Conference Paper

Effect of Heat Treatment and Use of Aluminum Foil on Physical and Mechanical Properties of Wood

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Abstract

Wood is hygroscopic. It can attract and hold water molecules from its environment depending on the humidity. Heat treatment can be used to reduce its hygroscopic properties and improve the stability of the wood. The application of heat treatment and the use of aluminum foil affects the physical and mechanical properties of the wood. This study seeks to evaluate the effect of these processes on wood. Oven temperature treatment with a variation of 170 and 180 degree Celsius for 2 hours; treatment with and without wrapping with aluminum foil were employed in this study. A comparison of the wood properties was performed before and after the treatment. The results revealed that the temperature treatment and the use of aluminum foil significantly affected the moisture content, weight loss and compressive strength parallel to the grain.

Keywords: heat treatment, aluminum foil, physical and mechanical properties

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Received: 24 May 2019
Accepted: 25 July 2019
Published: 4 August 2019

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ISTEcS 2019 Conference Committee.

1. Introduction

The wood used in the processing industry is fresh and rapidly growing. An example of a common fresh wood used in the processing industry is the Manglid wood (*Manglieta glauca* Bl). Young woods are the cells of the wood that are still growing, and they do not have the same properties as their parent wood. Therefore, efforts must be channelled towards improving the quality of the wood to utilize the manglid wood optimally.

A research was carried out on Sugi wood (Cryptomeria japonica). The wood was subjected to temperatures 170, 190- and 210-degree Celsius for 1 hour, 2 hours and 4 hours. The result revealed that the density, moisture content and hygroscopicity of the wood samples decreased as the treatment temperature and duration increased. The mass loss also increased under these same conditions. Also, it was found that the dimensional stability of the wood improved with increased temperature and prolonged durations. The result gotten from this experiment suggests that the application of heat treatment enhances the dimensional stability of wood. The surface color of wood

darkened progressively with increasing treatment temperature and duration, and the hydrophobicity of the wood sample enhanced as a result of the heat treatment [1].

Previous studies carried out on the effect of temperature and clamping during heat treatment suggested that the color change, weight loss, and volume shrinkage increased with increasing temperature, whereas the equilibrium moisture content (EMC) and water absorption (WA) decreased in the two types of wood. For sapwood, the density was not affected by temperature. Sapwood gave the highest color change while the magnitude of weight loss, volume shrinkage, EMC and WA was higher in heartwood than in sapwood.

Flat-sawn board from sapwood and heartwood of okan (*Cylicodiscus gabunensis* [Taub.] Harms) wood were prepared for heat treatment. The air-dry densities of sapwood and heartwood specimens ranged from 0.77 to 0.89 g/cm^3 and 1.16 to 1.23 g/cm^3, respectively. Each board was clamped edge-wise using flat metal and fastened using bolts and nuts equipped with metal springs. The heat treatment began at the initial temperature of 25 $\pm$ 5 degree Celsius and then was raised to the target temperature of 160, 180, 200 and 220 degrees Celsius with a heating rate of 2 degree Celsius /min. The target temperatures were maintained for two h[2].

This research focused on investigating the heating temperature and treatment method on physical properties and finishing quality of mahagony wood. Two treatment methods, i.e., oven method and steaming method, were used in this research. The heating temperatures were set at 90°C, 120°C, and 150°C. The effective heating time was 2hours.. The result gotten from this research showed that the treatment method and heating temperature affected the color change, radial shrinkage, cross cut test and delamination test. The moisture content, radial shrinkage, the light color was significantly reduced with increased wood quality when the oven method of treatment was used compared to the steaming process [3].

Further researches on the influence of heat treatment on the quality of the wood are still ongoing. It is because each wood responds differently to treatments. Therefore, this study aims at determining the effect of temperature and aluminum foil wrapping on the physical and mechanical properties in manglid timber.

2. Experimental

2.1. Material

The experimental samples were selected from a wood material store. Logs of ±300mm in diameter were used and formed into wooden planks. The wood was cut into 20mm × 20mm × 30mm when it reached an equilibrium moisture content, and then the cut pieces were randomly divided into control groups. Four treatment groups were used according to the designed treatment conditions.

2.2. Heat treatment and aluminum foil

The heat treatment was performed under low presence of oxygen in an electric oven with a programmable controller (Memmert type F-NL Germany). The samples were weighed before putting them in the oven. Heat treatment then began at 25± 5 degree Celsius and then was raised to 170 and 180 degrees Celsius. The duration of heating with the target temperatures was kept at 2 hours. After the heat treatment was concluded, the samples were removed from the oven and kept in the desiccator for samples conditioning. Then the treatment using aluminum foil is performed after weighing the samples before it is put inside the oven.

2.3. Testing of physical and mechanical properties

The physical properties that are tested in this experiment include moisture content, density, and weight loss. While the mechanical properties included are bending strength (MOR), modulus of elasticity (MOE) and compressive strength parallel to the grain. All the tests were carried out on the control samples and the treatment samples.

2.4. Statistical analysis

An analysis to evaluate the effect of temperature and wrapping aluminum foil on the selected properties of manglid wood using analysis of variance ($\alpha = 0.05$). Significant differences between the mean values of the testing group were determined using Tukey test (95 % significance level).

3. Result and Discussion

3.1. Physical properties

The result gotten from the experiment carried out on the moisture content analysis indicated that the control samples have higher moisture content than the treatment samples. This is consistent with the theory that a higher treatment temperature and a longer treatment time leads to a lower equilibrium moisture content [4, 5]. That is, the moisture content when the heat treatment is 180 degrees will be lower than when the heat treatment is 170 degrees Celsius. The moisture content of samples without wrapping aluminum foil was lower than samples with wrapping aluminum foil.

The statistical analysis revealed that temperature has a highly significant effect on the moisture content of the wood. An increase in heat treatment will lead to a subsequent decrease in the moisture content of wood and vice versa. Tukey analysis results revealed that there is a significant difference in the moisture content when the samples are subjected to 170 and 180 degree Celsius. That is, there I increased evaporation of water molecules when subjected to 180 degree Celsius leading to a decrease in the moisture content. The aluminum foil wrapping also had a significant effect on the moisture content of the wood. Increased moisture content is seen when the samples are not wrapped. This is due to the insulation properties of the aluminum foil which causes continuous reabsorption of evaporated water molecules. Without the aluminum foil, the evaporated water disappears, and the moisture content is reduced.

The moisture content of the wood wrapped with aluminum foil is different from the wood that is not wrapped in aluminum foil. Table 1 shows the effect of temperature treatment and aluminum foil wrapping on the moisture content.

Table 1: Moisture content.

Treatment	Moisture content (%)
Control	15.08
Temperature 170°C	12.73
Temperature 180°C	11.89
Without aluminum foil	11.93
Aluminum foil	12.69

The reduction of the water in the cell wall wood due to heat is responsible for the decreased moisture content as seen above. Chemically, there is a decrease in the number of hydroxyl groups as a result of this condition. Also, there is a consequent decrease in the weight of the wood due to the loss of extractive components in wood, decreased level of water in the cell wall and the degradation of hemicellulose[6, 7]. The hemicellulose component was degraded first when the samples were subjected to heat

treatment because it has the lowest molecular weight among wood polymer. The result of this is the reduction of the number of hydroxyl group and production of an O-acetyl group followed closely by crosslinks between wood fibers so that the wood becomes more hygroscopic [8].

The density of the manglid wood (control) before and after temperature treatment and wrapping aluminum foil remained unchanged. The result of variance analysis also shows that the temperature factor, aluminum foil wrapping factor and the interaction of both factors do not affect wood density. This occurs because the density is determined by the weight and volume of the wood. Also, it is postulated that the possibility of alteration or reduction of the weight and size of wood in the heat treatment and the treatment of aluminum foil wrapping takes place in proportion. Table 2 shows the effect of temperature treatment and aluminum foil wrapping on the density. The density value of manglid wood is following the results of research which state that the density of manglid wood of 0.38 g/cm^3 [9].

Table 2: Density.

Treatment	Density (g/cm^3)
Control	0.38
Temperature 170°C	0.38
Temperature 180°C	0.38
Without aluminum foil	0.38
Aluminum foil	0.38

Although the temperature treatment and aluminum foil wrapping have a very significant effect on the weight loss of wood, the interaction of temperature treatment and aluminum foil wrapping treatment had no significant impact on the weight loss of wood. Temperature treatment causes the weight loss of wood and the higher the temperature, the more significant the weight loss of wood. Weight loss at a temperature of 170°C is 10.63% and at a temperature of 180°C is 11.29%. Weight loss increased with increasing treatment of temperature and duration [10], while aluminum foil wrapping resulted in a more significant weight loss of weight. The weight loss of wood in aluminum foil wrapping treatment was 11.26%, and the treatment without wrapping was 10.66%. The Tukey analysis results show that the 170°C temperature treatment is very different from 180°C. Likewise, the treatment of aluminum foil wrapping is very different without aluminum foil wrapping. Table 3 shows the effect of temperature treatment and aluminum foil wrapping on the weight loss.

Table 3: Weight loss.

Treatment	Weight loss (%)
Temperature 170°C	10.63
Temperature 180°C	11.29
Without aluminum foil	10.65
Aluminum foil	11.26

3.2. Mechanical properties

The compressive strength parallel to the grain of experimental samples subjected to temperature treatment and aluminum foil wrapping increased significantly compared to that found in the control samples of mangli wood. This result resonates with the research carried out using fir wood (Abies nordmanniana subsp.)[5]. A minimum compressive strength parallel to the grain of 43.92 MPa at a temperature of 170 °C, and a maximum of 46.88 MPa at a temperature of 180 °C was seen in this experiment. The temperature treatment had an actual effect on the compressive strength parallel to the grain. Likewise, the treatment of aluminum foil wrapping has a very significant impact on compressive strength parallel to the grain. The compressive strength parallel to the grain of aluminum foil wrapping treatment is 46.86 MPa, and without aluminum, foil wrapping is 43.94 MPa. The compressive strength also parallels to the grain at the temperature of 170°C is different from that of 180°C. Similarly, the compressive strength parallel to the grain at the aluminum foil wrapping is also different from the compressive strength parallel to the grain that without the aluminum foil. Table 4 shows the effect of temperature treatment and aluminum foil wrapping on the compressive strength parallel to the grain.

Table 4: Compressive strength parallel to the grain.

Treatment	Compressive strength (MPa)
Control	39.23
Temperature 170°C	43.92
Temperature 180°C	46.88
Without aluminum foil	43.94
Aluminum foil	46.86

Bending strength (MOR) of samples subjected to temperature treatment and aluminum foil wrapping decreased when compared to the bending strength of the control samples. The mechanical strength at static bending, represented by MOR, decreased significantly with increasing temperature of treatment [5, 11, 12]. As the temperature

treatment increases, the bending strength decreases. While the treatment with aluminum foil results in a decrease in the bending strength. The results of statistical analysis showed that the temperature treatment, the aluminum foil wrapping treatment, and the interaction between temperature treatment and aluminum foil wrapping did not significantly affect the bending strength. The decrease in bending strength due to temperature treatment is likely due to the destruction of wood cell wall especially hemicellulose. It was also discovered that the bending strength of wood samples after heat treatment decreases with increased loss of mass[13]. Table 5 shows the effect of temperature treatment and aluminum foil wrapping on the bending strength.

Table 5: Bending strength.

Treatment	Bending strength (MPa)
Control	53.97
Temperature 170°C	52.83
Temperature 180°C	51.72
Without aluminum foil	52.22
Aluminum foil	52.33

Compared with the modulus of elasticity of control samples, the experimental samples treated with temperature and aluminum foil wrapping have a higher modulus of elasticity. Increased temperature treatment increases the modulus of elasticity of samples [5]. However, the temperature treatment has no significant effect on the modulus of elasticity. Although the modulus of elasticity of the aluminum foil wrapping sample was higher than without the aluminum foil wrapping the treatment of aluminum foil wrapping did not significantly affect the modulus of elasticity. Likewise, the interaction between the temperature treatment and aluminum foil wrapping have no significant effect on the modulus of elasticity. Table 6 shows the effect of temperature treatment and aluminum foil wrapping on the modulus of elasticity.

Table 6: Modulus of elasticity.

Treatment	Modulus of elasticity (MPa)
Control	3,789.63
Temperature 170°C	3,827.58
Temperature 180°C	3,976.95
Without aluminum foil	3,876.85
Aluminum foil	4,027.67

The mechanical properties were affected differently for the three wood species. Heat-treated Cumaru showed increased Janka hardness, MOR and MOE. Peroba mica

increased MOR and MOE but not Janka hardness; while Bracatinga was less influenced by the heat treatment [14].

4. Conclusions

From the experiment carried out above, it is discovered that physical properties such as moisture content are significantly affected by temperature treatment and aluminum foil wrapping. That is, the moisture content of treated wood decreased compared to control wood. There was also a noticeable loss of weight but not density. The temperature treatment and aluminum foil increased the compressive strength parallel to the grain significantly. However, this treatment did not affect the bending strength and modulus of elasticity.

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