

Engineering Evaluation of Pressing Temperature Effects on Mahogany Wood Particleboard Characteristics

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ABSTRACT

Particleboard is one of the products of the use of wood powder waste that can be used by the community. This study aims to analyze the effect of 140 °C, 160 °C, and 180 °C pressing temperature variations on the physical properties and mechanical properties of particle boards made from mahogany wood powder waste. In this study, the materials used are mahogany wood powder, citric acid, and PVAC. The composition used in the manufacture of the specimen is 60% wood powder and 40% adhesive and is pressed with a pressure of 15 kg/cm² for 10 minutes. The particleboard is tested for its physical and mechanical properties and will be compared with SNI 03-2105-2006. The results showed that the average density value ranged from 0.47-0.54 g/cm³ with the highest particleboard density value obtained at 180 °C pressing temperature. The average moisture content value ranges from 6.1-7.2% with the highest particleboard moisture content value obtained at 140 °C pressing temperature. The average MOE value ranges from 2135.7-2401.3 kg/cm² with the highest particleboard MOE value obtained at 180 °C pressing temperature. The average MOR value ranges from 31-38.3 kg/cm² with the highest particleboard MOR value obtained at 160 °C pressing temperature. In the physical properties test the entire particleboard has met the standard.

However, in the mechanical properties test, the entire particleboard did not meet the standard. The best treatment in this study is the particleboard resulting from the treatment of a pressing temperature of 160 °C.

Keywords: *Citric Acid, Composite, Mechanical Properties, Physical Properties, Polyvinyl Acetate.*

INTRODUCTION

Indonesia is a country known for its abundant forest wealth. This can be seen by the existence of a large population of tropical rainforests. One of the products produced from forest wealth is wood. Wood is widely used in daily life, for example as a basic material for construction, furniture, decoration, and others. This is the reason why there are many sawmill industries in Indonesia. With the large sawmill industry, the waste produced is also abundant. The types of waste produced are shears, powders and scrolls. From 30 m³ of processed blocks and boards, waste was produced as much as 46.73 %/m³ with an average type of slash waste of 7.47 %/m³, powder 6.80 %/m³ and scroll 32.47 %/m³. One of the waste products from sawing that is widely available and found is mahogany wood. The production of sawn timber from mahogany-based people's forests reaches more than 500,000 m³ per year, resulting in about 150,000–200,000 m³ of unfully utilised powder and cut waste.

Although the waste produced by the sawmill industry is included in the easily decomposed waste, if the amount of waste produced is large, it will still take time for everything to decompose and usually the waste will be burned. Therefore, the utilization of waste from the sawmill industry is needed. One of them is the use of wood powder into composite products such as particle boards. Composite is a material that is produced from the combination of two or more basic materials that are arranged so as to obtain new materials. Composite is a material that is produced from the combination of two or more basic materials that are arranged so as to obtain new materials. Mahogany wood is one type of hardwood that can be used as a raw material for particle board due to its chemical composition

and physical characteristics that support the process of forming and binding particles during production. Based on research by Mahogany wood contains cellulose, hemicellulose, and lignin in ideal amounts to produce strong natural bonding when processed at high pressure and temperature.

Particleboard is a composite product derived from wood particle waste and synthetic resin at high temperatures and pressures. Particleboard has advantages over its original wood, namely its size and density can be adjusted according to needs. The final properties of particleboard such as density, moisture content, modulus of elasticity (MOE), and modulus of rupture (MOR) are greatly influenced by the stages of the production process called hot pressing. This process is a crucial stage in particleboard manufacturing, as it serves not only to form the physical of the board, but also to determine the success of the bonds between particles through the activation of the adhesive used. The two main parameters in this process are the pressing temperature and the length of the pressing time.

The optimal pressing temperature will ensure an even distribution of heat throughout the panel, so that the polymerization reaction of the adhesive can take place perfectly. This reaction is important because it plays a role in the formation of a network of bonds between wood particles that determines the overall mechanical strength of the board. If the temperature is too low, the available thermal energy is not enough to fully activate the adhesive, resulting in a weak, inthorough, or even failed bond. This causes the board to be brittle, prone to delamination, and has low MOE and MOR values. On the other hand, pressing with too high a temperature or with too long a duration can cause thermal degradation of the chemical structure of the wood particles, making the board hard but brittle, losing flexibility, and cracking easily, especially when subjected to bending loads.

Therefore, research with an experimental approach is needed to identify the most effective pressing temperature parameters to optimize the physical and mechanical properties of the particleboard. Previous research has shown that increasing pressing temperatures generally increases mechanical strength to a certain extent, before eventually decreasing due to thermal damage. This confirms that

temperature control and pressing time are crucial to achieve the quality of the board that meets the standard.

Several previous studies have evaluated the effect of pressing temperature on the quality of fast-growing wood-based particleboards such as sengon and other biomass waste. The temperature factors affect specific gravity, moisture content, and static curve constancy for both MOR and MOE values. With a temperature of 160 °C and 10 minutes as the best result. Palm stalk-based particleboard shows that the optimal temperature of pressing is at 160 °C with a time of 7 minutes, because it meets the SNI 03-2105-2006 standard and saves the economic value of particleboard manufacturing. However, not all mechanical properties such as MOE can meet the standard, indicating that there are still aspects of the process that need to be optimized. Composite boards made of gambier-adhesive TKKS fibers shows that laminated composite boards that are pressed at a temperature of 130 °C have lower physical and mechanical properties than boards that are pressed at temperatures of 145 °C, and 160 °C. The temperature of 190°C gave the highest MOE value to particleboards from pine bark powder and empty bunches of oil palm, the MOR properties decreased at these temperatures. These differences in results indicate that the relationship between the pressing temperature, the materials used, and the quality of the board is not linear and can be further researched.

Based on this, a study was conducted with the title "Engineering Evaluation of Pressing Temperature Effects on Mahogany Wood Particleboard Characteristics".

This chapter aims to analyze the effect of pressure temperature variations on the physical properties (density and moisture content) and mechanical properties (MOE and MOR) of wood powder-based particleboards. This research will focus on the optimal temperature to produce boards with quality that meets or exceeds the SNI 03-2105-2006 standard. In line with the United Nations Sustainable Development Goals (SDGs), especially SDG 9 (Industry, Innovation, and Infrastructure) by developing and innovating composite materials, SDG 12 (Responsible Consumption and Production) by utilizing waste from the sawmill industry into composite products, and SDG 13 (Climate Action) by preventing the

burning of wood powder waste that can produce greenhouse gases such as carbon dioxide and Methane.

A. PRESSING PARAMETERS AND EXPERIMENTAL DESIGN

The tools used in this study are analytical scales, mesh 10 sieves, mixing containers, hydraulic hot press machines, measuring cups, jigsaw machines, calipers, bars, aluminum printing tools, ovens, Universal Testing Machine (UTM). The materials used in this study are mahogany wood powder, PVAC, citric acid, water.

The target density of the board is 0.67 g/cm³, with a board size of 27 cm x 27 cm x 1 cm. The adhesive used is a mixture of citric acid and PVAC with a ratio of 1:1 and an adhesive content of 40% of the weight of the board. The pressing pressure is carried out at 30 kg/cm² for 10 minutes. The temperature variations used are 140 °C, 160 °C, 180 °C. The total of the treatment is 3 with 2 repetitions, so there are 6 boards. To make it easier for readers to understand the order of this study, a flowchart is shown as shown in Figure 1.

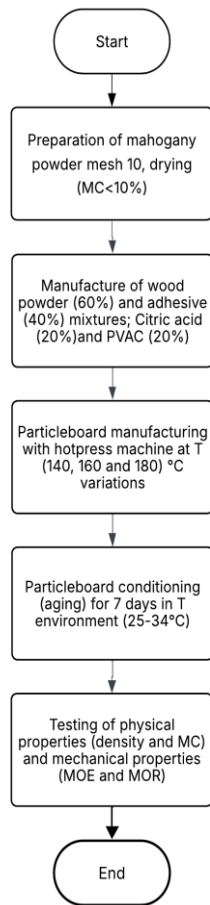


Figure 1. Flowchart

Prepare the material from mahogany wood powder and dry it until it reaches a moisture content of 8%. Then filtering is carried out with a 10 mesh sieve to get the desired particle size. The next stage is the mixing of raw materials with adhesives. The adhesives used are citric acid and PVAC with a ratio of 1:1. The composition of the adhesive used is 40% of the weight of the board. The process of mixing wood powder materials with adhesive is carried out manually with the media of the mixing container. The next stage is the making of sheets. The wood powder material that has gone through the mixing process with adhesive is put into a sheet mold with a size of 27 cm x 27 cm x 1 cm. It is then pressed with a pressure of 15

kg/cm² with some temperature variation for 10 minutes. The temperature variations used are 140 °C, 160 °C, 180 °C. The next stage is conditioning. Before the test is carried out, the particleboard will be conditioned. The purpose of particleboard conditioning is to bring the moisture content close to equilibrium before testing. Conditioning is carried out for 7 days at room temperature. In addition, the purpose of this conditioning is also to ensure that the adhesive hardens perfectly on the board as well as to eliminate the surface tension on the board. Next, the test specimen is cut with the aim of making the particleboard the size of the test equipment provided.

The properties of the particleboard are tested i.e., physical properties and mechanical properties such as density, moisture content, MOE, and MOR. The method of testing is guided by SNI 03-2105-2006.

1. Density

Particleboard density testing is carried out by weighing the weight in dry air conditions with a test specimen size of 10 cm x 10 cm x 1 cm. The particle board density value can be calculated using the following Equation (1).

$$\rho = \frac{B}{V} \quad (1)$$

Where

ρ = density (g/cm³)

B = test specimen weight (g)

V = test specimen volume (cm³)

2. Moisture Content

The size of the test specimen used for the moisture content test is the same as the density test, which is 10 cm x 10 cm x 1 cm. Then the specimen will be tested using a moisture meter in a dry state on each side of the test specimen.

3. MOE and MOR

MOE testing is carried out in conjunction with MOR testing using UTM machines with a test specimen size of 20 cm x 5 cm x 1 cm. The MOE value can be calculated using the Equation (2) and the MOR value can be calculated using the Equation (3).

$$MOE = \frac{\Delta PL^3}{4\Delta ybh^3} \quad (2)$$

$$MOR = \frac{3PL}{2bh^3} \quad (3)$$

Where

MOE = modulus of elasticity (kg/cm²)

MOR = modulus of rupture (kg/cm²)

ΔP = change in the load used (kg)

P = maximum load (kg)

L = test specimen length (cm)

Δy = change in deflection per change in load (cm)

b = test specimen width (cm)

h = test specimen thickness (cm)

B. EFFECT OF PRESSING TEMPERATURE ON PHYSICAL PROPERTIES

The particle board results obtained from the hot-pressing process with temperature variations can be seen in Figure 2. The results of the hot-pressing process significantly influence the physical and mechanical properties of the particleboard, including density, moisture content, MOE, and MOR. Variations in pressing temperature affect the internal bonding and compaction of particles, thereby altering these key properties.

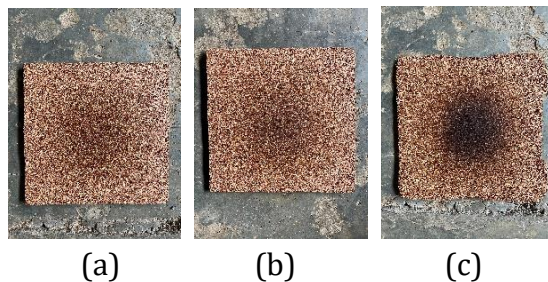


Figure 2. Particleboard samples produced at different hot pressing temperatures: (a) 140 °C, (b) 160 °C, and (c) 180 °C.

1. Density

The results of the density test on particle board in this study are shown in Table 1. The results of the particleboard density test that have been carried out show that the pressing temperature influences the particleboard density.

The density value of mahogany particleboard with citric acid and PVAC adhesives obtained from the variation in pressing temperature ranges from 0.47-0.54 g/cm³.

Table 1. Density Test Results

N	Pressing Temperature (°C)	Average Density (g/cm ³)
o.		
1	140 °C	0,47
2	160 °C	0,50
3	180 °C	0,54

The highest particleboard density value was obtained at a pressing temperature of 180 °C with a value of 0.54 g/cm³. Meanwhile, the lowest particleboard density value was obtained at 140 °C pressing temperature treatment with a value of 0.47 g/cm³. The particleboard density value obtained by the variation in the pressing temperature used has met the SNI 03-2105-2006 standard which limits the particleboard density value to range from 0.4 – 0.9 g/cm³.

The test results showed that the higher the pressing temperature caused the density value to increase. Increasing particleboard density is possible because high temperatures can support a better bonding process. On the other hand, at temperatures that are too low, it causes the gluing process to run poorly. Some of the factors that affect the density value of the board include the type of wood (wood density), the amount of pressure, the number of wood particles on the base, the adhesive content, the pressure thickness, and other additives.

2. Moisture Content

The results of the moisture content test on the particle board in this study are shown in Table 2. The results of the particleboard moisture content test that has been carried out show that the pressing temperature influences the moisture content of the particleboard. The moisture content value of mahogany particleboard with citric acid and PVAC adhesives obtained from the variation in pressing temperature ranges from 6.1-7.2%.

Table 2. Moisture Content Test Results

No	Pressing Temperature (°C)	Average Moisture Content (g/cm ³)
1	140 °C	7,2
2	160 °C	6,9
3	180 °C	6,1

The highest moisture content value of the particleboard was obtained at the treatment of pressing temperature of 140 °C with a value of 7.2%. Meanwhile, the lowest moisture content value of particleboard was obtained at 180 °C pressing temperature treatment with a value of 6.1%. The moisture content value of particleboard obtained by varying the pressing temperature used has met the SNI 03-2105-2006 standard which requires the moisture content value of particleboard to be around $\leq 14\%$.

Some of the factors that affect moisture content include temperature and pressing time factors and the type of adhesive that affects the moisture content. The value of the resulting moisture content will decrease as the temperature increases. At a felt temperature of 140 °C, the moisture content of the particleboard is higher than at a felt temperature of 180 °C, which decreases. This is because the increase in pressing temperature will accelerate the evaporation of water from the mold resulting in a low moisture content value. This is in line with what was said (Lindangan et al., 2019) that the moisture content is affected by the amount of water evaporated during the pressing process and the water content in the adhesive.

C. MECHANICAL PROPERTIES AND THERMAL SENSITIVITY ANALYSIS

1. MOE

The results of MOE testing on particle board in this study are shown in Table 3. The results of the particleboard bending robustness test that has been carried out show that the pressing temperature affects the MOE value of the particleboard. The MOE value of mahogany particleboard with citric acid and PVAC adhesives obtained from the

variation in pressing temperature ranges from 2135.7-2401.3 kg/cm².

Table 3. MOE Test Results

No.	Pressing Temperature (°C)	Average MOE (kg/cm ³)
1	140 °C	2135,7
2	160 °C	2301
3	180 °C	2401,3

The highest MOE value of particleboard was obtained at 180 °C pressing temperature treatment with a value of 2401.3 kg/cm². Meanwhile, the lowest MOE value of particleboard was obtained at 140 °C pressing temperature treatment with a value of 2135.7 kg/cm². The particleboard MOE value obtained by the variation in the pressing temperature used has not met the SNI 03-2105-2006 standard which requires a particleboard MOE value of $\geq 20,400$ kg/cm².

This is because the adhesion between the particles and the adhesive is not fused during the pressing process so that many pores are present on the particleboard which causes the MOE value to be low. Although the test results obtained still do not meet the standard, this study shows that the higher pressing temperature will increase the MOE value. The higher heating temperatures increase the bonding rate of the adhesive which will increase the strength. The increase in pressing temperature will be able to increase the MOE value for all adhesives. Lower temperatures during the hot heating process lead to low strength as the resin does not harden. Another study said that increased pressing temperatures resulted in better panel performance.

2. MOR

The results of MOR testing on particle board in this study are shown in the following Table 4. The results of the particleboard fracture test that has been carried out show that the pressing temperature affects the MOR value of the particleboard. The MOR value of mahogany particleboard with citric acid and PVAC adhesives obtained from the variation in pressing temperature ranges from 31-38.3 kg/cm².

Table 4. MOR Test Results

No.	Pressing Temperature (°C)	Average MOR (kg/cm ³)
1	140 °C	31
2	160 °C	38,3
3	180 °C	34,7

The highest particleboard MOR value was obtained at a pressing temperature of 160 °C with a value of 38.3 kg/cm². Meanwhile, the lowest particleboard MOR value was obtained at a pressing temperature of 140 °C with a value of 31 kg/cm². The MOR value of particleboard obtained by varying the pressing temperature used has not met the SNI 03-2105-2006 standard which requires a particleboard MOR value of ≥ 82 kg/cm².

The test results showed that when pressing particleboard with a temperature of 140 °C, a lower MoR value was obtained. This can happen because the adhesive bonds with the fibers are less fused so that the particleboard is fragile and the load-bearing ability decreases. In addition, the low MOR value is suspected to be due to the uneven distribution of particles in the board manufacturing process which results in there are still cavities on the particleboard. But too high a temperature can also reduce the mechanical properties of the particleboard itself. The high temperature in the heating process can contribute to the degradation of the crystalline structure of the cellulose chain and affect the heat conduction capacity, which can damage the mechanical strength of the panel. This can be seen in the treatment of 180 °C temperature which has a lower MOR value compared to the treatment at 160 °C temperature.

CONCLUSION

The results of the research that have been carried out show that the properties of particleboard are affected by the pressing temperature. The pressing temperature is an important parameter in optimizing the quality of particleboard. The quality of the physical properties of particleboard from mahogany wood powder waste with citric acid and PVAC

adhesives has shown that the density and moisture content values of all variations of pressing temperatures meet the standard of SNI 03-2105-2006. Although the value of the density is not in accordance with the density target. The quality of the mechanical properties of particleboard from mahogany wood powder waste with citric acid and PVAC adhesives has shown that the MOE and MOR values at all variations of pressing temperatures have not met the standard, namely SNI 03-2105-2006. The best particleboard treatment from this study is the particleboard resulting from the 160 °C pressing temperature treatment because it meets the SNI 03-2105-2006 standard in the physical properties of the particleboard although in mechanical properties it does not meet the standard.

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