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The Efficiency of Steel Plate Biomass Briquette Stove with Variation of Aluminum Cylinder Diameter

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Abstract

Aluminum has been known with the properties of lightweight and not easily corroded. It also has good thermal conductivity property. This reason motivates authors to modify the combustion chamber of the briquette stove with the addition of an aluminum cylinder to increase the stove performance. This research examines the thermal efficiency of biomass briquette stove using candlenut charcoal briquettes by providing 5 variations of aluminum cylinder diameter inside the stove combustion chamber shell. The cylinder diameter varies from 140, 150, 160, 170 and 180 mm to observe the comparative thermal efficiency and combustion temperature character. The briquette stove material was made of steel and the cylinder material added inside combustion chamber was made of Aluminum. The form of briquette used is the shape of a wasp nest. The results show that aluminum sleeve diameter of the 140 mm with candlenut shell briquettes has an optimum thermal efficiency of 28.9% with input power and output power of 0.40 kW, 1.40 kW respectively.

1. Introduction

One of the most significant current discussion are the increasing of fuel energy consumption and limited quantities of fossil fuel. Many efforts have been done to explore alternative energy sources.

. Unlike fossil fuel, biomass does not take millions of years to develop and can be reproduce, and for that reason, it is considered has a renewable character. Biomass is formed from the living species like plants and animals. A vast amount of biomass grow through photosynthesis by absorbing CO2 from the atmosphere. It can be considered as carbon neutral since it releases the carbon dioxide when it burns, but only recently. Thus, the burning of biomass does not make any addition to the earth.

These are what attracts researchers to utilize the remaining biomass, especially biomass from plant such as candlenut shells in the form of charcoal briquettes. A number of researchers have been reported a utilization of candlenut shell as a fuel. Njenga, et al[1] has been found that a charcoal briquettes can increase energy, reduce deforestation and have low emissions. Faryda, et al [2] shows a mixture of candlenut charcoal briquettes and rice husk with a ratio of 70%:30% produces good porosity of only 1.7%. The ratio of candlenut shells to other charcoal produces energy of 46.98 Watt [3]. And Daud Patabang, et al.,[4] found that the addition of 90% candlenut shell charcoal to coal charcoal can reduce SOx emission levels up to 80.67%.

The efficiency of briquette stove is an important aspect to provide better heat transfer contained in the briquette. Several studies have conducted in modifying briquette stove. Ji Wang, et al.,[5] have found that the modifications of the stove can produced a thermal efficiency of 68%. Arif Effendy and Suluh Sallolo[6] have investigated that the addition of an aluminum cylinder to a briquette stove produced thermal efficiency equal to 70.73% The previous studies without modification stoves Bolaji And Olalusi [7] and Er. Bhakta, et al [8] resulted in maksimal thermal efficiency of only 28.2% and 17%.

In this study, modification of briquette steel using steel material combined with aluminum cylinder inside the combustion chamber is investigate to obtain maximal thermal efficiency.

2. Material and Methods

The briquette stove is made from steel plates with dimension of 300 mm of high, 220 of mm outside diameter, 200 mm of inner diameter, and seat distance from the stove bottom of 10 mm, as in figure 1.

Fig. 1 Steel stove

The type of biomass used in this study was candlenut shell waste with a wasp nest form. The wasp nest form has been known had a larger flame surface area [6]. The cylinder diameter was added inside the combustion chamber and varies from 140, 150, 160, 170 and 180 mm to observe the comparative thermal efficiency and combustion temperature character. The combustion chamber is lined with aluminum plate walls which have an air holes with a diameter of 10 mm with a distance of 20 mm between holes along the diameter of the upper cylinder as seen in figure 2.

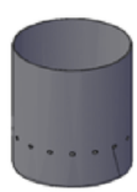

Fig. 2. Cylinder of a steel stove

The testing parameters used in determining the value of the heat value using the equation are as follows [6]:

Value calor HHV (cal/g)= $(T_A\text{-}T_M)/m$ x 2458 calori.................. (1)

Where:

T_A = The final temperature of combustion in the calorimeter bomb (°C)

T_M = The initial temperature of combustion in the calorimeter bomb (°C)

m = sample weight (g)

2458 = Calorimeter bomb coefficient

The several test parameters to analyze the value of the thermal efficiency of the briquette stove by adding variations of cylinder diameter inside the combustion chamber are using the following equation[5]:

1. Output Power (Pout)

   Output (Pout) is the ratio between the energy used to heat water to the length of time it takes to reach boiling point. The translation of the formula is as follows:

$$P_{out} = \frac{M_w \; x \; Cp_{air} \; x \; (T_f - Ti))}{t} \quad \text{..........................(2.)}$$

Where :

Pout : Output Power (watt).

Cpair : The specific heat of water 4.1866 (kJ/kg ^{0}C).

Ti : Initial temperature of water (^{0}C).

Tf : Final Temperature Of water (^{0}C).

t : Time to heat the water

2. Input Power (Pin)

   Input Power (Pin) is the ratio between the energy contained in a fuel and the length of time in the combustion process. The translation of the formula is as follows:

$$Pin = \frac{m_{bt} \; x \; LHV}{t} \quad \text{..(3)}$$

Where :

Pin : Input Power (kW).

LHV : heating value under fuel (KJ/Kg. 0C).

t : time to heat the water (s)

3. Thermal Efficiency (ηth)

   Thermal efficiency is the ratio between the net power used to heat water and the fuel combustion power. The translation of the formula is as follows :

$$\eta th = \frac{P_{Out}}{P_{in}} \; x \; 100\% \quad \text{..} \quad (4)$$

Where

Pin : Input Power (kW).

Pout : Output Power (kW).

ηth : Thermal Efficiency (%)

3. Results and Discussion

The process of this research begins with the manufacture of briquettes, heating value and combustion test (performance) on a combustion stove with a variation of 5 sizes of she5casings on a steel burning stove with a variation of one types of candlenut shells. The test results are summarized as in Table 1.

Table 1. Recapitulation of the measurement values and testing of 5 furnace variations cylinder diameter of the combustion chamber

DB (kg)	DV (mm)	ma (kg)	mbt (Kg)	B.T (M)	Ltb (M)	P out (kw)	P in (kw)	P losses (kw)	ηth (%)
Candlenut Shells	180	5	175	25	56	0,24	0,84	0,60	28,72
	170	5	165	31	56	0,37	1,35	0,98	27,42
	160	5	155	31	56	0,32	1,13	0,82	27,84
	150	5	145	24	56	0,30	1,03	0,73	28,74
	140	5	135	25	44	0,41	1,41	1,00	28,97

The best efficiency of 28.97% was obtain at the cylinder diameter of the combustion chamber of 140 mm by 28.97%.

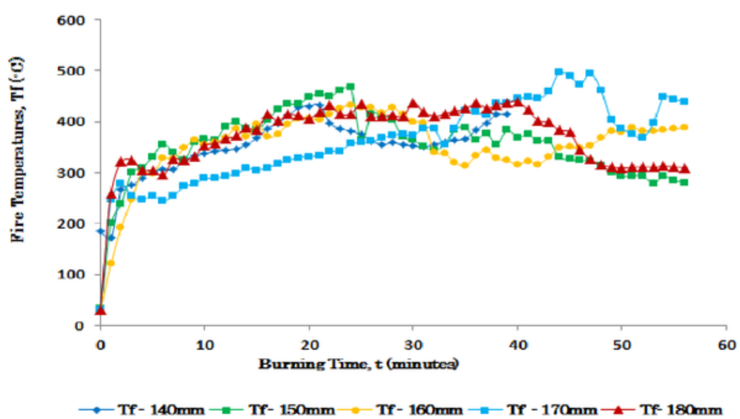

Fig 3. Flame temperature versus burning time

Figure 3 shows the characteristics of the flame temperature of each diameter of the combustion chamber. The magnitude of the temperature of each flame is 140 mm by 433⁰C, 150 mm by 467⁰C, 160 mm by 432⁰C, 170 mm by 496°C and 180 mm by 440⁰C. It can be seen that the best flame temperature was obtained in the combustion chamber with a diameter of 170 mm, an ignition time of 56 minutes with a flame temperature of 496°C. Larger diameter of the cylinder result in more air inside the combustion chamber and make the rate of combustion become faster. It is somehow not observed in the diameter of 180 mm due to the close position with outer surface of the stove that influenced by the environmental air.

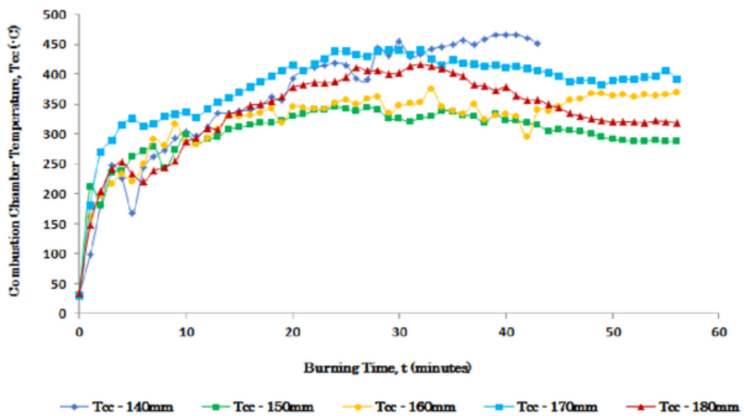

Fig 4. Combustion Chamber Temperature Versus Burning Time

Figure 4 shows the characteristics of the combustion chamber temperature of each diameter of the aluminum cylinder. The magnitude of the combustion chamber temperatur are 140 mm by 466^{0}C, 150 mm by 345,5^{0}C, 160 mm by 408,5^{0}C, 170 mm by 440,5^{0}C and 180 mm by 416,5^{0}C. The phenomenon shows the tendency of the combustion chamber which is further from the stove wall (closer to the combustion chamber) has a maximum temperature of 466oC at 140 mm cylinder diameter, although the combustion time only takes 46 minutes. This is much different from the temperature of the combustion chamber of other cylinder diameters. They tend to have a combustion time of 56 minutes, but a low combustion chamber temperature. The smaller the diameter of the cylinder, the longer in maintaining its heat due to good heat supply insulation and the hot air chamber of the briquette is more tight and focused so the rate of heat transfer is more maximal.

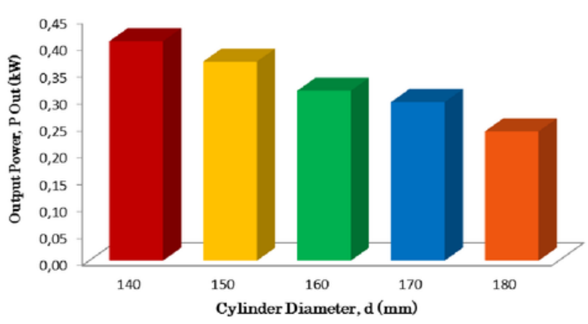

Fig 5. Output Power Of Cylinder Diameter

It can be observed in figure 5 that the best output power is 140 mm of cylinder diameter of 1.41 kW. This shows that the density of the combustion chamber towards the briquette has an effect in transferring the heat of the briquette to the stove.

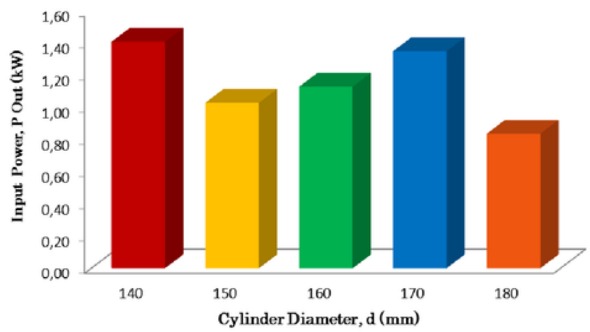

Fig 6. Input power of Cylinder Diameters

In figure 6 can be observed that the highest input power of 1,41 kW was obtained at is the cylinder diameter of a 140 mm. The results show that the greater calorific value of the biomass charcoal briquettes used result in greater input power used.

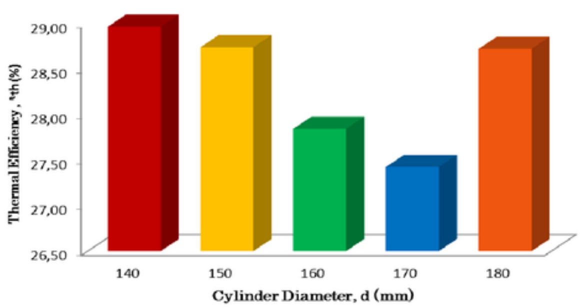

Fig 7. Thermal Efficiency of Cylinder Diameters

Figure 7 shows the influence of cylinder diameter to the thermal efficiency. It can be seen that the best thermal efficiency of 28.97% observed at 140 mm of cylinder. The smaller the diameter of the cylinder, the better the thermal efficiency produced due to the hot air chamber of the briquette is tighter and focused so the rate of heat transfer is more maximal.

4. Conclusion

- The best input power is shown in 140 mm cylinder diameter of 1.41 kW.
- The best output power is produced at 140 mm cylinder diameter of 0.41 kW.
- The optimum thermal efficiency of 28.97% was produced from a 140 mm cylinder diameter.

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