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by Heery Susanto

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Design of Rotary Dryer for Sand Drying using Biomass Energy Sources

Herry Susanto[1,2], *Roy* Hendroko Setyobudi[2,3*], *Didik* Sugiyanto[1], *Yefri* Chan[1], *Erkata* Yandri[2], *Satriyo* Krido Wahono[4], *Kamaruddin* Abdullah[2], *Yuris* Burlokvs[5], *Yogo* Adhi Nugroho[6,7], and *Abubakar* Yaro[8]

[1]Department of Mechanical Engineering, Darma Persada University, Jl. Taman Malaka Selatan No.22, Jakarta 13450, Indonesia
[2]Graduate School of Renewable Energy, Darma Persada University, Jakarta, Indonesia
[3]Department of Agriculture Science, Postgraduate Program, University of Muhammadiyah Malang, Jl. Raya Tlogomas No.246, Malang 65145, Indonesia
[4]Research Division for Natural Product Technology – Indonesian Institute of Sciences, Jl. Jogja - Wonosari, km 31.5, Gunung Kidul, Special Region Yogyakarta 55861, Indonesia
[5]Department of Water Management, Estonian University of Life Sciences, Tartu, Estonia; Friedrich Reinhold Kreutzwaldi 1a, 51014 Tartu, Estonia
[6]Individual Researcher, Alumni Graduate School of IPB University, Bogor, Indonesia
[7]Data Processing, *Rumah Paper* – Editage Services, Jl. Tokala No.1, Malang 65146, East Java, Indonesia
[8]Institute of Health Sciences & Research, AHRO Scientific Publishing, 272 Bath Street, Glasgow G2 4JR, Scotland, UK

Abstract. Hebel brick is used in making the walls of the house. One of the materials used in making hebel bricks is sand. The water content of the sand will affect the quality of the hebel bricks. The less water content in the sand, the better the quality of hebel bricks. In order to get sand with a little water content, it is necessary to do the drying process. To overcome this problem, a rotary dryer for sand drying using biomass energy sources was designed. It can be placed in a sand quarry near a river or near a beach. It is designed to have the ability to dry the wet sand by putting it in a rotary dryer, making this drying system usable both in sunny and rainy conditions. The drying process can take place continuously using heat from biomass energy. The heat is produced from the combustion process in the biomass furnace and then distributed to the rotary dryer. The advantage of this rotary dryer system could be done continuously with a little human power. Moreover, from these calculations can be analyzed the performance of this rotary dryer machine, to determine the suitability between design calculations and test results.

Keywords: Drying, dry sand, hebel brick, heat, rotary dryer, renewable energy.

* Corresponding author: roy_hendroko@hotmail.com; smt.eng77@gmail.com

1 Introduction

Hebel brick or lightweight brick is a type of building material replacement for red brick, has a lightweight compared to other bricks. Because of its various advantages, hebel bricks are increasingly sought after and in demand, especially by housing developers. Hebel brick is used as the main foundation in making the walls of the house. This is because hebel bricks are economical, lightweight, efficient, and fast enough to be used in the construction of housing projects, apartments, hotels, and other property projects. One of the materials used in making hebel bricks is sand. The water content of the sand will affect the quality of the hebel bricks. The less water content in the sand, the better the quality of hebel bricks. In order to get sand with a little water content, it is necessary to do the drying process. Some do the drying process by utilizing direct solar heat. And there are also some who do the drying process using a drying machine. The drying process uses a drying machine, in the use of energy for drying, some use electricity, some use fuel oil and some use renewable energy. Currently more and more renewable energy-based drying systems are being developed. Some developed a foodstuff drying system [1], developed a cocoa beans drying system [2], developed a wood drying system [3, 4], developed a shoe drying system [5], developed a biomass-energized drying system [6, 7], developed a cloth drying system [8], developed the radio frequency and microwave heating treatment to disinfest kutu beras [Sitophilus oryzae (Linnaeus, 1763] [9], development of building rehabilitation with dry and wet systems [10], development of heating zone temperature control for the drying process [11], and development of the solar-energized drying system [12]. Hence the development of a drying system using this renewable energy source, becomes a challenge and also a solution to improve economy and prepare for facing increasingly fierce competition.

2 Research methodology

2.1 Research flow diagram

In this paper, the research steps are shown in the following research flow diagram in Figure 1.

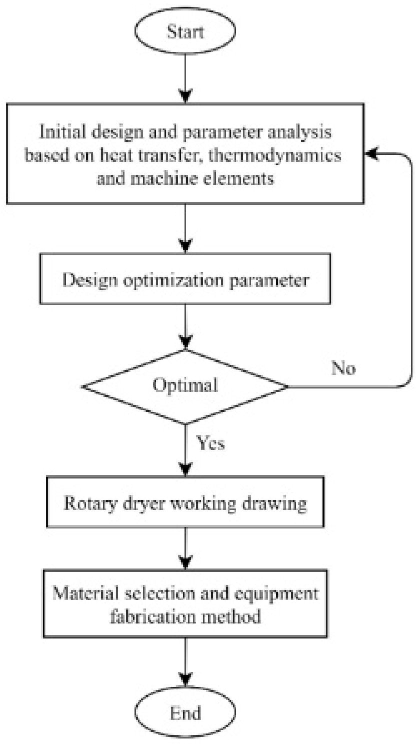

Fig. 1. Research flow diagram.

2.2 Rotary dryer of biomass-energized drying system

Design of the rotary dryer of biomass-energized drying system can be seen in Figure 2 and Figure 3, the advantage of this biomass-energized drying system is the drying process can take place continuously using heat from biomass energy. The heat from the biomass energy source is channelled to the drying machine after going through the energy conversion process in the biomass furnace chamber. The main components of the rotary dryer shown as the following figure:

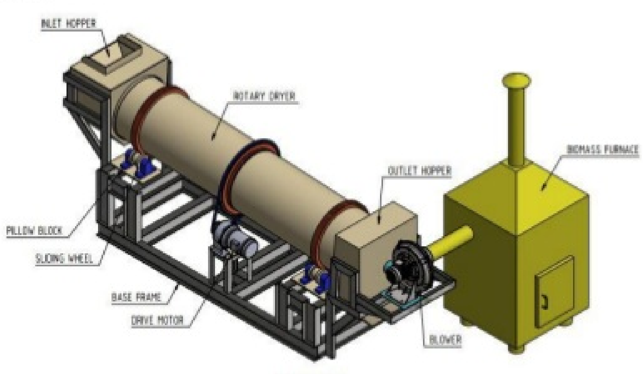

Fig. 2. The rotary dryer components.

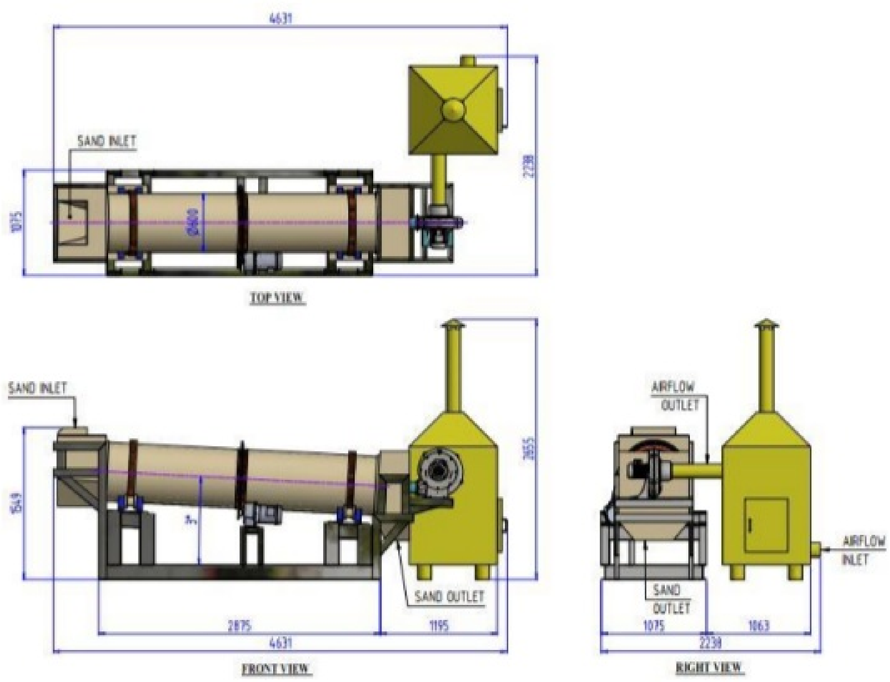

Fig. 3. The rotary dryer dimensions.

3 Mathematical equation

3.1 Rotary dryer performance

The performance of this rotary dryer, can be known through the following formulas. The first time we calculate the motor rotation output using the following equation [12, 13]:

$$n_m = \frac{f_m}{f_t} \cdot n_0 \quad (1)$$

Then calculate the rotary dryer rotation using the following equation:

$$n_r = \frac{z_m}{z_r} \cdot n_m \quad (2)$$

Calculate the transfer distance of the sand material to be dried in each rotation of rotary dryer using the following equation:

$$L_x = 2 \cdot D \cdot \tan\alpha \quad (3)$$

Calculate the maximum rotations number of the rotary dryer when transferring the sand from entry to exit using the following equation:

$$n_{max} = \frac{L}{L_x} \quad (4)$$

Calculate the traveling time of the sand material from entry to exit using the following equation:

$$t = \frac{n_{max}}{n_r} \quad (5)$$

Calculate the transfer speed of the sand material in the rotary dryer using the following equation:

$$v = \frac{L}{1\,000\,.\,t} \quad (6)$$

Calculate the drying capacity of the sand material in the rotary dryer using the following equation:

$$Q_r = \frac{3\,.\,m_i}{50\,.\,t} \quad (7)$$

Calculate the amount of torque that occurs in the rotary dryer using the following equation:

$$T = \frac{m_i\,.\,g\,.\,D}{2\,000} \quad (8)$$

Calculate the amount of power needed by the rotary dryer using the following equation:

$$P = \frac{2\,.\,\pi\,.\,n_r\,.\,T}{60} \quad (9)$$

Calculate the amount of motor power needed by the rotary dryer using the following equation:

$$P_m = \frac{P}{0.85} \quad (10)$$

Where:
f_m = Operational frequency of the inverter (Hz)
f_t = Maximum frequency of the inverter (Hz)
n_0 = Maximum output rotation of the motor (rpm) (1 rpm=1/60Hz)
n_m = Operational output rotation of the motor (rpm)
n_r = Output rotation of the rotary dryer (rpm)
z_m = The number of the sprocket teeth on the motor (th)
z_r = The number of the sprocket teeth on the rotary dryer (th)
L_x = The transfer distance in each rotation of the rotary dryer (mm rev^{-1})
D = Inner diameter of the rotary dryer (mm)
α = The tilt angle of the rotary dryer (°)
n_{max} = Maximum rotations number of the rotary dryer (revolution)
L = Length of the rotary dryer chamber (mm)
t = The traveling time of the sand material in the rotary dryer (min)
v = The transfer speed of the sand material in the rotary dryer (m min^{-1})
Q_r = The drying capacity of the sand material in the rotary dryer (t h^{-1})
m_i = The sand mass is put into the rotary dryer (kg)

T = The amount of torque that occurs in the rotary dryer (Nm)
g = Earth's gravity acceleration = 9.81 m s^{-2}
P = The amount of power needed by the rotary dryer (W)
P_m = The amount of motor power needed by the rotary dryer (W)

4 Result and discussion

4.1 Calculation and analysis of the rotary dryer performance

The initial design parameters and the rotary dryer perfomance can be seen in Table 1 and Table 2.

Table 1. Initial design parameter of the rotary dryer.

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No	Input Parameters	Value	Unit
1	Material	Sand	
2	Transfer distance	3	m
3	Drying system type	Rotary dryer	
4	Gearmotor Power	0.75	kW
5	Motor rotation (n)	1 400	rpm
6	Gearbox ratio (r)	1 : 20	
7	Motor rotation output (n_0)	70	rpm
8	Outer diameter of the rotary dryer shell (OD)	600	mm
9	Inner diameter of the rotary dryer shell (ID)	588	mm
10	Maximum frequency of the inverter (f_I)	50	Hz
11	The number of the sprocket teeth on the motor (z_m)	20	th
12	The number of the sprocket teeth on the rotary dryer (z_r)	106	th
13	The tilt angle of the rotary dryer (α)	3	°
14	The sand mass is put into the rotary dryer (m_i)	100	kg

Table 1. continue to the next page.

The data in Table 1 be used as a reference to calculate the rotary dryer performance using Equations (1) to Equation (10) as shown in Table 2.

Table 2. Calculation result of the rotary dryer performance.

f_m (Hz)	n_m (rpm)	n_r (rpm)	L_x (mm rev^{-1})	n_{max} (rev)	t (min)	v (m min^{-1})	Q_r (t h^{-1})	T (Nm)	P (W)	P_m (W)
25	35	6.6	61.6	49	7.4	0.41	0.81	288.4	199.5	234.6
30	42	7.9	61.6	49	6.1	0.49	0.98	288.4	239.3	281.6
35	49	9.2	61.6	49	5.3	0.57	1.14	288.4	279.2	328.5
40	56	10.6	61.6	49	4.6	0.65	1.30	288.4	319.1	375.4
45	63	11.9	61.6	49	4.1	0.73	1.47	288.4	359.0	422.4
50	70	13.2	61.6	49	3.7	0.81	1.63	288.4	398.9	469.3

The graph in Figure 4, Figure 5 and Figure 6 are shown of the rotary dryer performance.

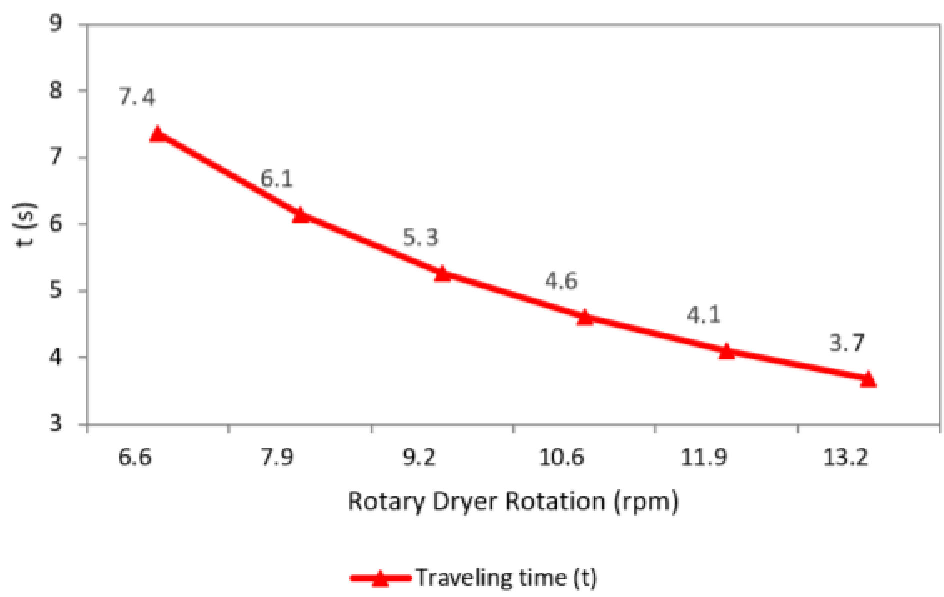

Fig. 4. Graph of traveling time (t) vs rotary dryer rotation (rpm).

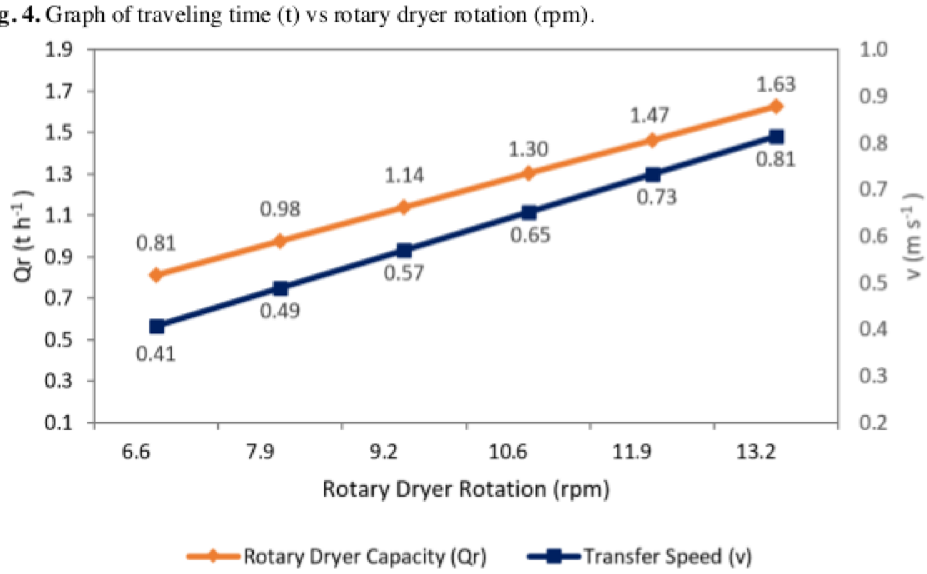

Fig. 5. Graph of transfer speed (v) & drying capacity (Q_r) vs rotary dryer rotation (rpm).

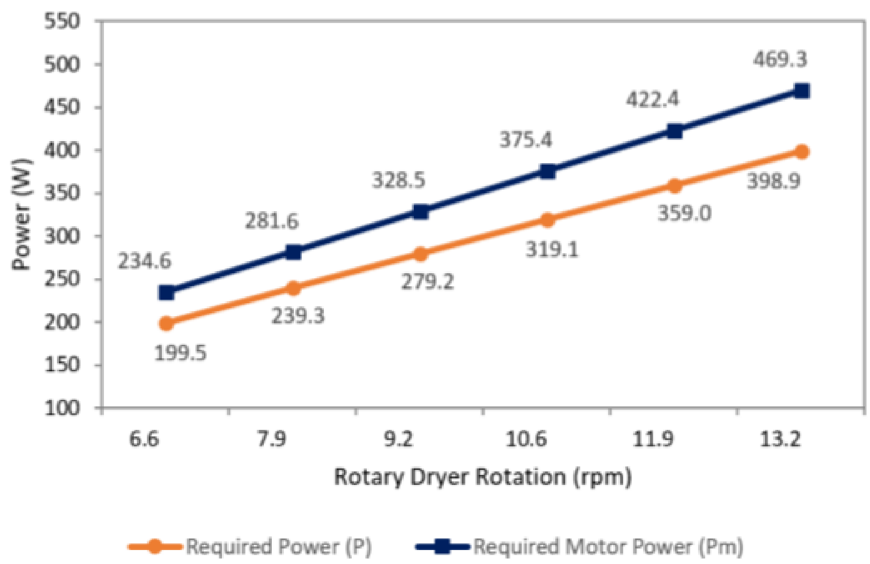

Fig. 6. Graph of required power (P) & required motor power (P_m) vs rotary dryer rotation (rpm).

4.2 Discussion of the rotary dryer performance

In the design of the rotary dryer of biomass-energized drying system, there are several things that must be considered properly, that is: This equipment will be used in sand mining sites close to rivers or the sea that have high salt content and allows corrosion, then all components, especially in the frame, must be coated with an anti-corrosion coating through the galvanic or hotdipe process. Moreover, because the dried material is sand, it must also be taken into account regarding the possibility of erosion on the shell of the equipment. Hence the thickness and lifetime can be determined [11–13]. Then this equipment might be used also in areas that are still not reached by electricity. Hence it needs to think about and develop the electrical energy source, the solution is by providing generators or power plants that use renewable energy [6–13]. The maintenance time of this equipment need to pay attention, hence it can more durable and be used longer [9–13]. Furthermore, the required motor power at maximum conditions is 469.3 W, hence it can use motors that are available on the market with a power capacity of 0.55 kW.

5 Conclusion

From the calculation results of the rotary dryer performance, by varying the rotary dryer rotation from a minimum rotation of 6.6 rpm to a maximum rotation of 13.2 rpm. The traveling time of the material reduced by 50 %. The rotary dryer capacity and the required motor power increase by 50 %. Moreover, the required motor power at maximum conditions is 469.3 W. Therefore, it is known that the faster the rotary dryer rotation, the rotary dryer capacity, and the required motor power will increase, but the traveling time will decrease.

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