Effects of Wood Modification Using Natural Resin on Wood Quality and Bonding Properties

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Abstract

The aim of this study was to investigate the effect of gum rosin impregnation upon a low quality young teak wood in order to enhance its quality. The main objective of the treatment was to enhance the dimensional stability, as well as strength and to reduce the hygroscopicity. A 15-years old thinned teak wood (*Tectona grandis* L.f.) and gum rosin from *Pinus merkusii* Jungh. et de Vries were used for wood modification treatment by impregnation. Three kinds of non-polar solvents, *i.e.* turpentine oil, petroleum oil and *n*-hexane-, were used to make gum rosin solution. The results indicated that gum rosin impregnation did not markedly enhance the quality of young teak wood in terms of either dimensional stability or hygroscopicity; however, a little enhancement was delivered by using 15% gum rosin solution with *n*-hexane as the solvent. The treatment with petroleum oil solvent (at concentration of 7.5%) and at 15% concentration with *n*-hexane solvent resulted in highest bending properties. The highest bonding strength in dry condition was resulted by treatment with turpentine oil solvent.

Keywords*:* wood modification, young teak wood, natural resin, non-polar solvent, wood quality, bonding properties.

Introduction

Modifying wood through resin impregnation is commonly conducted by using synthetic resin. It has been widely taken and commercially applied. In particular, the improvement of wood's dimensional stability is primarily caused by the bulking of cell wall due to resin penetration and a cross-linking that occurred among the chemical compound of the resin within the cell wall (Hill 2006). Furthermore, resins that have been generally taken for wood modification and reported to enhance wood properties, especially its dimensional stability, include formaldehyde-based synthetic resins. Among those, the finest one is phenolic resin. At the past, water soluble phenol formaldehyde (PF) resin has been applied for *impreg* and *compreg* by Stamm dan Seborg, as reported by Hill (2006). In fact, the utilization of a certain type of synthetic resin, *e.g.* acrylic, alkyd, straight chain hydrocarbon resin and hydrogenated rosin ester, as a basic constituent in water repellent organic solutions has been reported and known as quite a common practice. Water repellent materials applied to wood provide a protection from liquid water by reducing the capillarity rates and water uptake (Voulgaridis 1993). He has also mentioned that a resinous component in water repellents is required to enhance the mechanical strength of the wood.

In general, water repellents are known as a complex mixture of different materials, *i.e.* waxes, oils, natural resin, synthetic resin and solvent (Rowell and Banks 1985; Hyvonen *et al*. 2006; Scholz *et al*. 2010). However, many typical water repellents have been recognized as having negative effects to the environment. Following an increasing environmental responsibility, including policies that favor the use of renewable resources and environmental-friendly materials, people are currently interested in developing more eco-friendly methods and utilizing biodegradable materials in wood protection to enhance the quality of wood products. Therefore, more eco-friendly water repellent materials such as tree extractives and natural resin have been successfully examined in laboratory scale (Rowell and Banks 1985; Voulgaridis 1993). Other studies have also been performed to examine the water repellency and dimensional stability of wood through a natural oil treatment and its biological efficacy (Hyvonen *et al*. 2006). Natural oils are known to have ability for inhibiting water uptake, while unsaturated oils may oxidize when in contact with oxygen from the air, which then produces a more protective layer on the wood surface.

Furthermore, one of known natural resins is gum rosin, which is obtained by distilling resins from Pines. Voulgaridis (1993) has conducted an experiment by using oleoresin and gum rosin from *Pinus halepensis* Mill. as the water repellent. The study has concluded that oleoresin and gum rosin products (grade WW, WG, N) are usable for the basic constituents of water repellent, which may then substitute synthetic resin. In this study, gum rosin from *Pinus merkusii* Jungh. et de Vries was used for wood modification through an impregnation. Besides, three types of non-polar solvents, *i.e.* turpentine oil, petroleum oil and *n*-hexane, were used to make the impregnant solution. The study is aimed to examine the effects of wood modification by conducting natural resin impregnation using gum rosin solution to enhance wood properties and its adhesion properties.

Materials and Methods

Specimen Preparation and Treatments

Materials used in this study include 15-years old thinned teak wood (*Tectona grandis* L.f.), gum rosin (grade WG) from *Pinus merkusii* Jungh. et de Vries as impregnant and turpentine oil as solvent were obtained from *Perum Perhutani* (Indonesia State Owned Forestry Company). Other solvents were petroleum oil obtained from gas station and *n*-hexane purchased from chemicals store. There were 35 sticks measuring 25 × 25 × 500 mm were chosen for all of treatments which were then equilibrated in an ambient condition to achieve the level of moisture content at 12~15%. Both sides were covered by paraffin to inhibit longitudinal penetration of impregnant.

Before impregnation, the samples were measured its weight and dimensions. The samples were then placed in a vacuum pressure cylinder and impregnated through a vacuum-pressure treatment by utilizing gum rosin solutions with different kinds of solvent with a concentration ranged between 7.5% and 15%. A pre-vacuum at 1 atm was applied during the first 15 minutes. During a vacuum release, gum rosin solution is pulled into the cylinder, which is followed by applying a pressure of 10 atm for 1 hour. After the treatment, the samples were taken out from the cylinder and the residual solution on the surface was wiped off and immediately weighed to calculate the absorption of impregnant. The samples were then conditioned in an ambient condition for two weeks. Their weights were then measured to determine the Weight Percent Gain (WPG) of the gum rosin solution.

Specimen Evaluation

The samples were cut for all parameters of this study; moisture content, specific gravity and dimensional stability (total shrinkage) according to BS-373 (British Standard 1957), hygroscopicity by determining equilibrium moisture content (EMS) at relative humidity (RH) of 90% and 98% according to Sernek *et al*. (2008), and bending properties according to BS 373 (British Standard 1957). After bending evaluation, the specimens were then cut for shear bonding strength experiment and divided into two sticks. Melamine formaldehyde (MF) resin then was applied with glue spread of 40 lbs/MSGL. The samples were then clamped in a cold press for 6 hours and placed in an ambient condition for one week before being cut into specimens for shear strength test. Shear bonding strength was tested within two conditions, *i.e.* normal condition and wet condition. It was conducted by approaching to EN-314-1 (European Standard 2003). Shear bonding strength and percentage of wood failure were then determined.

Results and Discussion

Physical Properties

Fig. 1 shows the WPG of gum rosin solution into the wood and specific gravity of treated wood. Gum rosin solution with turpentine and petroleum oil as solvent resulted in WPG values of approximately 3.2~3.5% and 3.5~4.2%, respectively. Both of them resulted in higher WPG in concentration of 7.5% than that of 15%. It is thought that the gum rosin solution with turpentine and petroleum oil as solvent may have been more difficult to enter the wood cells. Contrarily, the solution with *n*-hexane resulted in a higher WPG at concentration of 15% than that of 7.5%. It implies that gum rosin solution with *n*-hexane solvent is easier to enter the wood cell compared to the other two solvents. In terms of specific gravity, the treatment resulted in a higher specific gravity of wood despite being insignificantly different to untreated wood with an exception for the treatment with petroleum oil solvent, which has 7.5% gum rosin solution. In particular, treated wood with the gum rosin solution at 7.5% and petroleum oil solvent have performed the highest specific gravity. The quite a little increase in terms of specific gravity for the treated wood may have been due to its little WPG values.

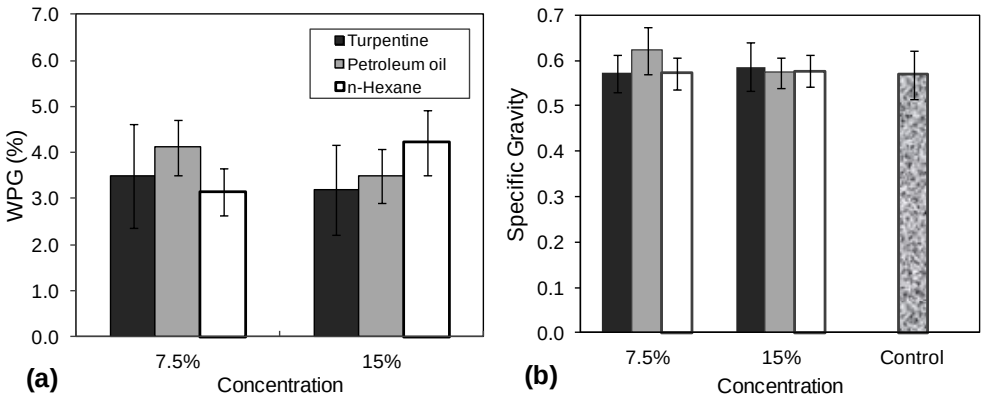

Figure 1. Weight percent gain (WPG) (a) and specific gravity (b) of teakwood treated with gum rosin at different concentrations and solvents. Error bars indicate the standard deviation.

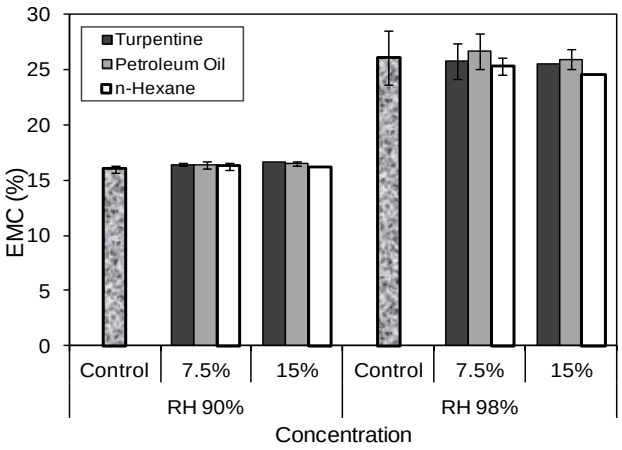

Figure 2. The equilibrium moisture content (EMC) at high relative humidity (RH) of teakwood treated with gum rosin at different concentrations and solvents. Error bars indicate the standard deviation.

The moisture content of treated wood was higher than that of untreated wood (not shown). After treatments, the amount of water may have been trapped in the wood and could not move outside the wood. This might cause a higher moisture content of the treated wood. Higher concentration of gum rosin solution resulted in a lower moisture content, except for gum rosin solution with petroleum oil as the solvent. Gum rosin solution with turpentine oil as the solvent provided the lowest moisture content of treated wood. Fig. 2 shows the EMC of treated and untreated teakwood. There was no difference between the EMC of treated and untreated teak wood. However, it appears that the treatment may have reduced the EMC of teakwood in 98% RH, especially the treatment with *n*-hexane solution. However, this reduction of EMC was not significant, indicating that the treatment with gum rosin solution as water repellent was unsuccessful to reduce water uptake.

Since impregnation treatment is aimed to improve wood dimensional stability due to the moisture, evaluating the treatment in terms of dimensional stability is important. Fig. 3 shows the total shrinkages of treated and untreated wood in tangential and radial directions. In general, the treatment did not significantly reduce the total shrinkage of teakwood. Treatments with 15% gum rosin solution with petroleum resulted in a lower tangential shrinkage than that of 7.5% solution. Gum rosin solution with 15% gum rosin and petroleum oil solvent resulted in the lowest tangential and radial shrinkages. The use of petroleum oil as solvent resulted in a better inhibition against shrinkage with the concentration of gum rosin at 15%. The use of *n*-hexane as solvent generally resulted a better application for inhibiting shrinkage, despite having resulted in a much higher shrinkage than petroleum oil solvent in a gum rosin concentration at 15%.

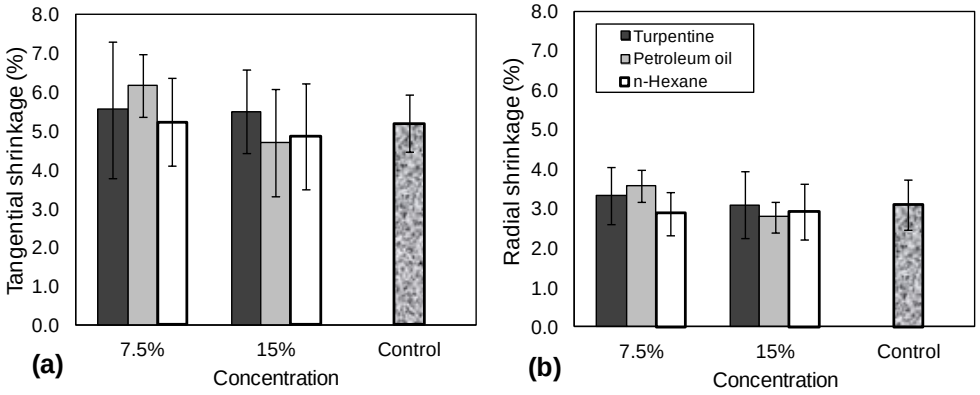

Figure 3. Total shrinkage on tangential (a) and radial (b) directions of teakwood treated with gum rosin at different concentrations and solvents. Error bars indicate the standard deviation.

Mechanical and Bonding Properties

Wood modification by resin impregnation is also reported to enhance mechanical properties of wood. Fig. 4 shows bending properties of treated and untreated teakwood. It appears that the treatment did not affect the bending MOE and MOR in general, except for the impregnation of 7.5% gum rosin solution with petroleum oil as its solvent. The use of turpentine as solvent in gum rosin solution did not enhance the bending properties of wood. The enhancement may possibly be achieved by gum rosin impregnation with either petroleum oil solvent in both concentrations or *n*-hexane solvent at concentration of 15%.

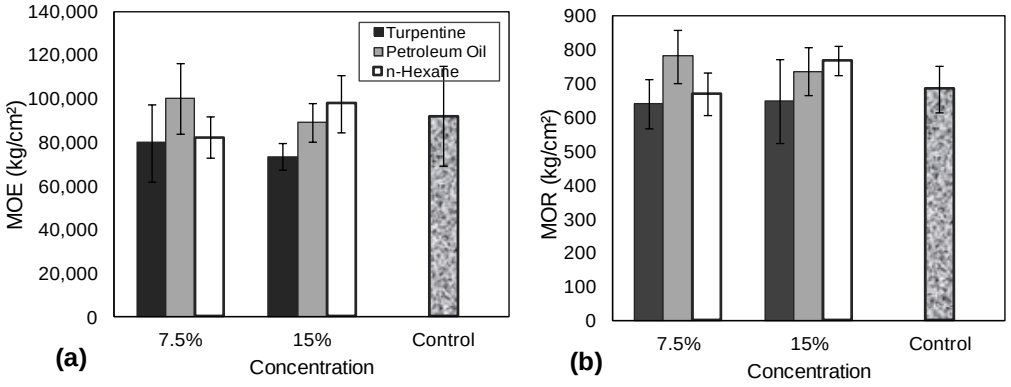

Figure 4. Bending modulus of elasticity (MOE) (a) and modulus of rupture (MOR) (b) of teakwood treated with gum rosin at different concentrations and solvents. Error bars indicate the standard deviation.

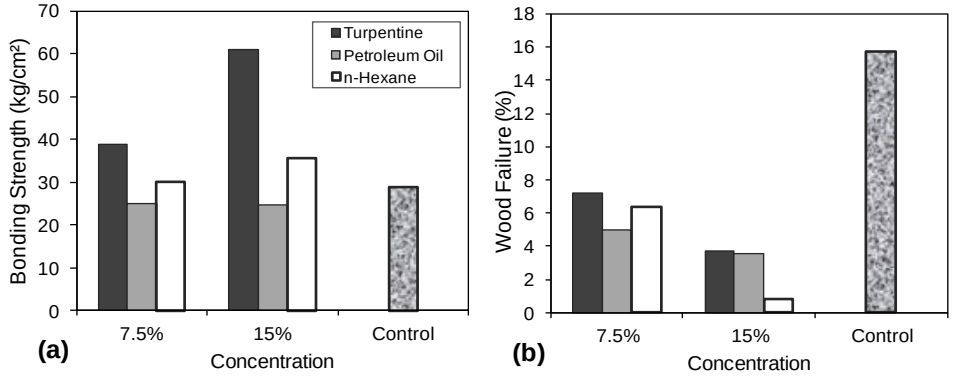

Figure 5. Bonding strength (a) and wood failure (b) at dry condition of teakwood treated with gum rosin at different concentrations and solvents.

Fig. 5 shows the shear bonding strength of the glue-line. In a normal (dry) condition, both solutions which used turpentine oil and *n*-hexane solvents provided a higher bonding strength than untreated wood, while the solution with petroleum oil solvent produced the lowest bonding strength. A higher concentration of gum rosin solution resulted in a higher bonding strength except for the solution with petroleum oil solvent. In a wet condition (not shown), the solution with turpentine oil solvent and at 15% gum rosin concentration is the only one that has a higher bonding strength than untreated wood. In terms of hydrophobicity as an objective of resin impregnation, the gum rosin with petroleum oil as solvent has been diminishing the ability of MF resin to wet the wood surface, which consequently results in a lower bonding performance. Based on the wood failure, the treatment resulted in lower wood failure than that of untreated wood. It implies that the glue-line was not strong enough to bond both wood surfaces.

Conclusions

Wood modification through gum rosin impregnation at different concentrations and three different kinds of solvent was applied to young teak wood to enhance its quality. Based on the findings of this study, it can be generally concluded that the treatment did not enhance the quality of young teak wood in terms of either dimensional stability or hygroscopicity; however, a little enhancement was provided by gum rosin

solution at 15% concentration with *n*-hexane as the solvent. On the other hand, the treatment with petroleum oil solvent and at 15% concentration with *n*-hexane solvent resulted in higher bending properties. Then, the highest bonding strength in a dry condition was obtained by gum rosin impregnation with turpentine oil solvent at concentration of 15%.

Acknowledgement

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