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], *Juris* Burlakovs[5],
Wahyu Widodo[3], *Yogo* Adhi Nugroho[6,7], and *Abubakar* Yaro[8,9]

[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
[9]Strathclyde Institute of Pharmacy & Biomedical Sciences (SIPBS), University of Strathclyde, SPBBS, 161 Cathedral St, Glasgow G4 0RE, 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 renewable energy, particular 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

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], elaborated a cocoa beans drying system [2], evolved a wood drying system [3, 4], promoted a shoe drying system [5], extended a biomass-energized drying system [6, 7], unfolded 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], promoted of heating zone temperature control for the drying process [11], and development of the solar-energized drying system [13]. 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

The initial step of this research is to collect the data needed in designing this rotary dryer and analyze these data, such as data on heat transfer, thermodynamics and machine elements. From the analysis of these data, the optimal design parameters will be obtained. After that, proceed with making a working drawing of this rotary dryer machine. And after the working drawing has been completed, the fabrication process for this rotary dryer will be carried out. The research steps are shown in the following research flow diagram in Figure 1.
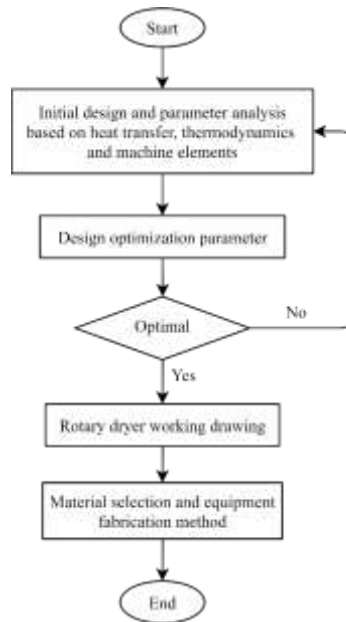
Fig. 1. Research flow diagram.

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 channeled 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 Figure (2):
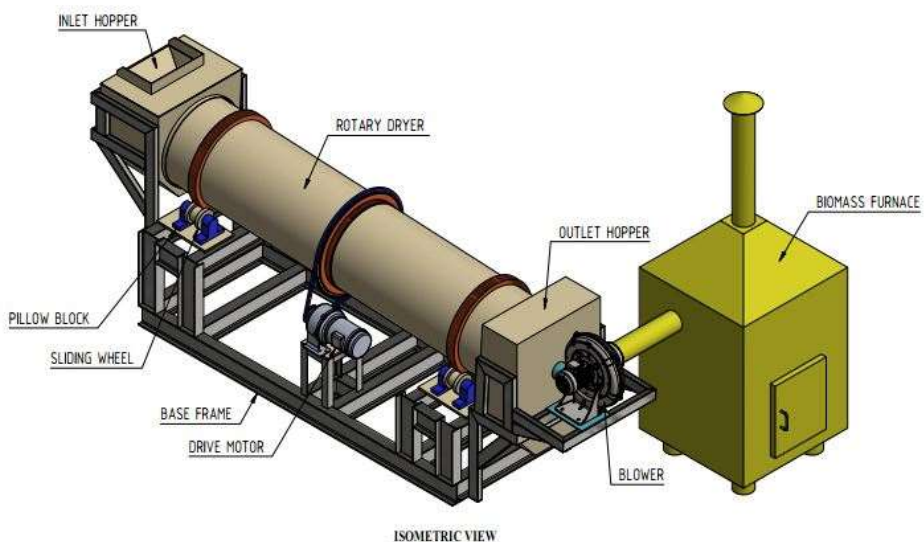

Fig. 2. The rotary dryer components.

The way this rotary dryer works is as follows, namely: The wet sand material to be dried is put into the rotary dryer through the inlet hopper. After the wet sand material reaches the rotary dryer shell chamber, the rotary dryer shell chamber will be rotated, hence the wet sand material in the rotary dryer shell chamber will be stirred using baffles attached to the wall of the rotary dryer shell. The stirring process of the wet sand in the rotary dryer shell chamber is carried out continuously, starting from the wet sand material is introduced until the dry sand material is removed from the rotary dryer shell chamber. The dry sand material will later be removed through the outlet hopper.

Meanwhile, the heat energy needed to dry the wet sand is produced by the biomass furnace which is used to burn biomass wastes. The heat energy produced from the biomass furnace is then channeled into the rotary dryer shell chamber using the blower that sucks the heat energy from the biomass furnace. The heat energy that is channeled will release the water content in the wet sand and then remove the water content from the rotary dryer shell chamber, hence resulting in the dry sand that will be used to make hebel bricks. The dimensions of the rotary dryer can be seen in Figure 3.
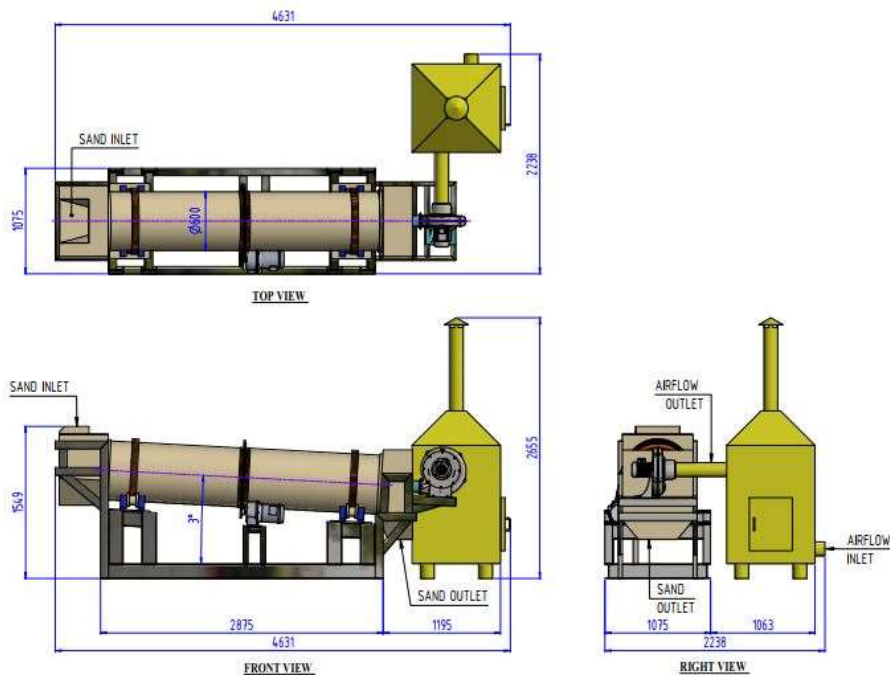

Fig. 3. The rotary dryer dimensions.

The initial design parameters of the rotary dryer can be seen in Table 1.

Table 1. Initial design parameter of the rotary dryer.

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

4

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_t)	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

[*]Note: 1 rpm = 1/60 Hz

This equipment will be used in areas that are still not covered by electricity. Hence, to operate the rotating motor of the rotary dryer shell and hot air distributing blower in the rotary dryer shell, an alternative source of electrical energy is needed that is not dependent on the supply of electrical energy from the State Electricity Company (PLN = *Perusahaan Listrik Negara*). Therefore, the solution is to provide a generator or power plant that uses renewable energy.

Currently, many researchers are conducting research to develop equipment that can be operated using electrical energy sourced from renewable energy. Among them are those who developed the Organic Rankine Cycle (ORC) turbine design, which is devoted to producing electrical energy from heat energy sources with a temperature of less than 100 ºC [12]. There are also researchers who develop drying machine equipment that can be operated using electrical energy generated from solar energy [13], and also develop livestock feed processing equipment that operates using electrical energy generated from biogas energy [14], and there are also researchers who develop equipment for moving goods that are operated using electrical energy generated from other renewable energy sources [15, 16]. Even now, a smart microgrid system equipment has been developed that can utilize solar energy and wind energy to produce electrical energy combined in a hybrid manner [17].

If the sand is taken from the river, it is possible to use renewable energy power plants, namely pico-hydro power to drive the rotary dryer. Reference [18–20] describes this technology, supported by several other researchers [21–23]. Bio-oil can also be used to drive rotary dryers. This vegetable oil can be produced from agricultural waste in villages around the river, including corn cobs [24]. Another renewable energy that can be utilized is biogas. Reference [25] has calculated the economic analysis of biogas production from agricultural biomass.

The quality of sea sand is considered lower as a building material. However, sea sand is needed for areas without volcanoes, with some technologies [26–29]. The rotary dryer on the beach can be operated with bio-oil. Reference [30, 31] describes bio-oil technology from fish waste. Another source of bio-oil is the use of cooking oil waste [32–34].

Reference [14–17] has stated biogas that drives several types of agricultural equipment. Precisely [15] recommends fish waste at the Fishing Ports (*Pelabuhan Perikanan*), Fish Auctions (TPI -*Tempat Pelelangan Ikan*), or Fish Auctions Center (PPI – *Pusat Pelelangan Ikan*) as feedstocks for the biogas digester. Intending to increase biogas production and also improve stakeholder fishery healthy, [15] suggests using multi feedstocks, among others are mixed with latrines. The application of a two-stage digester may overcome several difficulties that arise due to the unevenness of the feedstocks

[35, 36]. This biogas and bio-oil will be able to operate the rotary dryer for sand drying on the beach.

3 Mathematical equation

3.1 Rotary dryer performance

The performance of this rotary dryer, can be known through the following formulas [12–15]. The motor rotation output calculated using the Equation (1).

$$n_m = \frac{f_m}{f_t} . n_0 \qquad (1)$$

Then calculate the rotary dryer rotation using the Equation (2):

$$n_r = \frac{z_m}{z_r} . n_m \qquad (2)$$

Calculate the transfer distance of the sand material to be dried in each rotation of rotary dryer using the Equation (3):

$$L_x = 2 . D . \tan \alpha \qquad (3)$$

Calculate the maximum rotations number of the rotary dryer when transferring the sand from entry to exit using the Equation (4):

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

Calculate the traveling time of the sand material from entry to exit using the Equation (5)

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

Calculate the transfer speed of the sand material in the rotary dryer using the Equation (6):

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

Calculate the drying capacity of the sand material in the rotary dryer using the Equation (7):

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

Calculate the amount of torque that occurs in the rotary dryer using the Equation (8):

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

Calculate the amount of power needed by the rotary dryer using the Equation (9):

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

Calculate the amount of motor power needed by the rotary dryer using the Equation (10)

$$P_m = \frac{P}{0.85} \tag{10}$$

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

Table 2. Calculation result of the rotary dryer performance.

f_m	n_m	n_r	L_x	n_{max}	t	v	Q_r	T	P	P_m
(Hz)	(rpm)	(rpm)	(mm rev^{-1})	(rev)	(min)	(m min^{-1})	(t h^{-1})	(Nm)	(W)	(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.
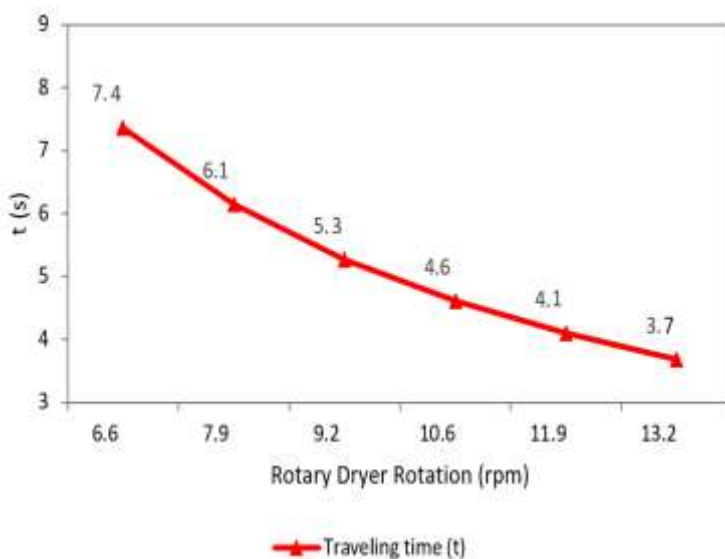
Fig. 4. Graph of traveling time (t) vs rotary dryer rotation (rpm).

Figure 4 illustrates the relationship between traveling time and rotary dryer rotation. This figure shows the decrease in traveling time from 7.4 s at the rotary dryer rotation of 6.6 rpm, to 3.7 s at the rotary dryer rotation of 13.2 rpm. This shows that by increasing the rotation of the rotary dryer, the traveling time of the dry sand will be shorter.
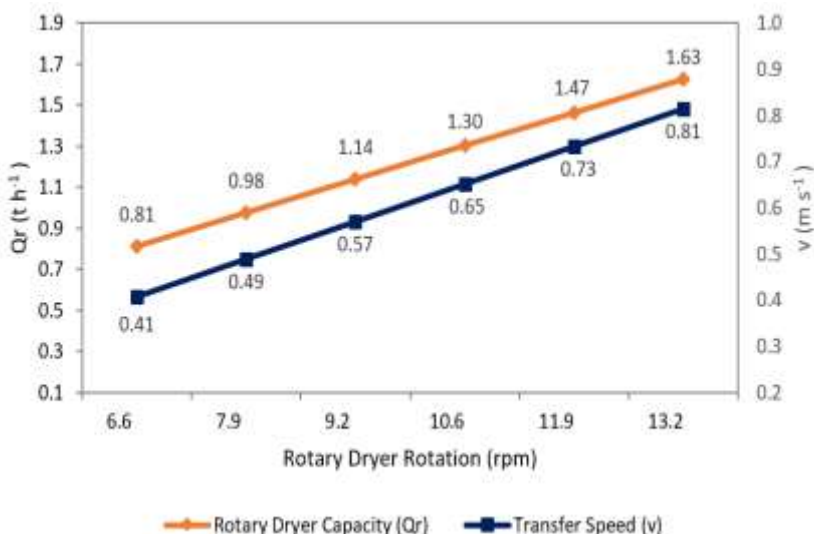

Fig. 5. Graph of drying capacity (Q_r) & transfer speed (v) vs rotary dryer rotation (rpm).

Figure 5 illustrates the relationship between drying capacity and transfer speed against the rotary dryer rotation. This figure shows an increase in the rotary dryer capacity of 0.81 t h^{-1} and the transfer speed of 0.41 m s^{-1} at the rotary dryer rotation of 6.6 rpm and become the rotary dryer capacity of 1.63 t h^{-1} and the transfer speed of 0.81 m s^{-1} at the rotary dryer

rotation of 13.2 rpm. This shows that by increasing the rotation of the rotary dryer, the capacity and the transfer speed of dry sand will increase.
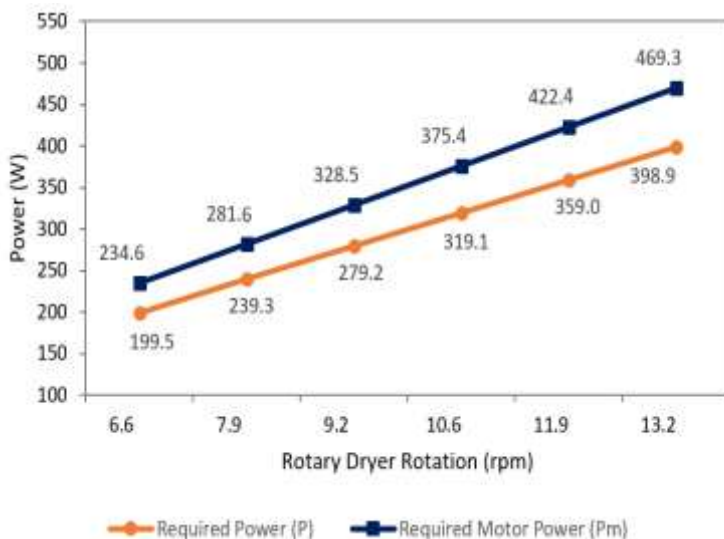

Fig. 6. Graph of required power (P) & required motor power (P_m) vs rotary dryer rotation (rpm).

Figure 6 illustrates the relationship between the required motor power and the rotary dryer rotation. This figure shows an increase in the required motor power of 234.6 W at the rotary dryer rotation of 6.6 rpm and become the required motor power of 469.3 W at the rotary dryer rotation of 13.2 rpm. This shows that the maximum required motor power is 469.3 W, hence it can use the motor that is available in the market with the motor power of 0.55 kW.

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. The maintenance time of this equipment need to pay attention, hence it can more durable and be used longer [12–15]. Determination of the number of baffles, size and position of placement in the rotary drayer shell chamber determine the success of the drying process. The speed of hot air distributed into the rotary dryer shell chamber must be regulated through the blower by adjusting the opening and closing of the inlet. And for safety during operation, it is necessary to add a safety cover on the chain and the sprocket of the rotary dryer.

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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