A research on the design a bamboo powder drying machine

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ABSTRACT
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 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). Bamboo powder drying machine plays a very important role in the production process of bamboo plywood. The function of the machine is drying bamboo powder to get the technical required appropriate moisture before pressing it into the standard bamboo boards. This article presents a design of bamboo powder drying machine with simple structure, long life, medium productivity and price suitable for medium and small scale production of Vietnam market. The first bamboo powder drying machine that was manufactured in DCSElab and its products are considered to respond the technical requirements of customers.

Key words: Bamboo powder drying machine, moisture, medium productivity, technical requirements

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 Vietnam.

With abundant bamboo resources, 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). Bamboo waste such as bamboo shoots thrown away after harvesters can be also used to recycle and produce bamboo boards, both for environmental protection and for economic benefits.
In the production process of bamboo plywood, bamboo pulp dryer plays a very important role. The function of drying bamboo powder process is getting the technical appropriate dryness before the pressing process to the bamboo board. This is an essential process in the whole chain of production of bamboo plywood board. Nowadays, there are many companies that have manufactured all kinds of wood dryer but the finished moisture cannot smaller than 12% and almost all products are general wood chip for paper making industry. Some of documents concentrated to the drying machines and processes of wood chips only. Because of above reasons, the demand of study, design and manufacture a specialist bamboo dryer machine to the collaboration project with Langtre PhuAn was setting up 2 years ago. The paper focusses on the process of bamboo powder dryer machine.

**METHODOLOGY OF RESEARCH - DESIGN STRUCTURE**

Functional analysis of bamboo powder dryer is shown in Figure 1. Arranging the functions of the bamboo powder drying machine is represented in the diagram in Figure 2. Finally, the modular structure of the bamboo powder dryer is illustrated in Figure 3. Normally, the bamboo pulp dryer consists of the following main components (Figure 4): 1) Electric motors; 2) Gearbox; 3) controller; 4) heating element; 5) Transmission chain; 6) Drying drum (Figure 5), 7) Radiator, 8) Ventilator, 9) Electric motor.

**RESULTS AND DISCUSSION - TECHNICAL DESIGN**

**Initial data and technical requirements**

Moisture of the initial pulp $0_1 = 26\% = 0.26$; Moisture of the finished pulp $0_2 = 4\% = 0.04$; Average remaining moisture of pulp $0_b = 0.5x(0_1 + 0_2) = 0.15 = 15\%$. Initial temperature of pulp $t_{i1} = 30^0C$. Output temperature of pulp $t_{i2} = 40^0C$. Medium size of bamboo powder $d = 1mm$. Specific weight of material $p_1 = 300 Kg/m^3$. Volume of drying drum $V_{drum} = \frac{G}{d} = \frac{100}{0.333} = 0.333 m^3$ (1) Herein: $G$: weight of bamboo powder; $d$: Specific weight of bamboo powder. Volume of drying drum $V_{drum} = \frac{G}{d} = \frac{0.333}{0.04} = 1.07 m^3$

With filling coefficient $\beta = 0.31$, select $L/D=2.5:7$, therefore with the diameter of drum is: $D = 0.8m$, the length of drum is: $L = 2 (m)$

Determine the thickness of the drum body: selected drum material is SS330 steel with bending stress $[\sigma] = 140 N/mm^2$; the pressure in the lower part of the body drum is:

$$p = pm + gph$$

Herein: $pm$ is the atmospheric pressure $1MN/m^2$; $g$: Gravity acceleration; $H$: the height of the material in the drum $\approx 0.25m$; the low thickness of the drum body is calculated according to the formula ($\varphi$: the reliability of welded structures 0.95):

$$\text{Temperature of drying agent:}$$

Input $t_1 = 150^0C$; output $t_2 = 40^0C$.

**Determining the size of the drying drum**

**Drying time**

$$\tau = \frac{120(p_1(0_1 - 0_2))}{A(0_1 + 0_2)} \cdot \ln \frac{30 - 40}{20}$$

Herein: Filling coefficient; $p$: Average foam density of material $(Kg/m^3)$; $0_1$, $0_2$: Input and output moisture of material (%); $A$: Evaporation intensity $(Kg/m^3.h)$. The selected productivity of dryer is $200 Kg/h$ that can be divided into 2 batches, each batch of $100 Kg$ dried in a selected drying time of 30 minutes. From the above formula, the filling coefficient of the bamboo powder in the drum with drying time of 30 minutes, so the filling coefficient is:

$$\beta = \frac{t_1(200 - (0_1 + 0_2))}{120(p_1(0_1 - 0_2))} = \frac{30 - 40}{20} = 0.31$$

Thickess of the drying bamboo powder tank:

$$S = \frac{Dp}{2\sigma\varphi} = \frac{0.8 \times 10^3 \times 1.001}{2 \times 140 \times 0.95 \approx 3 mm}$$

The selected thickness is $3 mm$.

**Determine the temperature in and out of the dryer**

With the selected revolutions per minute of drying drum 10 RPM, the stay time is: $\tau = \frac{60}{10} = 1.5s$

The required temperature for heating the pulp to attain the technical required dryness is:

$$t_0 = 2.218 - 3.343 \ln(t) + \frac{235}{37 + 0.060}$$

Herein: $\tau = 1.5(s)$, $0_b = 0.015 => t_b = 62.79^0C$

Maximum temperature of the drying agent:

$$t_2 = t_1 + (5 \times 10) = 62.79 + 5 = 67.79^0C$$

Mean temperature difference is taken from the empirical diagram that has the value of $\Delta t \approx 60^0C$. The temperature of the drying agent is determined by the formula:

$$\Delta t = \frac{t_1 - t_{i1} - t_2 - t_{i2}}{\ln\frac{t_1 - t_{i1}}{t_2 - t_{i2}}} \rightarrow t_1 = 73.74^0C$$
Figure 1: Diagram of functional analysis of bamboo powder drying machine

Figure 2: Diagram of arranging sub function of bamboo powder drying machine

Figure 3: Structure diagram of bamboo powder dryer machine
Calculating the heat of the drying process

The specific heat of vaporization of the drying agent in state \(d_1\): \[ C_{d1}(d_1) = 1.004 + 1.842d_1 = 1.04 \text{kJ/kg.k} \]

The extracted moisture from drying agent:

\[ d_2 = 0.0193 + \frac{1.04(150-45)}{2574} = 0.061 \text{kg/kg} \]

Enthalpy of drying agent after drying process:

\[ I_2 = 1.004t_2 + d_2(2500 + 1.842t_2) \]

\[ I_2 = 156.560 \text{KJ/kg} \]

\[ \dot{V}_c = \frac{1}{\rho_2} \left( \frac{I_2}{I_1-\dot{I}_v} \right) \]

\[ \dot{V}_c = 0.0949\frac{0.621+0.0610}{0.0610} = 86\% \]

Actual flow of drying agent \(L\):

\[ L = \frac{1}{\dot{V}_c} \]

\[ L = \frac{1}{\dot{V}_c} = 23.98 \text{kg/kgam} \]

Value of flow \(V_1\) (m\(^3\)/h): \[ V = L \times v = L \times \frac{1}{\rho_1} \text{ (m}^3\text{/h)} \]

Herein: \(\rho_b\) is average specific weight of dry air; \(\rho_b = 0.5(\rho_1 + \rho_2)\)

\[ \rho_b = 1.05 \text{ kg/m}^3 \]

\[ V = 1047 \text{ m}^2/\text{h} \]

The average speed of the drying agent in the dryer:

\[ v = 0.919 \text{ m/s} \]

Heat consumption for drying process:

\[ Q_c = L(I_1 - \dot{I}_v) \]

\[ Q_c = 1100(204.18-77.35) \approx 38.75 \text{kJ/h} \]

The amount of heat required per kg of moisture air:

\[ \dot{Q}_i = \dot{q}_i W \]

\[ \dot{Q}_i = 139513 \text{kJ/h} \approx 38.75 \text{kW} \]

Heat due to moisture content:

\[ W_{C1\dot{t}_v} = 22.92 \times 4.138 \times 30 = 2874 \left( \frac{V}{V} \right) \approx 0.8 \text{kJ/h} \]

Lost heat caused by the drying agent \(Q_{m1}\):
Select the drive system

Required power for rotating the drying drum \(11\):  
\[
\Delta P_{d} = 202 \times 0.9962 \times 9.81 = 20.3 \text{mmH}_{2}O
\]
\[
\Delta P_{T} = 1.05(\Delta P_{d} + \Delta P_{c}) = 67.25 \text{mmH}_{2}O
\]
Lost pressure at the inlet of the fan \((v = 20 \text{ (m/s)})\):  
\[
H = \Delta P_{T} + \Delta P_{d} = 87.55 \text{mmH}_{2}O
\]
Fan power:  
\[
N = k \frac{1000 \times 0.025 \times 0.92 \times 0.92}{102 \times 0.92 \times 0.92} = 0.32 \text{m}^{2}
\]
\[
h_{ib} = 0.576 \times 0.8 = 0.46 \text{ m}
\]
The selected geometrical parameters of the wings:  
\[
a = 100 \text{ mm}; b = 50 \text{ mm}; \cos \alpha = 0.4; d = 5 \text{ mm}; \alpha = 45^{\circ}
\]
The height of the material in the drying drum:  
\[
h = R (1 - \cos \alpha) = 0.4x(1 - \cos 45^{\circ}) = 0.117m
\]
Number of wings on one side: 8 wings. The designed bamboo powder-drying machine shown in Figure 6.

CONCLUSION

Performing an effective design of a technical required bamboo powder dryer is essential in saving effort and finance for manufacturing processes that provide more cheap domestic materials for decoration and construction in Vietnam.

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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.
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