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Research Article

Analysis of the Sand Drying Process in the Biomass-Energized Rotary Drying Machine

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Abstract: Hebel brick (also known as a lightweight brick) is a product of modern building materials because it has a lighter weight but it is stronger than cement bricks and red bricks. Hebel bricks can withstand pressures of more than 4 MPa and are suitable as building wall materials, and speed up construction, and save on cement material costs. One of the most important materials is silica sand in the manufacture of Hebel bricks. The silica sand used in the manufacture of Hebel bricks must have a moisture content of 10 % to 15 %. The purpose of this study is to provide a solution in the form of a drying technique design using a rotational speed control method and a machine that uses biomass-based energy sources. This rotary drying machine is designed to be able to dry wet silica sand into silica sand with water content according to standards. The development of this drying machine begins with making an initial design and parameter analysis. Then proceed to the design, manufacture, and performance testing. The calculation results show that the wet base moisture content has decreased from 33.17 % to 16.58 %, the dry base moisture content decreased from 49.63 % to 19.88 % and drying efficiency also decreased from 63.11 % to 17.11 %. Hence it can be seen that the percentage of wet base moisture content reduced by 50 %, the percentage of dry base moisture content reduced by 59.94 %, and the percentage of drying efficiency reduced by 72.9 %.

Keywords: Building Material, Drying Heat, Hebel Brick, Increase Cost Efficiency, Renewable Energy, Silica Sand.

1. INTRODUCTION

Modern buildings are characterized by the efficient use of raw materials and costs. Hebel brick is a building material that has shifted the role of cement brick and red brick because it has a lighter weight but is stronger than cement brick and red brick. Hebel brick has a dry density of about 520 kg m^{-3} and a normal density of about 650 kg m^{-3} and is also able to withstand pressures of more than 4 MPa and has a thermal conductivity of 0.14 W m^{-1} k^{-1}. Proven to be very strong for

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building wall materials, accelerate construction and save costs of using cement materials [1].

In the manufacture of the Hebel bricks, one of the most important materials is silica sand (SiO_2). Silica sand mining areas are usually close to rivers or beaches, hence after being taken from the mining area, the silica sand still has high moisture content ranging from 60 % to 80 %. Meanwhile, the silica sand used in the manufacture of Hebel bricks must have a slight moisture content ranging from 10 % to 15 %. Hence to get silica sand with moisture content (10 % to 15 %), a drying process is required. To get fast drying results, the silica sand drying process needs to be done using a drying machine. At this time many types of drying machines have been developed, ranging from conveyor-shaped drying machines, oven-shaped drying machines, and some even developing rotary drying machines. Most of these drying machines are still operated using sources of electrical energy and some are using fossil fuel generators. And in recent years, various studies have been conducted by making drying machines that use heat energy from renewable energy sources.

Several researchers have developed drying machines for various purposes, such as Susanto *et al.* [2] has developed the solar-energized drying machine for drying foodstuffs. Sandra [3] has developed a conveyor-shaped drying machine for drying cocoa beans. Estiasih *et al.* [4] has developed the oven-shaped drying machine for the development of food processing technology. Susanto [5, 6] have developed the renewable-energized drying machine for drying silica sand. Hussain *et al.* [7] has developed a drying machine for drying wood. Latifah *et al.* [8] has developed the shoe drying system. Atnaw *et al.* [9] and Yassen *et al.* [10] have developed solar biomass drying systems. Kirar *et al.* [11] has developed the solar cloth drying machine. Nyzam *et al.* [12] has developed a heating system to disinfect rice lice using radiofrequency and microwaves. Macieira *et al.* [13] has developed dry and wet systems to rehabilitate buildings. Rabidin *et al.* [14] has developed the vacuum drying system using kilns and radiofrequency. And Wutthithanyawat *et al.* [15] has developed a drying process by controlling the temperature in the heating zone. Hanif *et al.* [16] have discussed drying for chilies, while Abdullah *et al.* [17], Suwati *et al.* [18], and Siskawardani *et al.* [19] discussed seaweed drying. Hence with the increasingly widespread development of renewable-energized drying machines, It is hoped that it can reduce the use of fossil fuels, hence in the future, it can reduce the occurrence of environmental pollution.

2. MATERIALS AND METHODS

2.1 Flow Diagram of Research

The research process was carried out in several stages, namely the first stage by making an initial design and parameter analysis based on heat transfer properties, thermodynamics, and engine elements. The second stage is to optimize the design process. If the results are optimal, it will proceed to the third stage by making the drying machine design drawing. Meanwhile, if the results are not optimal, it will be repeated to the initial design process and parameter analysis. After making the drying machine design drawing is complete, it will proceed to the fourth stage by carrying out the fabrication process for the manufacture of the dryer machine. After the dryer machine is fabricated, it will proceed to the next stage by testing the performance and drying process on the dryer machine. Completely, Figure 1. shows stages carried out in this research.

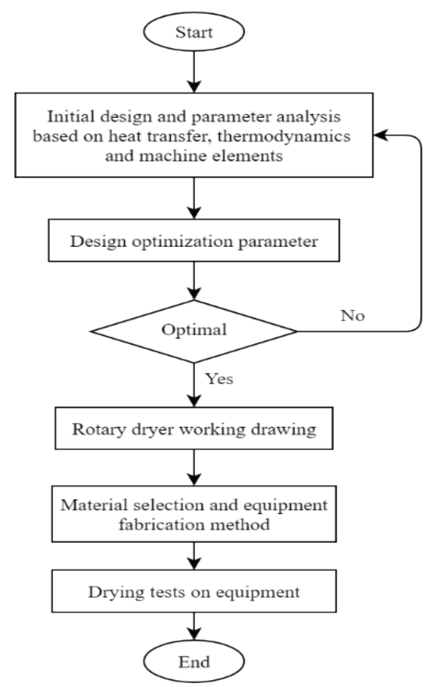

Fig. 1. Flow diagram of the research.

2.2 Working Principle of Biomass-Energized Drying Machine

In the research design of the biomass-energized rotary drying system, the heat used from biomass energy allows the drying process to take place continuously. The silica sand to be dried still has a high moisture content ranging from 60 % to 80 %. Meanwhile, the silica sand used in the manufacture of Hebel bricks must have a slight moisture content ranging from 10 % to 15 %. Hence it takes the amount of wood biomass waste as much as 15 kg h^{-1} with a specific heat of 19.94 kJ kg^{-1}. Figure 2 shows the components of the rotary dryer machine:

The first step in the drying process using the biomass-energized rotary dryer system is by inserting wet silica sand material through the inlet hopper to be channeled into the drying chamber. Drying process of wet silica sand material, by turning the drying chamber using drive motor and flowing hot air generated from the combustion process that occurs in the furnace of biomass. A combination of the drying chamber rotation and hot airflow will facilitate the drying process of wet silica sand material.

The drying chamber rotation will cause stirred and spread the wet silica sand material in the drying chamber, and facilitate the flow of hot air to release the moisture content present in the wet silica sand materials and remove it from the drying chamber. In addition, the drying chamber rotation will facilitate the wet silica sand material to move from the initial entry to exit the drying chamber. The hot air flowed from the biomass furnace, generated from the combustion of biomass waste in the biomass furnace combustion chamber. The heat generated from the combustion chamber is then transferred to the drying air chamber through a heat transfer process. The heat transfer process in the biomass furnace is shown in Figure 3.

3. RESULTS

3.1 Drying Process on the Rotary Drying Machine

To find out the drying process of this rotary dryer machine, it can be known through the following equation. The first step is to calculate the wet base moisture content of silica sand using Equation (1) [2, 5, 6]:

$$MC_{wb} = \frac{W_a}{W_b} \, x \, 100 \,\% \tag{1}$$

Then using Equation (2) to calculate dry base moisture content of silica sand:

$$MC_{db} = \frac{100MC_{wb}}{100 - MC_{wb}} \tag{2}$$

Equation (3) is used to calculate drying rate of silica sand:

$$M = \frac{M_0 - M_t}{\Delta t} \tag{3}$$

Equation (4) is used to calculate the amount of silica sand drying heat:

$$Q = Q_1 + Q_2 + Q_3 \tag{4}$$

Equation (5) is used to calculate Q1 (silica sand

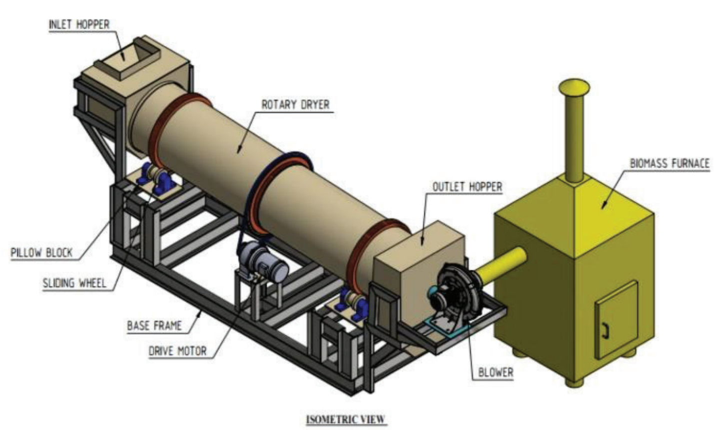

Fig. 2. The rotary dryer machine components.

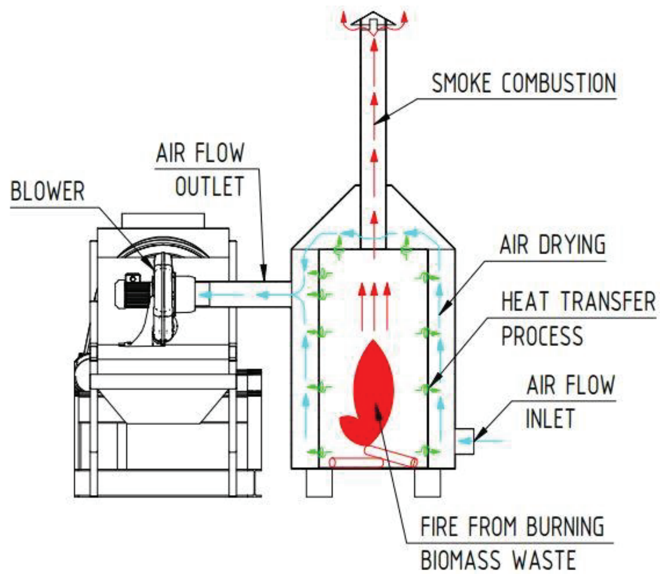

Fig. 3. The heat transfer process occurs in the furnace of biomass.

sensible heat):

$$Q_1 = m_k . c_p . (T_1 - T_0) \quad (5)$$

Equation (6) is used to calculate Q2 (water sensible heat) and it is used to increase the water temperature in silica sand:

$$Q_2 = m_a . c_a . (T_1 - T_0) \quad (6)$$

Equation (7) is used to calculate Q3 (water evaporation latent heat) which is the amount of heat used to evaporate water from silica sand:

$$Q_3 = m_w . h_{fg} \quad (7)$$

Equation (8) is used to calculate the amount of heat received by silica sand:

$$q = \rho . V . c_u . (T_{in} - T_{out}) \quad (8)$$

Equation (9) is used to calculate the drying efficiency of silica sand:

$$\eta = \frac{Q}{q} x\ 100\ \% \quad (9)$$

Where:

MC_{wb} = Wet base moisture content (%)
MC_{db} = Dry base moisture content (%)
W_a = Silica sand water mass (kg)
W_b = Silica sand wet mass (kg)
M = Drying rate of silica sand (kg s^{-1})
M_0 = Silica sand initial mass (kg)
M_t = Silica sand final mass (kg)
Δ_t = Time interval of drying (s)
Q = Silica sand drying heat (kJ)
Q_1 = Silica sand sensible heat (kJ)
Q_2 = Water sensible heat (kJ)
Q_3 = Water evaporation latent heat (kJ)
q = Heat received by silica sand (kJ)
m_k = Dry silica sand mass (kg)
m_a = Water mass in silica sand (kg)
m_w = Water evaporated mass (kg)
c_p = Silica sand specific heat (J kg^{-1} $°C^{-1}$)
c_a = Water specific heat (J kg^{-1} $°C^{-1}$)
c_u = Air specific heat (J kg^{-1} $°C^{-1}$)
h_{fg} = Water evaporation specific heat (J kg^{-1})
ρ = Silica sand density (kg m^{-3})
V = Drying chamber volume (m3)
T_0 = Silica sand initial temperature (°C)
T_1 = Silica sand final temperature (°C)
T_{in} = Burner intake temperature (°C)
T_{out} = Burner exit temperature (°C)
η = Silica sand drying efficiency (%)

3.2 Drying Process Data Analysis

The following data shows the drying process in the drying machine. Table 1 shows the initial data of the drying machine.

Equations (1) to Equation (9) are used to calculate the drying process and drying efficiency using the data in Table 1. Furthermore, Table 2 and

Table 3 show the calculation results.

Table 2 shows the calculation results of wet base moisture content, dry base moisture content, and drying rate. While Table 3, it shows the calculation results for drying heat and drying efficiency. The calculation results graphs of the drying process and drying efficiency are shown in Figure 4 and Figure 5:

The Figure 4 graph shows that with variations in the rotation of the rotary dryer chamber from 6.6 rpm to 13.2 rpm, the wet base moisture content decreased from 33.17 % to 16.58 % and the dry base moisture content also decreased from 49.63 % to 19.88 %.

The Figure 5 graph shows that with variations in the rotation of the rotary dryer chamber from 6.6 rpm to 13.2 rpm (in SI: 1 rpm = 1/60 Hz), the drying efficiency decreased from 63.11 % to 17.11 %.

4. DISCUSSION

In designing the biomass-energized rotary dryer system, several things must be considered carefully, namely: (i) the material being dried is silica sand, hence it must take into account the erosion of the drying chamber shell. Therefore, it is necessary to design the drying chamber shell with the appropriate thickness and safety with a relatively long lifetime [4, 5]. (ii) To anticipate this equipment used in areas that have not yet received electricity, a generator or renewable-energized power plant must be prepared in advance [2, 5, 6]. (iii) Since heat for the drying process is generated by the furnace of biomass, the fuel from the waste biomass used also affects

Table 1. The initial data of the drying machine.

No	Parameters	Value	Unit
i	Drying chamber Area (A)	0.272	m^2
ii	Drying chamber Length (L)	3	m
iii	Drying chamber Volume (V)	0.81	m^3
iv	Drying air speed (v_u)	11	$m\ s^{-1}$
v	Total volume of the outflow (Q_u)	0.050	$m^3\ min^{-1}$
vi	Wet silica sand mass (m_b)	100	kg
vii	Total mass of the outflow ($\dot{m}$)	4.5	$kg\ min^{-1}$
viii	Air specific heat (c_u)	1 004	$J\ kg^{-1}\ ºC^{-1}$
ix	Water specific heat (c_a)	4 180	$J\ kg^{-1}\ ºC^{-1}$
x	Silica sand specific heat (c_p)	664	$J\ kg^{-1}\ ºC^{-1}$
xi	Water evaporation specific heat (h_{fg})	2 260	$J\ kg^{-1}$
xii	Silica sand initial temperature (T_0)	20	ºC
xiii	Silica sand final temperature (T_1)	35	ºC
xiv	Burner intake temperature (T_{in})	80	ºC
xv	Burner exit temperature (T_{out})	50	ºC

Table 2. Drying process calculation results.

n_r (rpm)*	V (m^3)	m_a (kg)	m_k (kg)	MC_{wb} (%)	MC_{db} (%)	M ($kg\ min^{-1}$)
6.6	0.367	33.17	66.83	33.17	49.63	5
7.9	0.306	27.64	72.36	27.64	38.20	5
9.2	0.262	23.69	76.31	23.69	31.05	5
10.6	0.229	20.73	79.27	20.73	26.15	5
11.9	0.204	18.43	81.57	18.43	22.59	5
13.2	0.183	16.58	83.42	16.58	19.88	5

*) In SI: 1 rpm = 1/60 Hz

Table 3. Drying efficiency calculation results.

n_r (rpm)*	Q_1 (kJ)	Q_2 (kJ)	Q_3 (kJ)	Q (kJ)	q (kJ)	η (%)
6.6	665.63	2 079.73	74.96	2 820.32	4 468.73	63.11
7.9	720.69	1 733.10	62.47	2 516.27	5 806.06	43.34
9.2	760.02	1 485.52	53.54	2 299.09	7 143.39	32.18
10.6	789.52	1 299.83	46.85	2 136.20	8 480.72	25.19
11.9	812.46	1 155.40	41.65	2 009.51	9 818.05	20.47
13.2	830.82	1 039.86	37.48	1 908.16	11 155.38	17.11

*) in SI: 1 rpm = 1/60 Hz

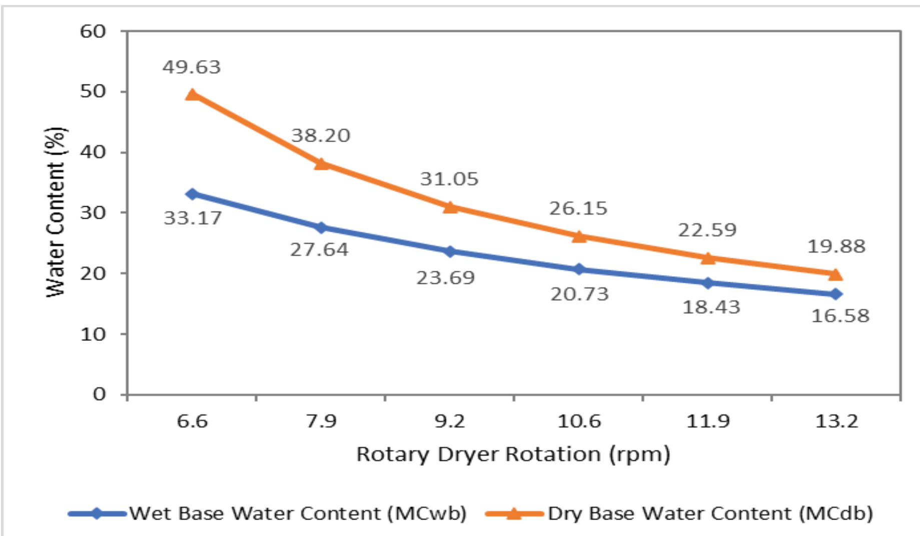

Fig. 4. Graphs of water content (%) vs rotary dryer rotation (rpm) [in SI: 1 rpm=1/60 Hz]

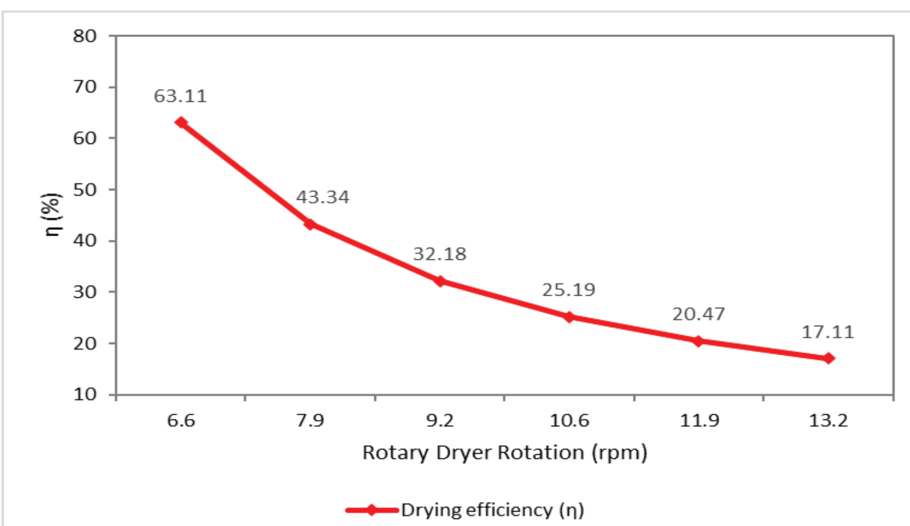

Fig. 5. Graph of drying efficiency (%) vs rotary dryer rotation (rpm [1 rpm = 1/60 Hz]).

the heat generated. The wet biomass waste used will not burn easily, hence it causes combustion in the furnace of biomass to take longer to reach the ideal drying temperature in the drying chamber. Conversely, the dry biomass waste used will burn easily, hence it causes combustion in the furnace of biomass to take faster to reach the ideal drying temperature in the drying chamber. In addition, because the drying process using the rotary dryer machine is carried out for 8 h d^{-1}, the availability of biomass waste is an important thing that must be available. And the amount of biomass waste required for burning in a biomass furnace is around 120 kg d^{-1} [4].

5. CONCLUSION

The biomass-energized rotary drying machine is designed to dry silica sand to make Hebel bricks. This drying machine is used to dry silica sand which has an initial moisture content of 80 % to a moisture content of 15 %. With variations in the rotation of the rotary dryer chamber from 6.6 rpm to 13.2 rpm. The calculation results show that wet base moisture content was reduced by 50 % and dry base moisture content was reduced by 59.94 %. In addition, drying efficiency was also reduced by 72.9 %. Therefore, it is known that drying efficiency gets better when the rotary dryer chamber rotates more slowly.

6. ACKNOWLEDGEMENTS

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7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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