The red-green axis color index a* and the yellow-blue axis color index b* of the hot wax test material after the treatment with the compound lye were the highest, and the a* and b* of the hot wax test material after the hydrothermal treatment were the lowest, indicating that the lye base was compounded. The liquid-treated hot wax test material is closer to the warm color than the hydrothermal heat-treated wax test material. The saturated wax sample treated with the compound lye has the highest saturation, and the C* of the hydrothermally treated wax sample has the lowest C*, indicating that the saturation of the hot wax sample treated with the compound lye is higher than that of the hydrothermal test. The difference in the color difference ΔE* of the hot wax test materials obtained by the three different pretreatment methods is not large, indicating that the hot wax process can basically maintain the original color tone of the test materials.

| Specimen type process | L* | a* | b* | C* | ΔE* |
|-----------------------|----|----|----|----|-----|
| Material Unheated wax | 65.5 | 7.9 | 29.3 | 30.3 | 72.2 |
| Hydrothermal treatment | 64.1 | 7.4 | 28.5 | 29.4 | 70.5 |
| Compound lye treatment | 64.4 | 8.2 | 29.5 | 30.6 | 71.3 |
| Plasma treatment | 65.1 | 8.1 | 28.6 | 29.7 | 71.6 |

3.2. Cross-cut test

The test results of the wax layer adhesion test are 0-5, of which 0 is the most complete wax film, the best adhesion, and gradually decreasing to 5 which is the most serious damage, and the wax layer is the worst. Among the waxing samples tested by three different pretreatment methods, the affected cross-cut area of the plasma pretreatment wax test material is about 5%, the grade is 1 which means the adhesion effect is the best; with the compound lye pretreatment, the affected cross-cut area is about 6%, and the grade is 2; the cross-cut area affected by the hydrothermal treatment is about 9%, the grade is 2, and the effect is the worst.

| Grading | Description |
|---------|-------------|
| 0 | The cut marks are flat and the edges are free of wax film |
| 1 | There is a wax film peeling off at the intersection of the cut marks, and the falling area is less than 5%. |
| 2 | The wax film has intermittent detachment along the cut, and the shedding area is 5%-15%. |
| 3 | The wax film continuously falls off along the cut, part of the large pieces fall off, and the falling area is 15%-35%. |
| 4 | The wax film peels off part or all of the large fragments along the cut, and the falling area is 35%-65%. |
| 5 | Shedding area exceeds 65% |
Table 3. Hot wax wood surface adhesion comparison table

| Material                  | Grade |
|---------------------------|-------|
| Hydrothermal treatment    | 2     |
| Compound lye treatment    | 2     |
| Plasma treatment          | 1     |

3.3. Film hardness pencil test standard

Table 4 showed that hot wax wood wax film hardness test results. The pencil hardness 9H-6B used when scratching on the wax film is used as the hardness of the paint film to be tested, wherein 9H represents the maximum hardness and 6B represents the minimum hardness. After determining the hardness of the three groups of hot wax samples, the hardness of the three groups of hot wax samples were changed within the range of B, wherein the compounded alkali liquid pretreatment wax grade was 3B, the hardness was the highest; plasma pretreatment The level of the hot wax pretreatment wax sample is 4B, and the hardness is small.

Table 4. Hot wax wood wax film hardness test results

| Material                  | Grade |
|---------------------------|-------|
| Hydrothermal treatment    | 4B    |
| Compound lye treatment    | 3B    |
| Plasma treatment          | 4B    |

3.4. Hydrophobic

Table 5 had shown that the wood surface maximum hydrophobic angle test results. The surface of the wood is highly hydrophilic and is obtained after the contact angle test. The maximum contact angle of the untreated sample is 65°, and the maximum contact angle of the sample after hydrothermal pretreatment is 35°. The test material after compound lye treatment is 39°, and the sample after plasma treatment is 25°. It can be seen that the pretreatment has certain influence on the hydrophobicity of the wood surface, wherein the plasma pretreatment has hydrophobicity on the surface of the wood. The influence is large; the maximum average contact angle of waxing test material under hydrothermal pretreatment is 132°, and the maximum contact angle of wax test material under the compound lye pretreatment is 121°, and the contact angle of hot wax test material under the plasma pretreatment is the largest, at 114°. It can be seen that the hydrophobicity of the wood surface is obviously enhanced after the waxing modification, and the hot waxing test material has the strongest hydrophobicity after the hydrothermal pretreatment.

Table 5. Wood surface maximum hydrophobic angle test results

| Pretreatment sample  | Maximum hydrophobic angle | Hot wax test material | Maximum hydrophobic angle |
|----------------------|---------------------------|-----------------------|---------------------------|
| Untreated            | 65°                       | Untreated             | 135°                      |
| Hydrothermal treatment | 35°                     | Hydrothermal treatment | 132°                      |
| Compound lye treatment | 39°                    | Compound lye treatment | 121°                      |
| Plasma treatment     | 25°                       | Plasma treatment      | 114°                      |

4. Conclusion

The study used three methods of surface treatment before wax coating on the Ash wood surface including hydrothermal method, compound lye method, and plasma method. The results indicate that:
1) Pretreatment of wood can enhance the activity of the wood surface and increase the bonding strength of the hot wax wood interface.

2) The hydrothermal pretreatment method is the most traditional. Compared with the other two pretreatment methods, the treated waxing specimens have the best hydrophobicity, but take longer.

3) The waxing wood treated with the compound lye is the strongest, but the treatment is the most complex and expensive.

4) The waxed wood after plasma treatment has the strongest adhesion and is easy to operate, but the instrument is relatively expensive.

5) When selecting the pretreatment method, it is necessary to select the most suitable pretreatment method based on the existing experimental conditions and the effect of the surface decoration performance of the waxing furniture.

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