



## RESEARCH AND DEVELOPMENT ADVANCES IN WOOD FUNCTIONAL MODIFICATION IN CHINA

Liu Shu<sup>[a]</sup>

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Since China carried out natural forest protection project in 1998, the timber supply in China depends mainly on international market. In order to solve the problem of the supply and demand of wood in China, the fast-growing plantations of aspen wood, eucalyptus, Chinese fir, and masson pine have been explored in China. The functional modification must be performed to make better due to the low quality of these kinds of plants species. The advances in wood functional modification, such as colour processing, softening, size stabilization, strengthening, fire-retardant treatment and preservative treatment in latest 10 years, has been summarized in the present paper.

\*Corresponding Authors

\*E-mail: liuxinlin-yj@163.com

[a] Fax: 86-24-56860869

Liaoning Shihua University, Fushun, Liaoning, P.R. China.

### Introduction

Logs are one kinds of the most important building materials. China is a larger producer of timber and wood products, and is also a huge consumer of wooden articles<sup>1,2</sup>. In the first half of 2012, the timber production of Chinese forestry industry was *ca.*  $3.502.55 \times 10^7$  cubic meters with an output value of *ca.*  $1.4 \times 10^{12}$  yuan. However, China is short of forest reserves. The country had carried out natural forest protection project in 1998, and took measures to reduce cutting of the domestic forest year after year, so a big gap of supply and demand in domestic timber market appeared and thus the timber supply in China is heavily dependent on international market. Wood is one of strategic commodities which play a important role in the sustainable development of China's economy. In order to solve the problem of the supply and demand of wood, the fast-growing plantations of aspen wood, eucalyptus, Chinese fir, and masson pine have caught more attention in China. These tree species usually are low quality, functional modification thus must be performed to make better. The functional modification on wood such as color processing, softening, size stabilization, strengthening, fire-retardant treatment and preservative treatment in recent 10 years, has been summarized in present paper<sup>3-9</sup>.

### Discussion

#### Color processing

Bleaching can removes Blue-stains and splashes on the veneer surface. Hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) and sodium hypochloride (NaClO<sub>2</sub>) are the most often used bleaching agents. Pretreatment by sodium hydroxide or ammonia will show a better effect of wood bleaching.

Decolourization of the timber is mainly caused by the external factors, such as bacteria, temperature, light, oxygen,

water, and acid and base substances, and ferric like which interact with the wood's components (lignin and extractives, etc.).

The anti-tarnishing process by employing chemical and physical treatments, can preserve the tones and texture of wood, and maintain the value of the furniture. The physical methods use extract agents to leach the extractives of wood, where controlled temperature and humidity contribute to inhibit or even kill the decolourant bacteria. The thin films coating on the wood surface by physical methods can play the role of water and light exclusions. The wood can be coated with ultraviolet absorbents using chemical methods, or the surface can be disposed with anti-oxidizing agent solution or the pH adjusting agent solution, to prevent from decolourization of wood.

The dyeing can improve decorative function and increase the value of the medium or low-rank wood. The dyeing effect depends on physical and chemical properties of the timber species and dyeing conditions. The Chromatic characteristics of dyeing on Chinese fir are associated to the anatomic factor, where the cellulose and hemicellulose are stained quite easier than other timber species. The dyeing rates of poplar, birch and oak species increase with an increased microwave power and longer treating time.

#### Softening treatment

Softening treatment of timbers presently involves cooking, microwave heating moulding at water-saturated state, alkali treatment, and the nitrogen-containing compound treating (liquid ammonia, gaseous ammonia, aqueous ammonia, hydrazine, etc.). The wood can be softened effectively by heating a urea solution with timber impregnated in it.

The expansion ratio increases with the higher abilities of the solutions to form hydrogen bonds with the three major kinds of components in wood. N atom forms a hydrogen bond much more easily than O atom, therefore, wood treating by using nitrogenous compounds generally shows a more obvious softening effect than the cooking method. The heating modes of wood softening also involve microwave heating and high-frequency electric heating.

### Size stabilizing treatment

Wood is hygroscopic *per se*. The change of moisture content in it is the main reason for the shrinkage and the swelling of wood. Heat treatment and waterproof treatment are the physical methods for size stabilization of wood. Silicone oil and paraffin are used as waterproof agents to modify the wood surface. After the timbers of ash, oak wood, camphor and schima superba ect. are treated in a low oxygen atmosphere at 200 °C, the population of hydroxyl group in cell wall decreases, leading to a significant decrease of moisture content, thus the dimension stability of wood can effectively improve. During the chemical treatment, polyethylene glycol, acetic anhydride, phenol formaldehyde resin, or urea formaldehyde resin can be used. These low molecular weight chemicals react with hydrophilic hydroxyl in wood to form thermosetting resin. The dimensional stability of eucalyptus greatly improves by dipping the timber in urea-formaldehyde resin modified by melamine and then heating. Chinese wood industry currently consumes large amounts of phenolic resin and urea formaldehyde resin in dimensional stabilizing process due to the significant improvement on the wood functions.

### Strengthening treatment

Strengthening treatment increases the densities and mechanical strength of low quality wood by using the physical, chemical or mechanical methods. The inner steam pressure of the timbers increases rapidly during hot-press oxidization treatment, where the drying of the timbers is accelerated. The densities of wood and the hardness of surface both increase, which lead to a promotion on the performances and a raise of the value of timbers. The best processing conditions of hot-pressure treatment for thinning wood of Chinese fir is a moisture content of 50% prior to the treatment, a time compression of about 30 min at 180 - 200 °C, where a Compression ratio of 50 % - 60 % is obtained with significant improved physical and mechanical properties.

Dipping treatment is used for medium and low-grade timbers by soaking them in low molecular weight polymers to increase the mechanical strength. Due to more refractory injection of heartwood than sapwood, extraction treatment and vacuum impregnation is often employed simultaneously as the injection to enhance the impregnation ratio and the uniform distribution of the polymers in the timbers.

### Flame retardant treatment

The effect of flame retardant treatment depends on the processing method and fire retardant used. The flame retardant processing mainly includes impregnation, spraying and coating, veneering, hot pressing, complex method, radiation method, ultrasonic method, centrifugal rotation method and high energy jet method and so on. The wood fire retardants usually are classified into phosphorus based, boron based, phenolic, halogenated, nitrogenous, and halogen-phenolic flame-retardants. The phosphorus-nitrogenous-boric composite fire retardants have been recently introduced into China market due to its multiple functions, such as flame retarding, smoke-suppression, anti-corrosion, and no pollution. Aqueous amino resin coating on

wood also has attracted a lot of attention now, because of the extended flame combustion time and the less released burning heat.

### Preservation treatment

Wood decay is mainly caused by wood rot fungi. On using wood preservatives lots of factors should be taken into consideration, such as human health, safety and environmental effects, effective recycling, with broad spectrum sterilization, resistance to erosion, the relatively low cost. Wood preservatives are mainly made down into three types in China, namely water borne type, oil loading type and preservative oil. The water borne preservatives are widely used in China, such as CCA (a solution of copper sulphate 35 %, potassium dichromate 40 % and arsenic pentoxide 25 %), ACQ (ammoniacal copper quaternary types), CA-B (copper azole-type B), ect.

### Research prospects on function modification of wood in China

Along with the change of national forest resources structure and the awareness of ecological environment protection, the functional modification of wood in China has focused in long term on the fast unripe plantation wood. Poplar, Paulownia, pine, eucalyptus, Sugiki are all abundant in china and with shortcomings in the performances. Multi-functional modification takes the trend in improvement of wood processing. Inorganic fillers have advantages of low cost, environmental protection, no volatile harmful gas etc. The poplar wood treated by silicate monomer solution gives a higher dimensional stability and resistance to erosion. Fir wood treated by a solution of aluminium sulphate solution or water glass solution produces significantly increased dimensional stability, the bending strength, bending modulus of elasticity, compression strength, compressive strength parallel to grain, and hardness.

Treating timber by using nanomaterials is highlighted in lumber functionality improvement in China during recently 10 years. The nanometer interstices between the micro fine fibres on the cell wall of the timber can accommodate the nanoparticles which can combine with the reactive groups there. The wood/inorganic nanocomposites can be produced by using the sol-gel method, in situ intercalation synthesis method, injection filling method, leading to a promotion of the performance of wood, even to producing a new performance.

The nano sized SiO<sub>2</sub> aero gels prepared by sol-gel method can be injected into the timber through the vacuum/pressure method to form a wood and nano particles composites of good performance. The wood/nano montmorillonite intercalation composite are produced by introducing montmorillonite into wood in phenolic resin medium. This intercalation composite shows a significantly lower water swelling ratio, an increased strength parallel to grain, a markedly improved thermal stability.

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