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Note from the field

An environmentally safe and nondestructive process for bleaching birch veneer with peracetic acid

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A R T I C L E I N F O

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A B S T R A C T

The industrial production of dyed wood veneers is increasing significantly. The bleaching process prior to dyeing is a key step. An effective and nondestructive process was developed in this work for bleaching the birch veneer by peracetic acid. The effects of bleaching parameters, such as whiteness increase, weight lose rate, dimensional stability and surface wettability were investigated, as well as a comparison of different bleaching processes with hydrogen peroxide and sodium hypochlorite as bleaching agents. Fourier transform infrared spectrum and Scanning electron microscope were used to characterize the bleached veneers. The obtained bleaching conditions are as follows: peracetic acid 10 g/L, sodium pyrophosphate 0.4 g/L, pH 6.5, material to liquor ratio 1:20, at 65 °C for 1 h. The whiteness increase from peracetic acid bleaching is a little lower than that of hydrogen peroxide bleaching, but far higher than that of sodium hypochlorite bleaching. The weight lose rate of veneers bleached with peracetic acid is only 1.74%, far lower than those with hydrogen peroxide and sodium hypochlorite. And the dimensional change sequence is peracetic acid <hydrogen peroxide <sodium hypochlorite. The initial contact angle of unbleached veneer is 82°. After bleached by peracetic acid, hydrogen peroxide and sodium hypochlorite, the initial contact angle changed to 81°, 65° and 56°, respectively. Fourier transform infrared spectrum and Scanning electron microscope results show that weakly acidic peracetic acid bleaching had no obvious impact on wood structure, however, the alkaline hydrogen peroxide and sodium hypochlorite bleaching indeed removed some lignin from the surface of the veneer. *Peracetic acid bleaching is advantageous for wood and is a promise method for commercial production. The present work can help to make technical innovations in wood bleaching process.*

1. Introduction

Wood has many superior properties, therefore, has been used in some fields for long time, such as furniture, artifact and constructure. As we all know that the natural wood pattern gives us a kind of artistic enjoyment, colors and patterns significantly differ from one wood species to others. In fact, color differences usually occur in one wood species, even on one wood plate for many reasons.

The color of furniture is so important for its appearance. In interior decoration, some specific colors are required to be coordinated with the other facilities. However, the natural color of wood cannot meet the requirements (Atar et al., 2004). Dyeing technology should be used to obtain the ideal color for wood (Yu et al., 1998). In the other hand, the production of reconstituted decorative veneer has been growing quickly. Thousands of patterns can not be obtained without dyeing process. In order to obtain uniform dyeing effect, bleaching process prior to dyeing should be needed.

Bleaching technology has been widely used in textile, paper industries (Avşar, 2008; Schückel et al., 2011; Sharma et al., 2014). Nowadays, conventional chloride oxidizing chemicals are still used in some factories involving flax fabric in China. But chloride oxidizing chemicals are highly toxic and can cause serious environment problems (Gonzalez et al., 2000). So that hydrogen peroxide has replaced most of conventional chloride oxidizing chemicals because of its environmental benefits (Torrades et al., 1996; Yetis et al., 1996; Deshmukh et al., 2009). However, hydrogen peroxide (H_2O_2) can exhibit superior bleaching effect under alkali condition. Lignin in wood is sensitive to alkali treatment. Therefore, bleaching under alkali condition may destroy lignin, leading to decrease of the strength of wood (Hashem, 2007; Abou-Okeil et al., 2010).

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Peracetic acid (Paa) was used as bleaching agent for bleaching cotton fabric, paper pulp in some researches (Gürsoy et al., 2000; Abdel-Halim et al., 2011). It is found that good whiteness can be obtained by peracetic acid under weakly acidic conditions (Steiner, 1995; Hickman, 2002). It is proposed that it may be more suitable for wood bleaching. So far, there is no report on wood bleaching by using peracetic acid.

In this work, peracetic acid was used to bleach birch veneers. The bleaching conditions were investigated. The bleached veneers were compared with those bleached by sodium hypochlorite and hydrogen peroxide by using Fourier transform infrared spectrum (FTIR) analysis, Scanning electron microscope (SEM) observation, and measurement of weight loss rate, wettability and dimensional stability.

2. Materials and methods

2.1. Materials and reagents

Birch veneers of 0.6 mm thickness were provided by a plywood factory and were cut into squares of 50 mm × 50 mm prior to bleaching process.

Three bleaching reagents were used, namely, peracetic acid (Paa) (CH_3COOOH, 15% w/w), hydrogen peroxide (H_2O_2, 30% w/w), and sodium hypochlorite (NaClO, 120 g/L). Sodium pyrophosphate ($Na_4P_2O_7$, 98% w/w) was used as stabilizing agent in Paa bleaching process. Sodium hydroxide (NaOH) was used to adjust the pH of the bleaching solution. All chemicals were of analytical grade and were commercially available.

2.2. Instruments

Beaching process was carried out in a DK-98-1 water bath (Tianjin Taisite Instrument Co., Ltd., China). The colorimeter (Model YQ-Z-48A) was used to test whiteness and the average of the values of 10 test points was used as the results of each sample. The analytical balance (Model ESJ2054, Shenyang Longteng Electronic Co., Ltd., China) was used to test the constant weight of the veneers before and after bleached. Scanning electron microscope (SEM, model Quanta 200, America FEI Company) was used to observe the surface morphology of samples sprayed with gold at voltage of 10.0 kV and various magnifications. The crystal structure of the samples was analyzed by X-ray diffraction (XRD, model D/MAX-3B, Rigaku) with 2θ from 10° to 70°. The change of functional groups of samples before and after bleaching were characterized by using Fourier transform infrared spectrum (FTIR, model MAGNA-IR560, Thermo Nicolet Corporation) from 400 cm^{-1} to 4000 cm^{-1} with resolution of 0.1 cm^{-1}. Thickness gages (Model ID-C112XBS, Mitutoyo) was used to measure the thickness of the samples before and after the bleaching. The wettability of all the samples was measured by OCA20 video optical contact angle measurement instrument from Germany Dataphysics Company via pendant-drop method at room temperature.

2.3. Paa bleaching procedure

The single-factor experiment was designed to find the suitable experimental conditions for bleaching treatment of birch veneer. Four different bleaching conditions (concentration of Paa and sodium pyrophosphate, temperature and initial pH) were investigated to determine the suitable conditions.

2.3.1. Paa concentration

The samples were dipped to a set of bleaching solutions of various Paa concentrations, namely, 4, 5, 6, 7, 8, 9, 10 and 11 g/L. The concentration of sodium pyrophosphate was used 0.4 g/L and initial pH of the bleaching bath was regulated to 6.5 by using sodium hydroxide. Each solution had a liquor ratio of 1:20. Heating was done at 65 °C for 1 h.

2.3.2. Sodium pyrophosphate concentration

Sodium pyrophosphate as stabilizing agent was used four different concentrations, i.e., 0, 0.2, 0.4 and 0.6 g/L. The concentration of Paa was controlled at optimum concentration resulting from the previous step, and all other conditions were same.

2.3.3. Temperature

To investigate the effect of bleaching temperature, birch veneers were bleached at different temperatures (55, 60, 65, 70 and 75 °C). The optimum concentrations of Paa and sodium pyrophosphate were determined in previous experiments. Other conditions were kept constant as those in the previous step.

2.3.4. Initial pH

The pH is a key factor in bleaching process, different whiteness appears in acid or alkali condition. So, initial pH of bleaching process was set at eight different values, namely, 5.5, 6, 6.5, 7, 7.5, 8, 8.5 and 9. Other conditions were the same as those in the previous step.

2.4. Comparison bleaching procedure

In order to compare the bleaching effects, hydrogen peroxide bleaching and sodium hypochlorite bleaching were carried out.

2.4.1. Hydrogen peroxide bleaching procedure

The hydrogen peroxide bleaching experiment was conducted under the conditions as: 30% hydrogen dioxide 4%, sodium silicate 0.4%, sodium hydroxide 1%, at 60 °C for 1 h. After bleaching process, the bleached veneers were thoroughly washed to pH of 7 with distilled water. Then, the veneers were flattened and dried in air.

2.4.2. Sodium hypochlorite bleaching procedure

The sodium hypochlorite bleaching experiment was done under 5% of sodium hypochlorite, at 75 °C for 0.5 h, then the bleached veneers were washed to pH of 7 with distilled water, flattened and dried in air.

2.5. Whiteness increase

The whiteness increase of bleached birch veneers were calculated according to the following equation:

$$\text{Whiteness increase}\,(\%) = W_2 - W_1 \tag{1}$$

where W_1 (%) and W_2 (%) are the whiteness of birch veneer before and after bleached, respectively.

2.6. Weight loss rate

The weight loss rate of birch veneers after bleaching was calculated according to the following equation:

$$\text{Weight loss rate}\,(\%) = (M_1 - M_2) \times 100/M_1 \tag{2}$$

where M_1 and M_2 are the weight of birch veneer before and after bleached, respectively.