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Optimization to Improve the Quality of Laminated Bamboo Wood for Furniture Processed Products

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ABSTRACT The use of bamboo as an alternative to wood in the furniture industry through lamination technology continues to grow, especially in the UMKM sector. However, until now the quality of laminated bamboo wood panels is uneven and not comparable to the quality of solid wood. This study aims to determine the effect of the smoothing and pressing process on the quality of laminated bamboo wood panels in matching the quality of solid wood. Through the design and testing of an optimized lamination machine, this study is expected to contribute to improving the quality of laminated wood panel production in the UMKM sector, so that the results can be comparable to solid wood.

INDEX TERMS Bamboo, Laminate Technology, Solid Wood, Laminated Wood Panels, Furniture.

I. INTRODUCTION

Bamboo is one of the natural raw materials that has great potential as an alternative substitute for wood in various industries, including the furniture industry [1]. The advantages of bamboo include its rapid growth, flexibility, and sustainability as a natural resource [2]. Amidst the limited supply of solid wood due to deforestation and environmental conservation policies, bamboo lamination technology has developed as a promising solution. Currently, there have been many studies with special studies on the processing of bamboo into wood using lamination techniques. However, until now it is still uncertain whether wood from bamboo substitution using lamination technology has the same or comparable material properties as solid wood or not. The purpose of this study was to determine the effect of the smoothing and pressing process on the quality of laminated bamboo wood panels, and what processes and machines should be used in production so that the quality of laminated bamboo panels matches the quality of solid wood. Through the design and testing of optimized lamination machines including smoothing machines and pressing machines. It is hoped that the quality of laminated bamboo wood panels will have the same or comparable quality to solid wood in terms of the material properties they have.

II. RESEARCH METHODOLOGY

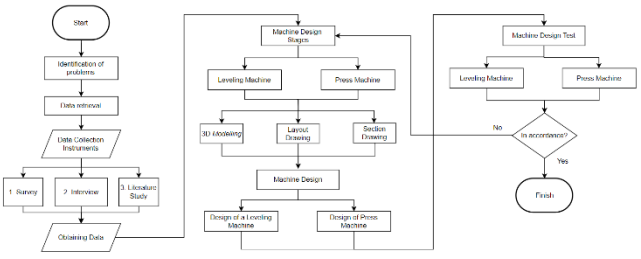

FIGURE 1 Problem Solving Methodology

The flowchart in Figure 1 illustrates the research and design process of bamboo lamination machines, starting from problem identification to testing the machine design. The initial stages include data collection through surveys, interviews, and literature studies to determine how much influence the smoothing and pressing processes have in the bamboo lamination process to produce laminated bamboo wood panels that have the same quality as solid wood which are then used to design the smoothing machine and press machine. The design is made through 3D modeling and preparation of technical drawings, which are then tested to ensure suitability. If the test results are not suitable, the machine design is revised until it reaches the desired quality, then the research process is considered complete.

III. RESULTS AND DISCUSSION

A. UTILIZATION OF BAMBOO INTO FURNITURE PRODUCTS

The use of bamboo is very suitable for making furniture products because furniture products do not require special specification demands, unlike if bamboo is to be used as a material for civil products that require further processing with the process of injecting carbon materials into laminated wooden boards. A comparison of the properties of wooden board materials for furniture products and civil industry products can be seen in Table 1 below [3].

TABLE I
UNITS FOR MAGNETIC PROPERTIES

Nature	Need For Furniture	Need For Civil
Density	0.60 g/cm^3 – 0.70 g/cm^3	0.80 g/cm^3 – 0.90 g/cm^3
Modulus of Elasticity (MOE)	143.127 kg/cm^2 - 172.673 kg/cm^2	2.400,00 kg/cm^2
Modulus of Repture (MOR)	1.107,24 kg/cm^2 - 1.410,18 kg/cm^2	1.150,12 kg/cm^2 – 2.225,36 kg/cm^2

B. FACTORS INFLUENCE THE QUALITY OF BAMBOO LAMINATED WOOD PANELS

Factors Influencing the Quality of Bamboo Laminated Wood Panels involve several important aspects that must be considered carefully. First, the selection and management of bamboo is a crucial initial step, because high-quality bamboo with appropriate characteristics will produce stronger and more durable panels. Second, the smoothing of bamboo slats must be done carefully to ensure that each slat has a uniform thickness, so that the resulting panel has a smooth and consistent surface. Finally, the process of Pressing bamboo slats into wood panels is also very important, where the right pressure and even distribution will ensure the structural integrity and overall quality of bamboo laminated wood panels [4]. The complete influencing factors can be seen in Table 2 below.

TABLE 2
FACTORS INFLUENCING THE QUALITY OF LAMINATED BAMBOO WOOD

No	Influencing Factors	Description
1	Bamboo Selection and Processing	Bamboo Selection and Processing Process is an important process that affects the quality of laminated wood later because the specifications and properties must meet the criteria so that the quality of the laminated bamboo wood panel can be the same or comparable to the quality of solid wood. Ideally, the bamboo used is bamboo that is 2.5-3 years old and has a diameter of 10-13 cm [5].
2	Bamboo Slats Flattening Process	The bamboo splitting process usually uses an automatic splitter machine or a sun-cutting knife, but this method often produces bamboo slats that are not straight and curved. As a result, the leveling process is not optimal and many slats do not meet the standard size even though the process time is fast. The bamboo slat leveling process is very important because flat slats are needed to produce quality laminated bamboo wood panels that are comparable to solid wood.
3	The pressing process or pressing of bamboo strips that have been glued to be laminated	The process of pressing bamboo slats into wood panels is the crucial final stage in the manufacture of bamboo laminated wood panels. At this stage, the flattened bamboo slats are arranged and pressed together using high pressure. The right pressure and even distribution are essential to ensure that the slats adhere firmly and form a solid and consistent panel. Too little pressure or uneven distribution can result in brittle panels with inconsistent thickness and strength. Therefore, the press machine must be properly calibrated to ensure optimal results.

C. DESIGN OF A FLATTERNER MACHINE

Based on the results of the literature study, information was obtained regarding the main processes that affect the quality of laminated bamboo wood panels, one of which is the leveling process. In the bamboo leveling process, the problem that occurs is the structure of the bamboo blades that have been split, the shape is not all straight and relatively curved so that when the leveling process the top, bottom, and sides of the bamboo blades are not optimal and many bamboo blades fail in terms of size. In this study, the author tries to create a solution to this problem, namely in the form of designing a Flatterner Machine, where this Flatterner Machine in addition to having a leveling function, also has a splitting or splitter function. So that the splitting and leveling processes are carried out at the same time and the result is that the quality of the bamboo blades will be even. Where the design concept of the Flatterner Machine that has been considered and through the assessment process is depicted in Table 3 and the 3D design model can be seen in Figure 2 below.

TABLE 3
CONCEPT OF THE FLATTERNER MACHINE SYSTEM

System Concept	Description
Guide system	The guide uses a slider system with 1 control lever on each side
Grading and cutting system	The leveler and cutter use a fixed double saw system
Drive system	The driver uses a 1 phase electric motor
Frame system	The frame uses L angle iron material

D. UTILIZATION OF BAMBOO INTO FURNITURE PRODUCTS

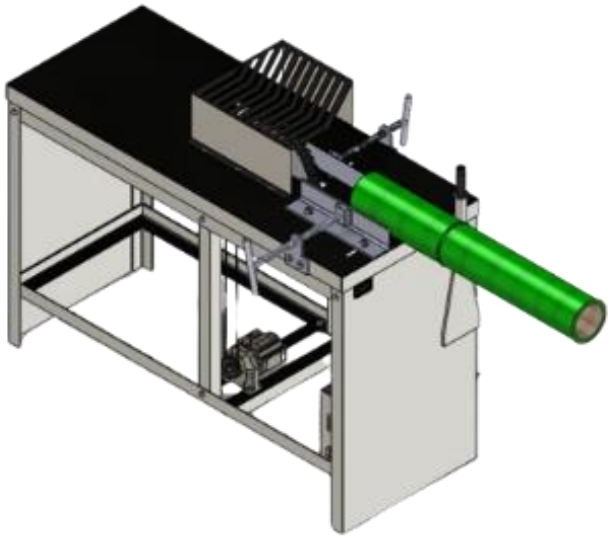

FIGURE 2 3D design model machine

FIGURE 3 The bamboo blades produced

The detailed specifications of the Flatterner Machine are as follows:

1. Processing time of the Flatterner Machine : 7 minutes / bamboo (left side, right side, top, and bottom alignment)
2. Drive motor : Sumitomo 0.1 kW electric motor
3. The size of the bamboo blades produced : 2000 mm x 20 mm x 8,5 mm

E. DESIGN OF PRESS MACHINE

The process of pressing bamboo slats into wood panels is the final stage that is very important in making bamboo laminated wood panels. At this stage, the flattened bamboo slats will be arranged and pressed together using high pressure. The right pressure is very important to ensure that the slats adhere to each other firmly, forming a solid unit. If the pressure used is too low, the bamboo slats may not adhere properly, which can result in a fragile panel that is easily separated. In addition to the right pressure, even pressure distribution is also a key factor. Uneven pressure distribution can cause some parts of the panel to be denser while other parts are less dense, resulting in panels with inconsistent thickness and strength. To avoid this, the Press machine used must be properly calibrated to ensure that pressure is applied evenly to the entire surface of the panel. The Press machine designed by the author has 4 Hydroulic Powerpack cylinders, so that the pressing process is faster, the pressure is even, and the quality of the resulting wood panels can be equal to or comparable to the quality of solid wood. The detailed concept can be seen in Table 4 and the 3D design of the machine in Figure 4 below.

TABLE 4
CONCEPT OF THE FLATTERNER MACHINE SYSTEM

System Concept	Description
Pressure system	Hydraulic power pack system with 4 cylinders.
Drive system	The drive uses a 1 phase electric motor.
Frame system	Frame system with H and U profiles.

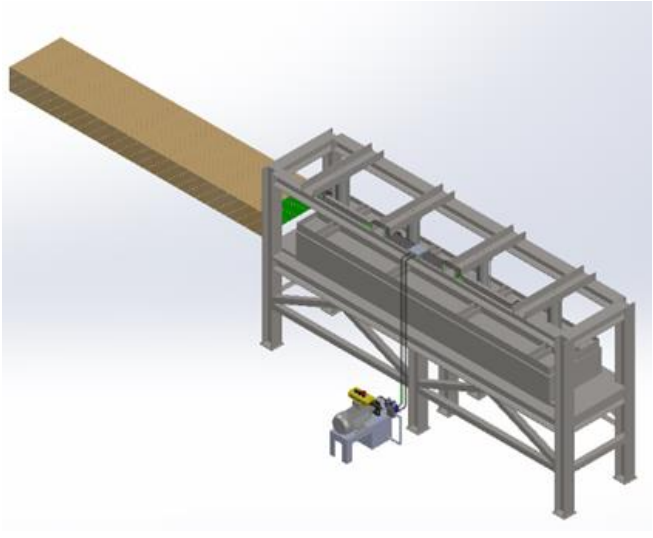

FIGURE 4 3D design model machine

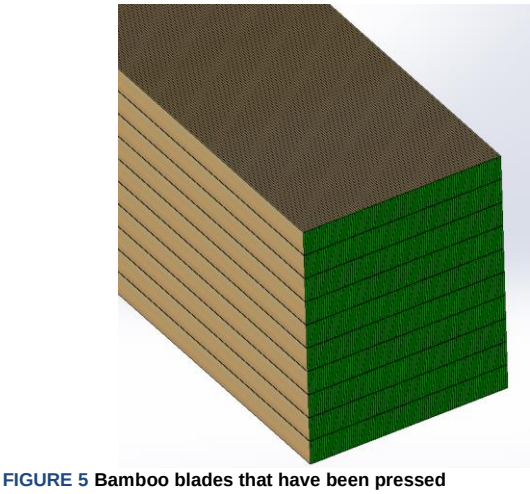

FIGURE 5 Bamboo blades that have been pressed

The detailed specifications of the press machine are as follows:

1. Processing time of the Flatterner Machine : 5 minutes / 1 process
2. Drive motor : Sumitomo 5,5 kW electric motor
3. The size of the bamboo blades produced : 2000 x 200 x 20 mm

F. MACHINE DESIGN TESTING

Comparison of Existing Leveling Process and New Leveling Process:

The difference between the existing leveling process and the new leveling process is in the splitting or splitter process, where in the new leveling process there is no previous splitter process but the splitter process is combined with the leveling process. The detailed comparison of the processes can be seen in Figure 6 and Figure 7 below.

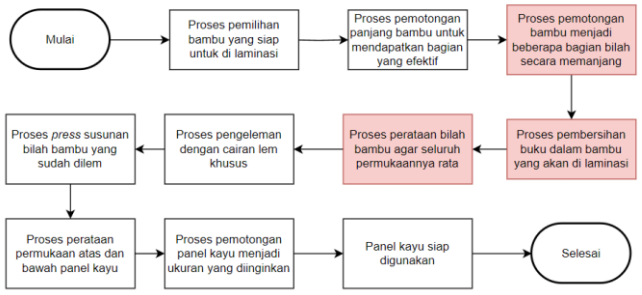

FIGURE 6 **Existing bamboo slats leveling process**

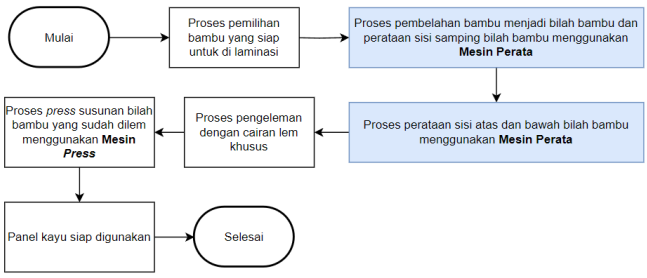

FIGURE 7 **New bamboo slats leveling process**

From Figure 6 and Figure 7, it can be seen that there are 2 processes that are optimized or eliminated, namely the splitter process and the bamboo blade book smoothing process, where both processes are combined in the smoothing process using a new smoothing machine design.

Results of Testing the Strength of the Design Frame of the Press Machine:

The Press machine design test was carried out using software simulation, namely Autodesk Inventor. The scope of the test is related to the strength of the Press machine frame and the Press machine bed. The simulation was carried out to determine whether the designed frame is strong and sturdy or not, as seen from the stress that occurs in the frame and bed of the frame. The following are the results of the frame strength test, which can be seen in Figure 8 and Figure 9 below.

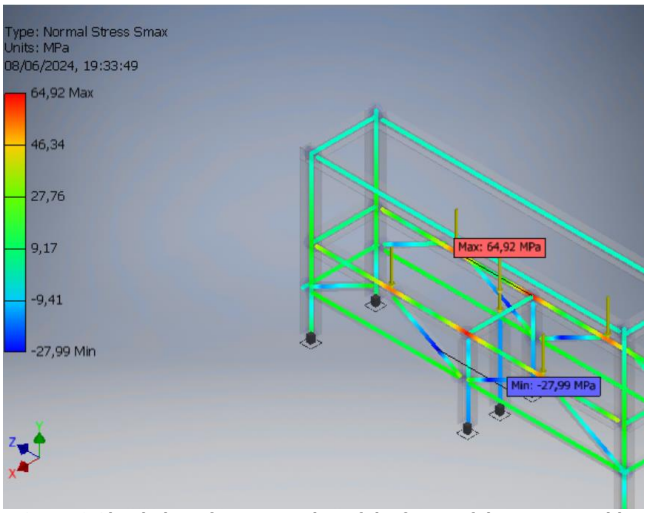

FIGURE 8 **Simulation of stress testing of the frame of the Press Machine**

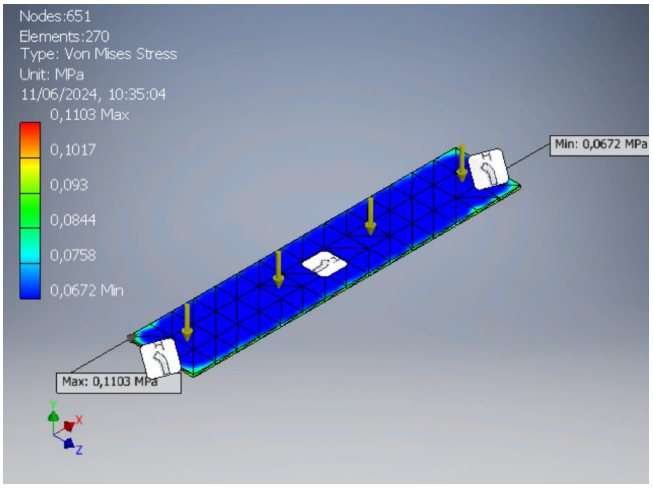

FIGURE 9 **Simulation of stress testing of the frame of the Bed Press Machine**

From the results of the software test simulation, the maximum stress that can occur is 64.92 Mpa, which is smaller than the stress value of the frame material used, which is 566.62 Mpa. So, it can be concluded that the designed frame construction is strong and sturdy to withstand a press load of 15 tons. Then, from the results of the software test simulation, the maximum stress that can occur is 0.1103 Mpa, which is smaller than the stress value of the bed material used, which is 566.62 Mpa, and it can

be concluded that the designed bed construction is strong and sturdy to withstand a press load of 15 tons.

G. LAMINATED WOOD PANEL MODULE RESULTS

The resulting laminated wood board module is a wood panel with a size of 2000 x 200 x 20 mm. The material properties of the wood panel after going through the appropriate leveling and pressing process are as follows in Table 5.

TABLE 5
PROPERTIES OF LAMINATED BAMBOO MATERIAL, NON-DESTRUCTIVE TEST RESULTS [4]

Properties	Unit	Laminated Wood Panels	Solid Wood Panels
Moisture content	(%)	12,33	13,93
Density	(g/cm^3)	0,72	0.65
Thickness swelling	(%)	6,75	0,65
Water absorption	(%)	37,12	
MOR	(kg/cm^2)	397,94	37,12

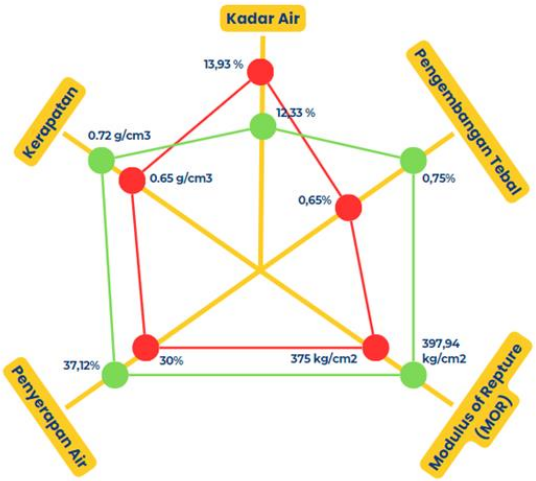

FIGURE 10 Comparison diagram of material properties of laminated bamboo wood and solid wood

As can be seen in Table 5 and Figure 10 above, it can be seen that the quality of laminated bamboo wood panels has a quality comparable to solid wood which is usually used for furniture products when viewed from the material properties it has.

IV. CONCLUTIONS

The Flattening and Pressing process in bamboo lamination technology is very important and determines the quality of the resulting wood panels. The design of the flattening machine is a flattening machine that combines the splitting or splitter and flattening processes at once so that the process of lamination of bamboo into wood will be more optimal, effective, and efficient so that the resulting wood panels can be of equal or comparable quality to solid wood. The designed Press Machine also has 4 Hydroulic Powerpack cylinders, so that the pressing process is faster, the pressure is even, and the quality of the resulting wood panels can be equal or comparable to the quality of solid wood.

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