A study on the design of bamboo grinding machine

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ABSTRACT

Bamboo is a sustainable and environmentally friendly material that has the potential to improve the global decline of natural resources. Bamboo is one of the popular flora in Southeast Asia, it is also traditional plants that grow abundantly in Vietnamese villages from north to south. Its ability can replace some kinds of wood in decoration and household goods. bamboo grows up rapidly and can be harvested within 3 to 5 years of planting, in the meantime 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 production of bamboo plywood will become a great potential for the bamboo plywood industry in Vietnam. Generally, the fabrication of bamboo plywood depends on the following processes such as cutting, grinding to powder or pulp, drying and pressing processes. In cutting and grinding processes, the trivial remains of bamboo after use, shoots... can be chopped and grinded to powder that is dried and pressed into bamboo plywood by specialized machine similar to the production artificial wood particleboard (PB). The aim of this paper is a representation of a design, a computing the structure of a version of bamboo grinding machine that is sustainable, responds to technical requirements and protect of environment. The result of the design was applied for manufacture a typical bamboo machine in CAD-CAM workshop of DCSELAB in the framework of a project between DCSELAB and PhuAn Village Corporation that has evaluated with satisfaction the realistic proof of the design. The machine has been in the session of initial testing and exploitation.

Key words: Bamboo plywood, Bamboo powder, Grinding machine

INTRODUCTION

Bamboo is a sustainable and environmentally friendly material that has the potential to improve the global decline of natural resources, particularly its ability of replacing the natural wood. From planting to harvesting there are only 3 to 5 years in comparison of the hard tree, it must be from 10 to 20 years to mature for harvesting. The inherent characteristics of bamboo in daily life, decoration and construction confirm its valuable position in consumer market such as: leaves for covering some kinds of traditional cakes, stem for column of thatched cottage, bamboo mat, bamboo plywood... Abundance and cheap price are the bamboo specificity that it can substitute for wood in flooring furniture with social and environmental benefits. Currently, 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 and applied logically in our country.

The closure and restrictive exploitation of forests in many countries around the world are an opportunity for the great demand of bamboo, but it is also a big challenge for businesses in developing of quality bamboo in Vietnam ¹. With abundant bamboo resources, the production of bamboo plywood becomes a great potential for the domestic bamboo plywood industry. The first process

Figure 1: Schema of production of bamboo powder in functional modules.


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after bamboo harvesting is grinding bamboo to pulp or powder. All kinds of bamboo waste such as bamboo shoots, bad stems, roots can be raw material for the process.

In the production process of bamboo plywood powder, the bamboo-grinding machine plays a very important role in the production of bamboo powder, the basic material for plywood. The schema of grinding process is illustrated in Figure 1.

**METHODOLOGY OF RESEARCH - STRUCTURAL DESIGN**

Functional analysis of bamboo grinding machines is illustrated in diagram in Figure 2. Figure 3 represents the structure of the designed bamboo-grinding machine.

Generally, a bamboo grinding machine consists of the following main components:

- Electric motors
- Mechanical transmission
- Feeder (feed hopper)
- Grinding spindle of the machine (disk of cutters, hammers...)
- Discharge unit

**RESULTS AND DISCUSSION - COMPUTING STRENGTH MATERIAL**

**a. Initial data**

- Productivity 200 Kg/h.
- Main raw materials: bamboo shoots, stem, roots.
- Size of raw materials: 20 - 100mm.
- Size of bamboo powder after grinding process: 0.5 - 3mm.
- Specific density of bamboo: 800 Kg/m3.
- Average powder moisture 12-14%.

The general structure of the machine is as shown in Figure 4.

**b. Cutting parts:**

According to the principle of slice pieces, the 4 cutters are freely mounted on the disk via a hinge that allows the cutter a free rotation of an angle ±60° around its radial position that formed in advance by the centrifugal force in operation.

**Cutting angle** of the cutter blade is selected about 12 – 15° because of cutting of tough and medium wood materials.

**Cutting speed** is selected in a range of 30-60 m/s.

The power of cutting is determined by the formula:

\[ N_1 = k \times b \times h \times v/10^2 \]

Herein: 
- \( b \): Cutting thickness is about 0.5mm;
- \( h \): thickness of the raw bamboo material is 25 - 50mm;
- \( k \): specific deflection coefficient is 1;
- \( v \): velocity of the hash, \( v = 30 \text{m/s} \)

We have:

\[ N_1 = \frac{k \times b \times h \times v}{10^2} = \frac{1 \times 0.5 \times 50}{30} = 7.5 \text{Kw} \]

The revolution on the spindle is calculated according to the formula:

\[ n = \frac{30 \times v}{\pi} = \frac{30 \times v_b}{(\pi \times R)} = \frac{30 \times 30/(\pi \times 0.1)}{2864 \text{rpm}} \]
Figure 3: Structural diagram of bamboo crush machine.

Figure 4: Structure of the designed bamboo-grinding machine. 1- Machine cover; 2-Cutter Frame; 3-Cutters; 4-Material input; 5-Shaft; 6-Circular Filter screen
Selected transmission ratio for the drive system is 1, we have the number of motor rotation 
\[ n = 2864 \text{ rpm} \]

**c. Grinding parts:**

Because of the product size of 0.5-3mm with the impact velocity of the machine is about 25-60m/s, combined with the condition of cutting speed, the cutting speed... The selected weight of each cutter is about 30-50N.

Selective shape of cutter is triangle with 3-4 rows of cutters.

The power of the grinding machine is determined by the formula:

\[ N_2 = 0.15 \times D^2 \times \frac{L \times n \times i}{\pi \times n} = 0.15 \times 0.22 \times 0.1 \times 2864 \times 3 = 5.2kW \]

Herein: \( D \) - rotor diameter, \( D = 60 \times \frac{v}{(\pi \times n)} = 60 \times 30/((\pi \times 2864)) = 0.2m \).
\( L \) - Length of rotor \( L = 0.1m \).
\( n \) - Revolution of shaft \( n = 2864 \text{ rpm} \).
\( i \) - Number of cutters rows \( i = 3 \).

Motor and transmission selection:

The belt feeder is used to transfer power from the engine to the grinder. With the transmission rate is 1, total performance coefficient is \( \eta = \eta_1 \times \eta_2 = 0.99 \times 0.96 = 0.95; \eta_1 \times \eta_2 \) - efficiency of the drive and belt transmission \( P_{ct} = P_1 + P_2 = 7.5 + 5.2 = 12.7kW \).

The 3K200M8 electric motor that has parameters of motor power of 15kW and revolutions of 2800 rpm is selected. The grinding module include motor and belt transmission is displayed in Figure 5.

**CONCLUSION**

The research performed an efficient design process to produce bamboo-grinding machine that meet the technical requirements. Experimental results show that complete grinding bamboo machine responds all the technical requirements of the production system of bamboo plywood powder.

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**CONFLICT OF INTEREST**

There is no conflict of interest.

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Figure 5: Experimental bamboo grinding machine.