Characteristics Of Powder Rice Husk Burning On Cyclone Burner

Sigit Purwanto, Karyawan Pudjianto, Ferdy Pradana

Abstract: Cyclone burner is a direct combustion technology, fuel used is rice husk powder of biomass with particle size <177 μm (-80 mesh). The combustion process in the cyclone burner utilize swirl flow, with lab-scale testing. Influence of air fuel ratio (AFR) and temperature distribution in combustion chamber is an important factor of combustion process, resulting in the ratio of air requirement to fuel and performance of combustion chamber in the cyclone burner. The results of the cyclone burner test with rice biomass powder showed optimum AFR at 8.37, 8.63 and 7.82, with variations mass flow rate of the fuel. Maximum combustion temperature with biomass fuel rice husk powder reached 861 ^{0}C with mass flow rate of fuel 3.25 kg/h.

Keywords: cyclone burner, air fuel ratio, biomass powder, temperature distribution

INTRODUCTION

Direct combustion of powdered biomass fuel is the easiest use of solid biomass to get heat. Various studies with direct combustion methods using solid biomass fuels have been carried out, including fixed bed combustion and moving bed combustion. This study aims to design a biomass burner, then the testing process is carried out with the swirl flow method made from rice husk biomass. Cyclone burners have a cylindrical shape with the air duct pipe is placed in the position of the tangential direction, while the fuel feeding pipe is placed in the position of the radial direction that forms an angle of 900 to the air duct pipe. LPG is a source of flame which has a function as an igniter that is placed nearby the pipe feeding biomass in the direction of the airflow. The swirl flow formed in the cyclone burner combustion chamber is caused by the air duct pipe that is placed in the tangential direction of the combustion chamber. The swirl flow can also increase the intensity of combustion in the combustion chamber because of the increased fuel mixing process and prolong the residence time (Wahid, 2006). The swirl flow characteristics which are accompanied by tangential velocity components are generally made using vanes. The function of this vanes is as a flow guide and adjusts the flow velocity so that the swirl flow can be adjusted (Kitoh, 1991). Based on the description above, it is necessary to conduct cyclone burner experiments with swirl flow method which considers the characteristics of powdered solid fuels. This study uses biomass fuels namely powdered rice husk. The size of powdered rice husk particles is <177µm (-80 mesh). The goal is to find out the characteristics of the combustion temperature in the cyclone burner combustion chamber.

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METHOD

Research Material

In this study, the fuel used was powdered rice husk. Making rice husk powder using a rotary mill machine. This machine has a grinding chamber equipped with a rotating disc. The function of this disc is as a shredder for shale biomass into powder biomass. The process of collecting powdered rice husks using cyclone equipment. Proximate analysis of the fuel carried out is shown in Table 1.

Equipment

The cyclone burner unit consists of a combustion chamber, fuel storage, a blower as an air supply and a temperature measurement device. The cyclone burner unit scheme is shown in Figure 1.

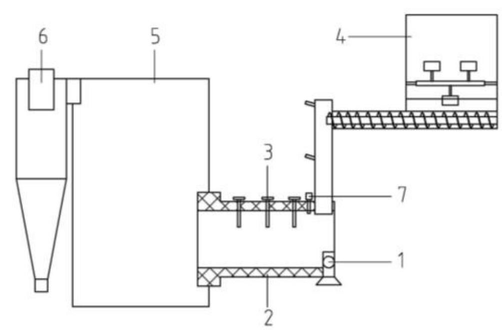


Figure 1. *Scheme of cyclone burner. 1. Air Blower; 3. Termocouple; 4. Storage; 5. Gas collector; 6. Dust collector; 7. Igniter*

Table 1. *Proximate Analysis (wt.%)*

Component	Rice Husk *(wt.%)*
Moisture content	3.73
Volatile matter	58.75
Fixed carbon	15.60
Ash	21.91

The combustion chamber of the cyclone burner is cylindrical, with a horizontal position. The dimensions of the combustion chamber are 0.22 m in diameter and 0.5 m in length. The outer combustion chamber wall is installed with a heat insulator with a thickness of 2.5 cm. This Cyclone burner is equipped with a gas collector, which functions to drain the exhaust gas into the atmosphere during the combustion process. The combustion chamber of the cyclone burner is placed in three thermocouple points, with the aim to determine the distribution of the axial and radial direction of combustion temperature. The position of each thermocouple in the axial direction is T1 = 1 / 2D, T1 = 3 / 2D and T3 = 2D (D = diameter of the combustion chamber). While the position of the thermocouple radial direction varied with positions 0, 3, 5, 7 and 11 cm against the cylindrical radius of the combustion chamber. In this trial, the thermocouple used is type K and is connected by a data logger. Thermocouple position scheme as in Figure 2.

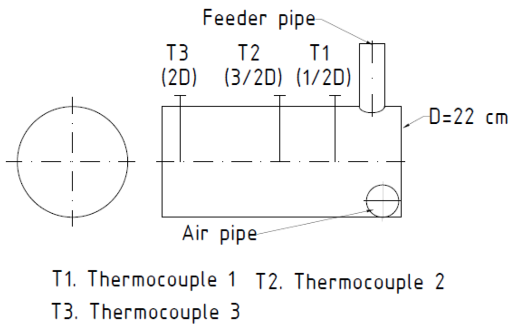


Figure 2. *Thermocouple position scheme*

The fuel supply system consists of screw feeder, feed inlet, agitator and electric motor. In the vertical direction feed inlet installed secondary airways are placed after the orifice, this serves to anticipate the occurrence of back air in the combustion chamber towards the storage feeder. The air flow rate is supplied through an air blower, the main airway is installed an orifice measuring instrument and is connected to a manometer U measuring instrument which aims to determine the air flow during the combustion process.

Procedure

The combustion process testing procedure is preceded by a preliminary test, to determine the reference value of the mass flow rate of fuel and air. So that obtained the reference value of the test for the mass flow rate of fuel ($\dot{m}_f$) 2.5, 3.0 and 3.25 kg / hour. As shown in Table 1. Cyclone burner testing starts with the operation of an air blower along with LPG gas ignition. LPG gas mass flow rate is made constant at 0.6 l / minute. Then the temperature in the combustion chamber is maintained until relatively stable. Then the screw feeder is operated, with the fuel mass flow rate in accordance with the reference value specified. At the same time there is a temperature change in the combustion chamber and the data will be recorded in the data logger, until the maximum combustion temperature is obtained. Maintain the test operating conditions until a stable temperature is obtained. After a maximum stable temperature, it is continued by varying the AFR. Tests related to the influence of the Air Fuel Ratio (AFR). It is carried out by means of a constant mass flow rate of fuel and then changing the variation in air mass flow rate.

RESULTS AND DISCUSSION

Air Fuel Ratio (AFR) is an important factor for predicting combustion results and representing the amount of air used per unit of mass of fuel during the combustion process.

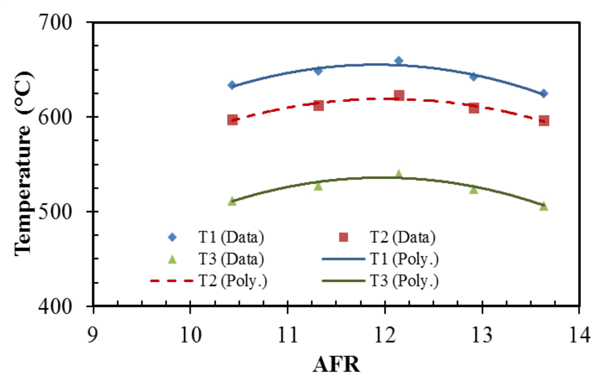
AFR effect on combustion temperature

The effect of AFR can be seen by changing the variation of air mass flow rate ($\dot{m}_a$) and maintaining a constant mass flow rate of fuel ($\dot{m}_f$). In this study the fuel mass flow rate ($\dot{m}_f$) has three variations, namely 2.5, 3.0 and 3.25 kg / hour with the AFR specified as in Table 1.

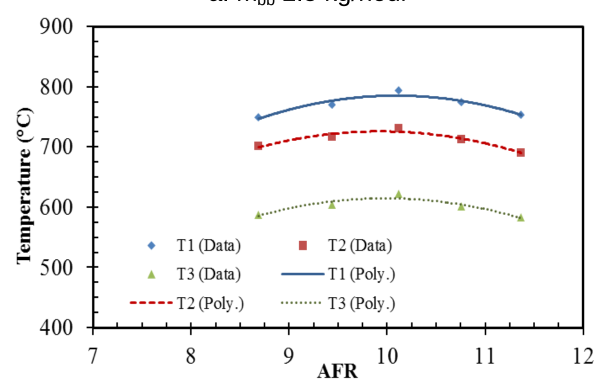
Table 1. *Air mass flow rate and AFR data on the type of powder biomass*

Parameter	Reference Point I ($\dot{m}_f$ = 2.5 kg/hour)				
Δh (mmH_2O)	22	26	30	34	38
$\dot{m}_a$ (kg/hour)	26.08	28.31	30.36	32.29	34.1
AFR	10.43	11.32	12.15	12.94	13.64
Parameter	Reference Point II ($\dot{m}_f$ = 3.0 kg/hour)				
Δh (mmH_2O)	22	26	30	34	38
$\dot{m}_a$ (kg/hour)	26,08	28,31	30,36	32,29	34,1
AFR	8,69	9,44	10,12	10,76	11,37
Parameter	Reference Point III ($\dot{m}_f$ = 3.25 kg/hour)				
Δh (mmH_2O)	22	26	30	34	38
$\dot{m}_a$ (kg/hour)	26,08	28,31	30,36	32,29	34,1
AFR	8,02	8,71	9,34	9,94	10,49

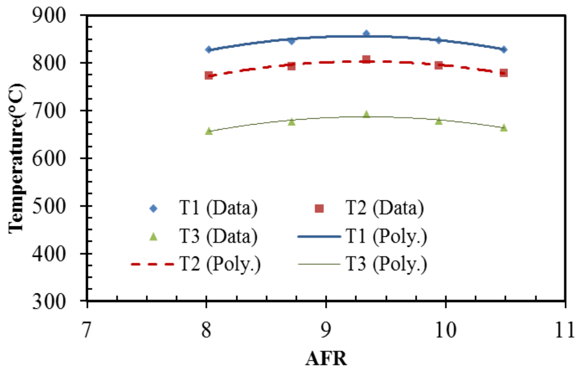
Δh is the result of measuring the difference in fluid height (water) on the manometer. Variation in values Δh starts from the smallest value of 22, 26, 30, 34 and 38 mm. Whereas the value of Δh has six Δh values as reference points. This process is carried out in powdered rice husk biomass fuel, with varying fuel mass flow rates.



a. $\dot{m}_{bb}$ 2.5 kg/hour



b. $\dot{m}_{bb}$ 3.0 kg/hour



c. ṁ$_{bb}$ 3.25 kg/hour

Figure 3. *The Relationship Between Temperature of Combustion Against AFR*

From the picture above shows that the variation of AFR affects the results of the combustion temperature, for each fuel mass flow rate is obtained a different maximum combustion temperature. Relatively similar trend patterns are shown in the results of testing AFR variations. This is indicated by the position of the thermocouple at T_1, T_2 and T_3. In the initial AFR variation the combustion temperature has a tendency to rise until it reaches the maximum temperature, then the combustion temperature decreases when the AFR variation gets bigger. AFR is a factor that plays a role in determining the ratio of the amount of air and fuel requirements during the combustion process. Variations in AFR can also affect changes in temperature resulting from combustion. From the experimental results show that the combustion temperature tends to rise until it reaches the maximum temperature, then the combustion temperature decreases. This is because the combustion process with excess air supply causes the nitrogen content in the air to absorb most of the heat energy released by the fuel. The results of combustion testing also show that, a lot and the least amount of powdered rice husk fuel supply affects the results of combustion temperature, but the amount of fuel supply is not always followed by an increase in combustion temperature, especially at low AFR. The use of AFR variations in cyclone burner testing has a wide range due to significant changes around the combustion temperature.

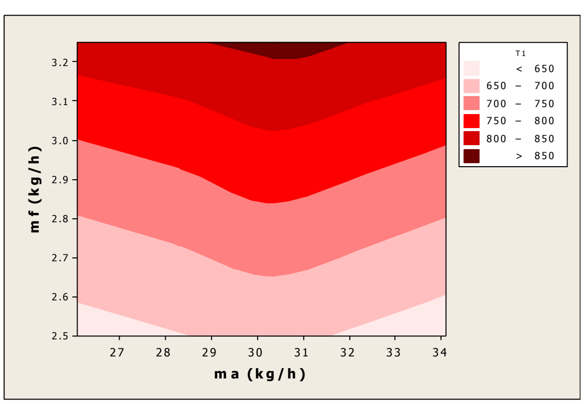


Figure 4. *Contour plot of combustion temperature*

In Figure 4 shows that the air mass flow rate (ṁ$_a$) at 30.36 kg / hour is the optimum air mass flow rate (ṁ$_a$). So that the variation of the fuel mass flow rate (ṁ$_{bb}$) has the same optimum point for variations in the air mass flow rate (ṁ$_a$). From the test results it can be seen that, the mass flow rate of fuel (ṁ$_{bb}$) includes factors that influence the results of combustion temperatures. The amount of powdered rice husk fed into the combustion chamber through the screw feeder, affects the amount of heat energy produced during the combustion process. This is because the amount of mass supply of fuel that is converted into heat energy will be smaller. But the greater amount of fuel mass supply has an impact on incomplete combustion, resulting in a decrease in combustion temperature in the cyclone burner.

Long dimension effect of combustion chamber

The combustion temperature in the axial direction or thermocouple observation is installed at the position of T_1, T_2 and T_3 with the powder husk mass flow rate (ṁ$_{bb}$) 2.5 kg / hour, at AFR 12.15 shows a significant decrease in combustion temperature. The combustion temperature was obtained 659, 623, and 540˚C respectively. The pattern of the tendency to decrease the combustion temperature occurs also in the variation of the rice husk mass flow rate of 3.0 and 3.25 kg / hour. The highest combustion temperature is in the T_1 thermocouple position. This shows that the distance of the flame source can affect the distribution of heat transfer that occurs in the cyclone burner combustion chamber, resulting in a different heat release. This condition occurs also in the position of T_2 and T_3 thermocouples. The farther the distance of the source of the flame is burning, the combustion temperature tends to decrease. From the best observation of the thermocouple position, to get the maximum temperature at 1 / 2D or at a distance of 0.11 - 0.33 m. The stability of the combustion temperature in the cyclone burner combustion chamber is also influenced by the stability factor during the fuel feeding process because the biomass powder particles have a high shear strength (Falk, 2013). The use of screw feeder as a feed fuel (rice husk powder) is an alternative to maintain feed stability and reduce the strength of high shear forces between powdered rice husk particles. In addition, the chemical content of a fuel will also affect the calorific value of the material. The high ash content in a fuel will reduce the heating value of the material (Gracia et al. 2014). Whereas high bonded carbon in a material will increase the heat value of the material (Liu et al. 2008).

CONCLUSIONS

AFR variation has a very significant effect on combustion temperature. The maximum AFR is at a value of 12.15 for the mass flow rate of 2.5 kg / hour powdered rice husk fuel, with a temperature of 659˚C. For a mass fuel flow rate of 3.0 kg / hour the maximum AFR is at 10.12, with a temperature of 793˚C. Whereas the mass flow rate of 3.25 kg / hour powdered rice husk fuel was obtained by AFR 9.34, with a temperature of 861˚C.The best length dimension of the combustion chamber to get the maximum temperature is at a distance of 0.11 - 0.33 m. Further research is needed regarding the combustion characteristics of cyclone burners such as exhaust gas and ash analysis.

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