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ANALYSIS AND INNOVATION ON RDF DRYER MACHINE

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ABSTRACT

The function of vibration is to smooth the flow of hot air into the Refuse Derived Fuel *(RDF)* which is put on the drying trays, so during drying process the door of drying chamber are not necessarily to be opened. The vibration components are placed just below the drying trays and consist of electrical motor, spring, total mass and unbalance mass which is connected to the motor shaft. *RDF* Dryer machine in this research would not take heat energy from coal fuel but from dried *RDF* fuel through shell and tube heat exchanger. Beside that, the research would not take electrical energy from government company but from micro hydro power plant. The objective of this research is to perform analysis and innovation on *RDF* dryer machine. This research uses observation, analysis and innovation methods and the material tested in the drying chamber was *RDF*. The total length of the *RDF* dryer machine is 5.8 m and its drying chamber has a dimension of: Length 4 m, Width 3 m, and Height 2 m. Based on the analysis and innovation result the optimal motion of the samples being dried occurred at angular speed near its natural frequency. Analysis heat Transfer was obtained that the average air temperature in the drying chamber could be achieved by the utilization of shell and tube heat exchanger. Shell and tube heat exchanger was made of aluminium material with a thickness of each material of 0.001 m. Analysis electrical energy was obtained that electrical power output more than required electrical energy by *RDF* dryer machine.

KEYWORDS

Dryer machine, Electrical energy, Heat transfer, *RDF*, Vibration.

1. INTRODUCTION

Increasing heat energy and vapour transfer between air and *RDF* to be dried is an important issue in drying of *RDF*. Generally, manual mixing is used to increase the contact area between air and *RDF* to be dried. However in most types of dryer machines including *RDF* dryer machine use manual mixing. That's why, on a certain time the *RDF* should be taken out of the drying chamber to be manually moved and this case will heat losses due to the drying door opened often. This way will result in significant heat losses and inconvenient operation. In this research, the using of vibration components on drying tray in the *RDF* dryer machine will change the function of manual mixing.

Heat energy resource from *RDF* fuel is new and renewable energy but it still has high moisture content, where the RDF regulations in the current time need the higher heating value energy condition because its condition can give the more advantages i.e it can produce the low emissions towards the environment, the ease of storage and handling, and The RDF can give the homogeneity on the physical and chemical composition of the material [1-4]. Small industries in Indonesia, usually drying of *RDF* under solar energy because this way is relatively easy and cheap. This way results in some problems among others are the process of drying depends on the climate condition and *RDF* still have high final moisture content. Nowadays there are some *RDF* dryer machines use coal fuel and also some times the *RDF* dryer machine use solar energy through solar collector as heat energy resource. However, heat energy resource from coal fuel is not new and renewable energy and it is not environmentally friendly whereas the using of solar collector is not efficient. In this research, the using of *RDF* fuel will change the function of coal fuel and solar collector.

Usually *RDF* dryer machine uses electrical energy from Government Company. The electrical energy is used to operate mean and infrastructure, for example: pump, blower, Fan and other components. Then drying process on *RDF* dryer machine is depending on electrical energy from Government Company. In this research the using of electrical energy from micro hydro power plant will change the function of electrical energy from government company [5].

The previous studies on the utilization of shelf vibration for dryer machine, among others: research of vibration system on the cashew nut shelves using coal as the fuel, piston engine and unbalance mass had been done [6]. The experimental results shown of the spring used as pedestal of shelves would be broken fast. The vibration components were placed under the shelf such as four springs, one piston engine, and one unbalances mass and one electrical motor. Analysis and simulation results showed that the vibration components influenced vibration. The most vibration condition occurred at n = 335 rpm and r = 1. The utilization of piston engine caused greater spring load and the spring used as pedestal of shelves would be broken fast. Harahap did research about analysis and experimental vibration on cashew nut racks by using unbalance mass [7]. The total length of a drying chamber is more or less 4.8 m and its drying chamber had a dimension of: length 4 m, width 3 m, and height 2 m. The material tested in the drying chamber was cashew nut. The optimal motion for 120 kg cashew nuts on each drying tray occurred at ratio r = 0.97 or the angular speed near its natural frequency.

Dryer machine in this research was not environmentally because gas from fuel burning could not be cleaned well. Suyono did research about pyrolysis by using green incinerator or green and zero waste pyrolysis [8]. The research was completed with gas cleaner using cyclone and wet scrubber, and gas from fuel burning in the green incinerator will be cleaned by cyclone and wet scrubber. To increase temperature in the reactor of pyrolysis, then the green and zero waste pyrolysis used *RDF* as solid fuel but water content of *RDF* relatively still high, so it needs *RDF* drying process by using *RDF* dryer machine. These conditions will arise some problems on *RDF* dryer machine. To resolve all the problems above then a *RDF* Dryer machine which is equipped with vibration components, shell and tube heat exchanger, micro hydro power plant are used in this research. The objective of this research is to perform analysis about the optimal motion on drying tray, the air temperature in RDF dryer machine, electrical energy, and also innovation *RDF* dryer machine. Analysis of each parameter and innovation are needed to develope the results of the research before. The optimal motion can be found from analysis about vibration on each drying tray. The air temperature after heat exchanger and the required air temperature by the drying chamber can be found from analysis heat transfer on *RDF* dryer machine [9]. Produced electrical energy through generator of micro hydro power plant and required electrical energy by *RDF* dryer machine can be found from analysis electrical energy.

The research was conducted in October 2017 until April 2018 in laboratory of Mechanical Engineering, University of Pancasila, South Jakarta, Indonesia. The methods used in this research are observation on some *RDF* dryer machines; study of literature in accordance with the field of research; analysis and innovation on *RDF* dryer machine. The material tested in the drying chamber was *RDF*. Based On Observation On Some *Rdf* Dryer Machines Were Obtained That Application Of Solar Energy As The Energy Resource for the drying Chamber Only Producing Drying Air Temperature Less Than 65 °C, That why Heat Exchanger And Heat Energy Resource From Dried *Rdf* Fuel burning were very needed. This Is Illustrated In Figure 1.

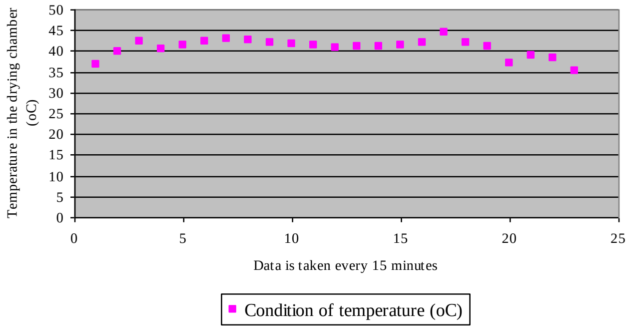

Figure 1: Application of solar energy as the energy resource for the drying chamber

2.VIBRATION, HEAT TRANSFER AND WATER POWER

Vibration components were placed under the drying trays and consist of one electrical motor, four springs, total mass, one pulley and one unbalance mass which is connected to the motor shaft. This is illustrated in Figure 2.

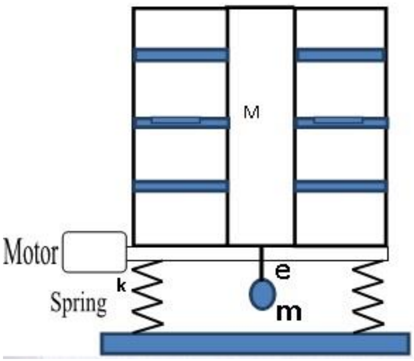

Figure 2: Vibration components.

If the Total of mass, M, Proportionality constant, k, Unbalance mass, m and its Length, e. Vibration Amplitude, X, Ratio, r, Angular speed, ω, and Natural frequency, ω_n are given Equation (1), (2) and (3) [2, 10].

$$X = \frac{m\varepsilon\omega^2}{\sqrt{(k - M\omega)^2}} \quad (1)$$

$$\frac{X}{me/M} = \frac{r^2}{\sqrt{(1-r^2)}^2} \quad (2)$$

$$\omega_n = \sqrt{\frac{k}{M}} \text{ and } r = \frac{\omega}{\omega_n} \quad (3)$$

The drying chamber applied heat energy from dried *RDF* fuel and also heat energy from solar energy. Heat energy from dried *RDF* fuel is flowed to the drying chamber through heat exchanger (*HE*) and heat energy from solar energy is absorbed by solar collector in the drying chamber. Heat energy will be used to dry *RDF* in the drying chamber. The required air temperature for *RDF* in the drying chamber, T_r = 65 °C. This is illustrated in Figure 3.

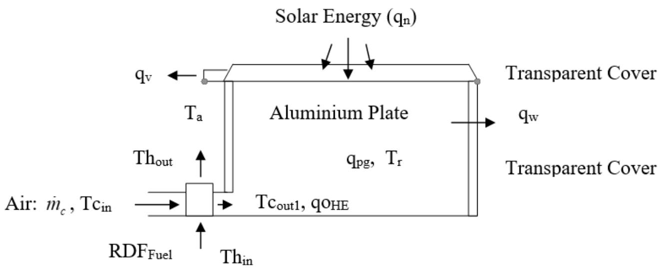

Figure 3: Dried *RDF* fuel and solar energy for *RDF* dryer machine

The heat transfer in heat exchanger can be calculated by Equation (4) [11].

$$qo_{HE} = \dot{m}_c * cp_c * (Tc_{out1} - Tc_{in}) \quad (4)$$

The air temperature after heat exchanger can be calculated by Equation (5) [11].

$$Tc_{out1} = Tc_{in} + \frac{C_h}{C_c} * (\varepsilon) * (\Delta T_{max}) \quad (5)$$

The required air temperature by the drying chamber can be calculated by Equation (6).

$$Tc_{out2} = \frac{(q_v + q_w \quad q_{pg})}{\dot{m}c * cp_c} + Tc_{in} \quad (6)$$

Water power in rural river, Indonesia would be used to rotate a turbine on micro hydro power plant. Electrical energy would be obtained by generator that had been connected to the turbine. Turbine and generator are located in the power house [7]. Electrical energy from micro hydro power plant is illustrated in Figure 4.

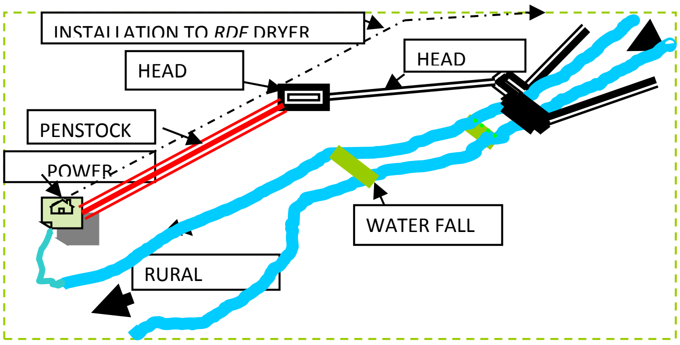

Figure 4: Electrical energy from micro hydro power plant

3. RESULTS AND DISCUSSIONS

RDF Dryer machine in this research is very important for development of the quality of *RDF* fuel in rural, Indonesia. The application of vibration components caused optimal motion and the trays to be vibrated, so hot air flow would hit the entire surface of the *RDF* on the drying trays. That's why during drying process, the doors of the drying chamber were not necessarily to be opened. Shell and tube heat exchanger and dried *RDF* fuel were placed in the green incinerator but *RDF* as material tested was placed in the drying chamber. Incinerator in this research is called green incinerator because cyclone and wet scrubber are able to clean gas from dried *RDF* fuel burning. The total length of the *RDF* dryer machine was 5.8 m and its drying chamber has a dimension of: Length 4 m, Width 3 m, and Height 2 m. Left side wall, right side wall and the floor were made in three layers and consist of: Aluminium material with thickness of 0.001 m and the next material was glass wool with thickness of 0.1 m and the last material was aluminium material with thickness of 0.001 m. Whereas the front wall, rear wall and the roof were made of transparent cover with thickness of 0.006 m. Innovation on *RDF* dryer machine was illustrated in Figure 5:

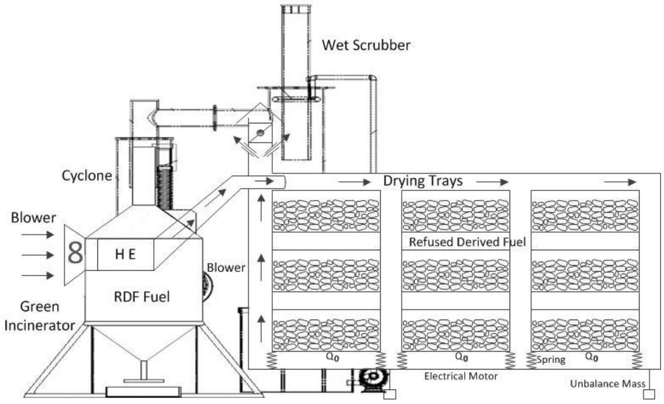

Figure 5: *RDF* dryer machines by using Vibration Components, Heat Exchanger, Micro Hydro Power Plant and Green incinerator.

Heat exchanger applied in this research was shell and tube heat exchanger having a dimension of: Diameter of tube was 1.25 in or 0.032 m, Total of tube was 42 tubes, Height of tube was 0.3 m, pitch 19/16 in or 0.03 m. Shell and tube heat exchanger in this research was made of aluminium material with thickness of 0.001 m. The *RDF* dryer machine was equipped with some rotation speed of electrical motor and temperature gauges, 2 blowers of 1.5 kW, 2 exhaust fans of 1.5 kW. Each drying tray for the first analysis had 10 kg *RDF*, the second analysis had 20 kg *RDF* and the third analysis had 30 kg *RDF* and Each drying tray had 1 electrical motor of 2.2 kW. Beside that, *RDF* dryer machine in this research applied 6 drying trays, 1 water pump of 0.75 kW, 6 electrical motors of 13.2 kW. In addition that the Proportionality constant is k, Horsepower of electrical motor is P and Length of an unbalance mass is e. They are constant, namely: k = 49050 N/m, P = 1.0 HP and e = 0.12 m.

The analysis and innovation results obtained that the optimal motion of the *RDF* could be found by changing unbalance mass and rotation speed of electrical motor. The electrical motor in this research must be equipped with manual tool that could adjust the rotation speed of electrical motor, so *RDF* that were on the drying trays always in optimal motion. Based on analysis and innovation results obtained that the optimal motion of the samples being dried occurred at angular speed near its natural frequency. Analysis and innovation results of vibration as shown in Table 1.

Table 1: Vibration on each drying tray by changing unbalance mass and rotation speed of electrical motor

Total of mass, M (kg)	Numbers of *RDF* M_{RDF} (kg)	Unbalance mass, m (kg)	rotation speed, n (rpm)	Angular speed, ω (rad/s)	Natural frequency, ω_n (rad/s)	Ratio, r (-)
20	10	0.2	475	47.5	49.5	0.96
		0.25	395	39.5	49.5	0.80
		0.3	298	29.8	49.5	0.60
30	20	0.2	469	46.9	40.4	1.16
		0.25	438	43.8	40.4	1.08
		0.3	256	25.6	40.4	0.63
40	30	0.2	476	47.6	40.4	1.36
		0.25	438	43.8	40.4	1.25
		0.3	413	41.3	40.4	1.12

The analysis of heat transfer in this research used heat energy resource from dried *RDF* fuel burning through shell and tube heat exchanger. Factors and Temperature in shell and tube heat exchanger could be shown in Figure 6.

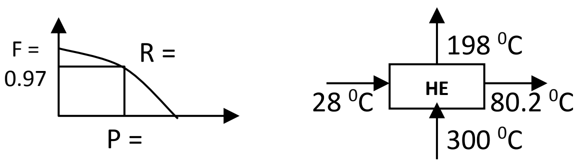

Figure 6: Factors and Temperature in shell and tube heat exchanger.

To dry *RDF* required air temperature in the drying chamber, Tr = 65 °C for about 5 hours drying time and the air temperature after shell and tube heat exchanger, Tc_{out} = 80.2 °C. Micro hydro power plant will be used to supply electrical energy to the *RDF* dryer machine in rural, Indonesia. Electrical energy for the mean and infrastructure of the *RDF* dryer machine in rural, Indonesia could be fulfilled by converting the water power become an electrical energy. That's why the drying process of the *RDF* in the drying chamber did not depend on the electrical energy from the government company. Table 2 shows the complete results and discussions and also several equations of water power become an electrical energy [7]. The analysis was obtained that electrical power output more than required electrical energy by *RDF* dryer machine. Analysis results of on micro hydro power plant as shown in Table 2.

Table 2: Water power become an electrical energy on micro hydro power plant

Name of River		Rural River, Indonesia
Potential Head	H_p	26 m
Capacity	Q	0.8 m^3/s
Capacity Design	Q_d	0.4 m^3/s
Water Power	$P_h = 9.81\ Q_d\ H_p$	102 kW
Efficiency	η_T, η_G, η_M	0.74, 0.85, 0.98
Electrical Power Output	$P_g = P_h\ \eta_T\ \eta_G\ \eta_M$	62.9 kW
Required Electrical Energy by *RDF* dryer machine	P_r	18.2 kW
Turbine Type	Tt	Cross Flow Turbine

4. CONCLUSION

Based on the analysis and innovation on *RDF* dryer machine were found as: The optimal motion was influenced by unbalance mass and speed rotation. Arrangement system of unbalance mass and speed rotation was very important to find the angular speed near its natural frequency. The most optimal motion for 10 kg *RDF*, 20 kg *RDF*, and 30 kg *RDF* on each drying tray occurred at ratio, r = 0.96, 1.08, 1.12. These results show that the angular speed near its natural frequency. The required air temperature in the drying chamber of *RDF* dryer machine was depending on the air temperature after heat exchanger. The required air temperature in the drying chamber in this research was 65 °C. The air temperature after shell and tube heat exchanger, Tc_{out} = 80.2 °C cause air temperature in the drying chamber, Tr = 65 °C. Electrical energy from micro hydro power plant was needed to supply electrical energy to the *RDF* dryer machine in rural, Indonesia. Micro hydro power plant in this research was able to produce electrical energy in generator, P_g = 62.9 kW while the required electrical energy by *RDF* dryer machine, P_r = 18.2 kW. Innovation in this research was the using of green incinerator and the using of shell and tube heat exchanger in the green incinerator.

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