A Design of Bamboo Plywood Pressing Machine

Le Khanh Dien¹,*, Tran Van Hung², Hoang Duc Lien³, Svetlin Antonov⁴

ABSTRACT
Bamboo is very popular in countryside of almost all Southeast countries, particularly in Vietnam. Its ability can replace some kinds of wood in decoration and household goods. Bamboo grow up rapidly and can be harvested within 3 to 5 years of planting, in the meanwhile the harvesting time of other hardwood trees must be from 8 to 10 years or longer. The inherent characteristics of bamboo is lighter than other wood materials and has a value in social and environmental benefits. Its advances in manufacturing technology have created high value products such as bamboo flooring and bamboo furniture that can substitute for wood flooring and wood furniture. Bamboo plywood presses play an important role in the production bamboo plywood in industry. The machine has the function of pressing bamboo powder and binder has been mixed from the front to the bamboo plank to meet the technical requirements. This article presents a design of bamboo plywood pressing machine that combines the heating function for the block board and keeps that temperature during the pressing process to create a suitable size bamboo plywood according to customer requirements. The simulation results show that the complete bamboo plywood-pressing machine is appropriate and authentic to the initial design. The result of the design was applied to manufacture the machine in DCSELAB workshop via a collaboration project between Langtre PhuAn company and the DCSELAB. The system is installed a resistance flat plate capacity of 1KW, and 2 resistors flat plate with capacity of 0.8KW. The first manufactured machine is now in the initial working session in Langtre Village, Binhduong province. The initial experimental products were accepted by the partner company and we have recommended some measures to ameliorate time by the quality as well as the productivity of the machine. There are really not yet an official statistic on the comparison with the products of similar machine and we are attending the respond of the customers.

Key words: Bamboo plywood, Pressing machine, Bamboo powder, Functional analysis

INTRODUCTION
BAMBOO is a sustainable and environmental friendly material that has the potential to improve the global decline of natural resources. Bamboo is very popular in countryside of almost all Southeast countries, particularly in Vietnam. Its ability can replace some kinds of wood in decoration and household goods. Bamboo grow up rapidly and can be harvested within 3 to 5 years of planting, in the meanwhile the harvesting time of other hardwood trees must be from 8 to 10 years or longer. The inherent characteristics of bamboo is lighter than other wood materials and has a value in social and environmental benefits. Its advances in manufacturing technology have created high value products such as bamboo flooring and bamboo furniture that can substitute for wood flooring and wood furniture. According to the biology studies, the bamboo has the characteristics that can replace the natural wood, but the direction of development from the stage of cultivation to the stage of finished products has not been exploited thoroughly. The closure and restrictive exploitation of forests in many countries around the world are an opportunity, but also a big challenge for businesses in developing wood alternative products of bamboo, especially in Vietnam¹.

With abundant bamboo resources, the production of bamboo plywood will become a great potential for the bamboo plywood industry in Vietnam. However, the bamboo plywood industry in Vietnam is only developing and stopping in the production of pressed bamboo. Therefore, instead of using the technology of squeezing bamboo together, we can chop and grind the bamboo tree to powder that is dried and pressed into bamboo plywood by specialized machine similar to the production artificial wood particleboard (PB).

Bamboo waste such as bamboo shoots thrown away after harvesters can be used to recycle and produce bamboo boards, both for environmental protection and for economic benefit³.

In the production process of bamboo plywood, the bamboo-pressing machine plays a very important role of the function of pressing bamboo powder plywood...
board after the the blending bamboo process and before cutting and trimming process to standard industrial dimensions. It is necessary to design carefully the bamboo plywood pressing machine because it is the main facture to decide the quality, the productivity and the saving energy of the chain of production of bamboo plywood. In the word, India and Thailand have had many experiences and applications of bamboo machine.

**METHODOLOGY OF RESEARCH**

**STRUCTURAL DESIGN FOR BAMBOO PRESSING MACHINE**

Functional analysis of bamboo pressing machine is shown in Figure 1.

To arrange the functions of the bamboo pressing machine, we have the following diagram (Figure 1)

System design, structure of bamboo pressing machine (Figure 2):

**RESULTS & DISCUSSION – DESIGN CALculATIONS OF BAMBOO PRESSING MACHINE**

In one word, the bamboo-pressing machine consists of the following modules: 1) Electric motors; 2) Gear box; 3) PLC controllers; 4) Load cell; 5) Mixing module; 6) Feed material module; 7) Hydraulic module; 8) Pressed module (Figure 3).

The selected machine size 500x300x200mm is appropriated to the volume of finished product after pressing is 0.03m³ according to the diagram in Figure 4.

- The density of pressed plywood is 800kg/m³.
- The volume of 1 mixed batch after squeezing is 800x0.03 = 24kg.
- Mixture ratio of bamboo glue: 8 ~ 12%.
- Maximum pressure on the surface p = 26 at.
- Total pressure on the surface: P = 50x30x26/1000 = 39 tons.
- The thickness of blended pulp: h = 200mm.
- Pressing course: S = 1050mm.
- Time holding pressure: t = 15 minutes.
- Maximum press temperature: T = 180°C.
- Heat resistance is applied.
- Power source: electric motor and hydraulic system.

**Select the cylinder**

Due to the system working with pressure (39 tons), we choose the working pressure of about 200 bar (20MPa)

The inner radius of the cylinder is given by the formula:

\[ r_B = \sqrt{\frac{P_H}{\pi p}} = \sqrt{\frac{39 \times 1000}{\pi \times 200}} = 7.88 \text{ cm} = 78.8 \text{ mm} \]


The inner diameter of the calculations of the cylinder:

\[ D_B = 2r = 157.6 \text{ mm.} \]

Selected D_B = 160mm.

The outer diameter of the cylinder: \( D_H = 2.5r \)

The cross-section area of the cylinder:

\[ F = \pi D_B^2 = \frac{3.14 \times 160^2}{4} = 20106.2 \text{ mm}^2 \]

The volume of fluid oil in the cylinder: \( A_{\text{max}} = H.F = 100 \times 20106.2 = 2010620 \text{ mm}^3 \) or \( 2.01062 \text{ m}^3 \)

\[ H = \frac{t}{2r} = \frac{15}{2 \times 78.8} = 0.22 \text{ m} = 22 \text{ cm} \]

\[ D = \frac{q}{F} = \frac{3.9 \times 1000}{3.14 \times 200} = 157.6 \text{ mm} \]

\( q \) is the flow supplied by the pump (litre/s).

\( v \) is the flow velocity (m/s).

\[ Q = v.A \]

\( v \) is the flow velocity (m/s).

\[ v = \frac{A}{t} = \frac{2.01062 \times 10^3}{22 \times 60} = 120.6 \text{ litres/minute} \]

**Selection of oil pump**

Following to the schema of hydraulic system in Figure 5, the flow is calculated by the formula: \( Q = vxA \)

Q is the flow supplied by the pump (litre/s).

\( v \) is the flow velocity (m/s).

A is the piston bottom area \( [\text{m}^2] \).

The speed of the piston in the working direction is \( v_1 = S / t_1 \). Therefore, the supply flow rate for the cylinder in working direction is \( Q_1 = v_1xA = \frac{S}{t_1} \times \frac{A}{4} = \frac{1}{100} \times 3.14 \times 0.16 = 0.000201 \text{ m}^3 / \text{s} = 12.06 \text{ litres/minute} \).

The speed of the piston in the return direction is \( v_2 = S / t_2 \). The supply flow rate for the cylinder in the return direction is \( Q_2 = v_2xA = \frac{S}{t_2} \times \frac{A}{4} = \frac{1}{100} \times 3.14 \times 0.16 = 0.188 \text{ m}^3 / \text{s} = 11.3 l / \text{min} \).

Hence the flow rate of the source pump must be chosen to the bigger one Q1. The selected revolution per minute of the shaft of the pump is \( n = 1470 \text{ rpm} \) that is the most suitable revolutions of gear pumps.

Therefore, the specific flow of the pump is: \( Q = \frac{Q}{n} = \frac{12.06 \times 10^3}{1470} = 8.2000 \text{ mm}^3 / \text{loop} \).

Based on the following influential parameters such as pressure, flow rate, operating speed of the pump, the type of fluid, and cost of the system, the gear pump is the most reasonable choice because of its compact size, low cost and suitable pressure but small flow, easy maintenance and simple control.
Figure 1: Diagram of functional analysis of bamboo polywood pressing machine, mixed powder glue and squeeze the mixture by heating are very important session.

Figure 2: Functional arrangement map of bamboo plywood pressing machine, the recognition process is controlled by sensor with high accuracy.

Gear pump has the pressure in the range of \( p = 100 - 280 \) bar; suitable flow rate is \( Q = 100 \) (l/min);

Finally the gear pump HYDROMAX coded HGP-3A-8 is selected with specific flow: \( Q = 8000 \) mm\(^3\)/course; Maximum operating pressure \( P_{\text{max}} = 250 \) bar; Maximum rotation speed: \( n = 3500 \) rpm.

Computing the electric motor

System power: \( N = \frac{P \cdot Q}{612} = \frac{200 \times 12.06}{612} = 3.94 \) (kW).

Herein: \( Q \) is the flow rate of the pump; \( P \) is the system pressure.

From the above data, we have selected 4A100L4Y3 with specific parameters: 1500 rpm, power is 4 kW motor.

Testing the strength of the pressing barrel

Testing the strength of the pressing barrel with Solidworks software (Figure 6), the material is medium carbon steel with the following results:

Computing of heating

Parameters:
Figure 3: Structural plan of bamboo plywood pressing machine, heating queue is remote controlled

Figure 4: Dynamic diagram of bamboo plywood pressing machine
Figure 5: Schema of hydraulic system of bamboo plywood pressing machine

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Figure 6: Simulation result on resistance of material of the machine
\[ P = \frac{Q}{t} = \frac{1116}{24} \approx 1.24 kW \]

The schema of heating by shunt resistor is illustrated in Figure 7. The total structure of the designed bamboo plywood-pressing machine is illustrated in Figure 8 with high power.

**CONCLUSION**

The bamboo plywood pressing machine is one of the important machines that decide the quality of the plywood product. The simulation results show that the complete bamboo plywood-pressing machine is appropriate and authentic to the initial design. The result of the design was applied to manufacture the machine in DCSELAB workshop via a collaboration project between Langtre PhuAn company and the DCSELAB. The first manufactured machine is now in the initial working session in Langtre Village, Binhduong province. The initial experimental products were accepted by the partner company and we have recommended some measures to ameliorate time by time the quality as well as the productivity of the machine. There really are not yet an official statistic on the comparison with the products of similar machine and we are attending the respond of the customers.

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**AUTHOR’S CONTRIBUTION:**

The authors declare that all authors discussed the results and contributed to the final manuscript.

**CONFLICT OF INTEREST**

There is no conflict of interest.
Figure 7: Overall drawing of bamboo plywood pressing machine

Figure 8: Shuntresistor is controlled by computer and thermal sensor was applied for heating