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ENERGY POTENTIAL OF FLUE GAS ALUMINUM SMELTING FURNACE SOLAR FUEL WITH THE ADDITION OF TEAK WOOD PELLETS

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Abstract: The choice of fuel (fuel oil) whose price is higher needs a solution, especially for conventional foundry entrepreneurs. We need alternative energy that is cheap and easy to get. Wood pellets are an attempt to replace fuel with cheap fuel. As with previous studies, the main objective of this study was to measure the energy potential of the smelting furnace flue gas. The analysis results show that 365,413.3 kJ of heat energy is wasted from the total point required for smelting. The flames sometimes coming out of the furnace flue gas channel indicate that some heat energy is smashed into the free air. The exhaust gas temperature is measured at 500-550ºC, and you can see flashes of fire coming out frequently. This indicates that there is energy potential for the working process of the pyrolysis reactor; apart from that, the moments of fire that often appear indicate an excess of the combustion process in the furnace. This study's results may differ from other smelting furnace constructions and conditions.

Keywords: BBM, Pellets_wood, Potential, Energy, Furnace

1. INTRODUCTION

The smelting process in the foundry industry, in this case, the aluminium casting industry, now requires a lot of energy. The large number of conventional industries that have smelting furnaces of poor quality will impact energy waste. Previous research found a case of energy wastage in traditional industrial stoves. The analysis results show that in the case studied; there is a heat energy of 332933.94 kJ which is wasted from the total point required for smelting. The choice of fuel (fuel oil) whose price is higher needs a solution, especially for conventional foundry entrepreneurs. We need alternative energy that is cheap and easy to get. Wood pellets are an attempt to replace fuel with cheap fuel. One of the materials that are easy to obtain is wood pellets from sawdust waste materials, one of which is teak sawdust. Many teak furniture entrepreneurs were found at the research location, precisely in the Gunungkidul area. In this case, teak wood sawdust is a raw material that is easy to obtain. In principle, wood pellets are an alternative to diesel fuel which can be applied to an aluminium smelting furnace.

The problem is that the calorific value of teak wood pellets is far below the calorific value of diesel fuel. Combustion uses diesel oil with a calorific value of 45,113 kJ/kg. At the same time, teak wood pellets, according to Siman (2018), with a size of 40-60 mesh with tapioca adhesive, have a calorific value of 18,478 kJ/kg. Therefore if it is applied to a melting furnace, it is more appropriate as an additional heater. Thus it is expected to reduce the use of diesel as the primary fuel. As with previous studies, the main objective of this study was to measure the energy potential of the smelting furnace flue gas. This potential is intended to determine whether the value of wasted energy can be applied to the concept of pyrolysis of plastic waste. Previous research shows that 332933.94

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kJ of heat energy is tired from the total energy required for smelting. While the temperature entering the reactor prototype was only measured at 200-250ºC, it did not reach the minimum pyrolysis temperature, which ranged from 400ºC and above.

The sample selection for this research location is still the same in the aluminium pan casting home industry in PSoftan Village, Gunungkidul Regency. Through this research, it is hoped to improve the quality of the furnace, minimize heat losses and utilize the energy in the flue gas properly. It is necessary to measure the impact of adding wood pellets on the efficiency of the fuel used. Some of the literature used in this research are; 1. Teak wood pellets, according to Siman et al. (2018), with a size of 40-60 mesh with tapioca adhesive having a calorific value of 4,399.64 calories/gram or 18,478 kJ/kg. 2. Pyrolysis is the popular recycling technique for processing plastic into liquid fuel. Pyrolysis is the chemical decomposition and thermal decomposition of molecules in conditions without oxygen (Sharobem, 2010). 3. Traditional casting techniques usually consider the quality of casting results essential and ignore energy saving or energy efficiency (X Dai et al., 2012). 4. Flue gas from aluminium furnaces is the most critical waste because it can be recovered with a high energy content (S.K. Das et al., 2008). 5. “It is also reported that somewhere between (20…50) % of industrial energy input is lost as waste heat in the form of hot exhaust gases, cooling water, and heat lost from hot equipment surfaces and heated products (*** BCS Incorporated, USA-2008).” 6. “The proposed heat recovery system can recover ≈680 kW from the available waste, representing more than 25% of the total thermal power of the burners and more than 60% of the exhaust waste (Pocola et al., 2016)”.

2. METHOD

This study aims to measure the potential of heat energy in a simple aluminium smelting furnace. Data was collected at an aluminium pan-cast factory with a furnace construction, as shown in Figure 1. In the previous study, diesel fuel was used, while teak wood pellets were added in this study. The pellet burner is equipped with a blower. However, research has yet to be carried out on the effect of air velocity. What is measured is the burning rate of the wood pellets (grams/minute).

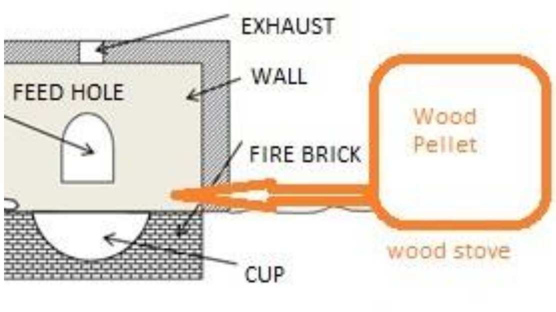

Fig. 1. Scheme of an aluminium smelting furnace (object of research) with the addition of a wood stove.

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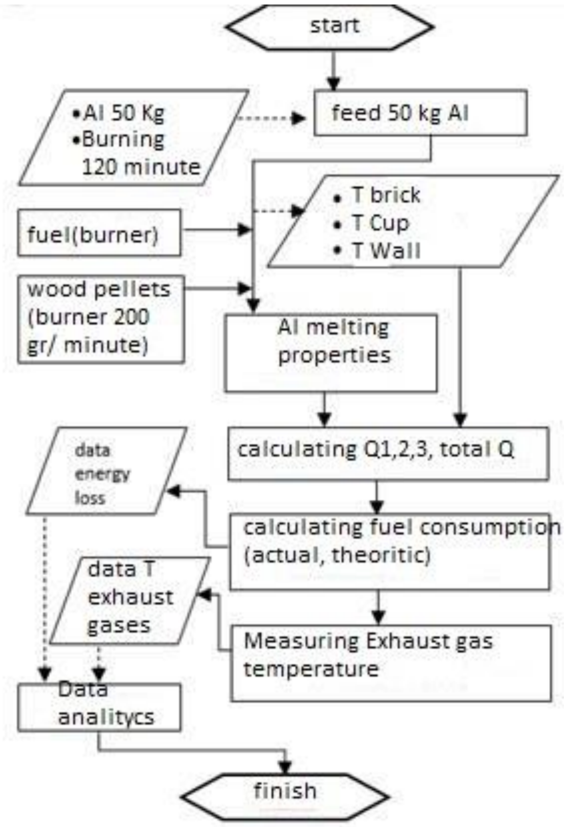

Fig. 2. Research Flowchart

The stages carried out as in the flowchart (Figure 2) are:

As much as 50 kg of aluminum raw material is burned with a diesel heater and wood pellets. In this experiment, wood pellets were fed to the stove at the rate of 200 grams/minute, while the amount of diesel fuel was calculated based on the amount at the end of the experiment. Temperature measurement at several points of the furnace component, including changes in temperature in the cup, refractory bricks as the support for the cup, and the walls of the furnace cover. Measurement for 120 minutes starts from the time the burner is turned on. Measurement of cup and refractory bricks using thermocouples and recording of temperature data on bricks, cups and walls which are recorded every 15 minutes. Some calculations are carried out in stages as follows:

Calculating the heat required in smelting aluminum (Q1). Calculated by the equation:

$$Q1 = \left(m_{al} \cdot C_{p1} \cdot \Delta T_1\right) + \left(m_{al} \cdot h\right) + \left(m_{al} \cdot C_{p2} \cdot \Delta T_2\right) \quad (1)$$

Calculating the heat absorbed by refractory bricks (Q2) with a specific heat of 0.84 kcal/kg°C. Calculated with the following equation:

$$m_b = \frac{1}{4} \cdot \pi \cdot \left(D_l^2 - D_d^2\right) \cdot t_b \cdot \rho \quad (2)$$

$$Q2 = \left(m_b \cdot C_{pb} \cdot \Delta T_b\right) \quad (3)$$

Calculating the heat absorbed in the cup (Q3) with a specific heat of 0.46 kcal/kg°C. Calculated with the following equation:

$$m_c = \frac{1}{4} \cdot \pi \cdot (D_l^2 - D_d^2) \cdot t_c \cdot \rho \quad (4)$$

$$Q3 = \left(m_c \cdot C_{pc} \cdot \Delta T_c\right) \quad (5)$$

With the calculation data that has been done, it is known that the total heating rate absorbed by the components at the time of casting is; Qtotal = Q1+Q2+Q3

The theoretical amount of fuel that should be used in the smelting process is;

$$m_{fuel} = \frac{Q_{total}}{calorific\ value} \quad (6)$$

Calculating the amount of pellet fuel and the resulting calorific value are as follows:

Number of pellets (kg) = feed x time

Total pellet calorific value (kJ/kg) = calorific value x Number of pellets.

Calculation of energy to heat used during the aluminum smelting process is carried out, to further calculate the theoretical fuel consumption. Comparing the actual amount of fuel consumption from the theoretical value, the aim is to find out the heat energy that is wasted beyond the need for smelting. Measure the temperature at the exhaust hole of the smelting furnace. The final stage is to analyze the energy potential in terms of heating value and furnace flue gas temperature for pyrolysis reactor recommendations.

3. RESULT AND DISCUSSIONS

Data on temperature distribution for comparison of diesel fuel with mix (diesel + teak wood pellets).

Table 1. Temperature distribution during smelting

FUEL >	**solar**	**mix**	**solar**	**mix**	**solar**	**mix**
Time (minute)	**Brick (^{0}C)**	**Brick-mix (^{0}C)**	**Cup (^{0}C)**	**Cup-mix (^{0}C)**	**Wall (^{0}C)**	**Wall-mix (^{0}C)**
0	29	29	28	28	29	29
15	60	60	180	190	41	54
30	80	95	260	285	55	68
45	140	155	345	370	87	100
60	210	225	495	562	103	116
75	301	326	558	625	120	133
90	332	357	680	747	160	173
105	401	426	730	797	200	213
120	410	435	760	827	202	215

The data listed in Table 1 shows a 120-minute measurement of smelting 50 kg of aluminium. Combustion using diesel oil with a calorific value of 45113 kJ/kg has been carried out in previous studies, so in Table 1, the combustion data is compared with mixed fuel (diesel + wood pellets). They were burning for 120 minutes with 35 litres of diesel previously obtained liquefaction results in the 90th minute. In this research, burning with two systems (diesel burner and pellet stove) melts aluminium in the 75th minute. However, the amount of diesel fuel is less than in previous studies. Therefore it is necessary to see the impact of adding wood pellets at the end of the calculation. Figure 3 shows a visualization of Table 1 in a line graph.

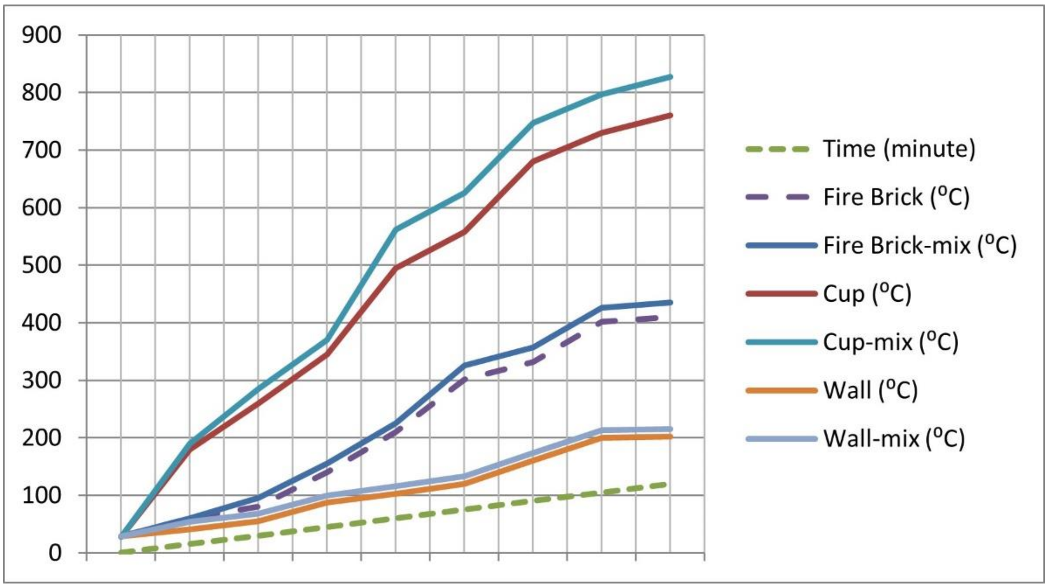

Fig.3. Graph of temperature rise distribution of the furnace section (120 minutes)

By observing the values in Figure 3, based on the assumption that the melting temperature of aluminum is at 680 ºC, ΔT1 and ΔT2 can be known as well as several parameter values that will be used for calculations, as shown in Table 2.

Table 2. Material parameter values

m (al)	Cp1 (al-solid)	Cp2 (al-liquid)	h(al)	ΔT1	ΔT2	Dl (bata)
50 kg	0,215 kkal/kg^{0}C	0,26 kkal/kg^{0}C	95 kkal/kg^{0}C	652 ^{0}C	**147 ^{0}C**	1 m
Dd(brick)	**t (brick)**	**ρ(brick)**	**Dl (cup)**	**Dd (cup)**	**t (cup)**	**ρ(cup)**
0,64 m	0,80 m	1600 kg/m³	0,64 m	0,60 m	0,30	7833 kg/m³

Figure 4 is the data for the entire process for 240 minutes, approaching the 100th minute until the end of a stable temperature trend. Under these conditions, it is generally possible to add a stock of raw aluminium material, which will melt immediately. Therefore, this study only collected data for up to 120 minutes with a total raw material of 50 kg.

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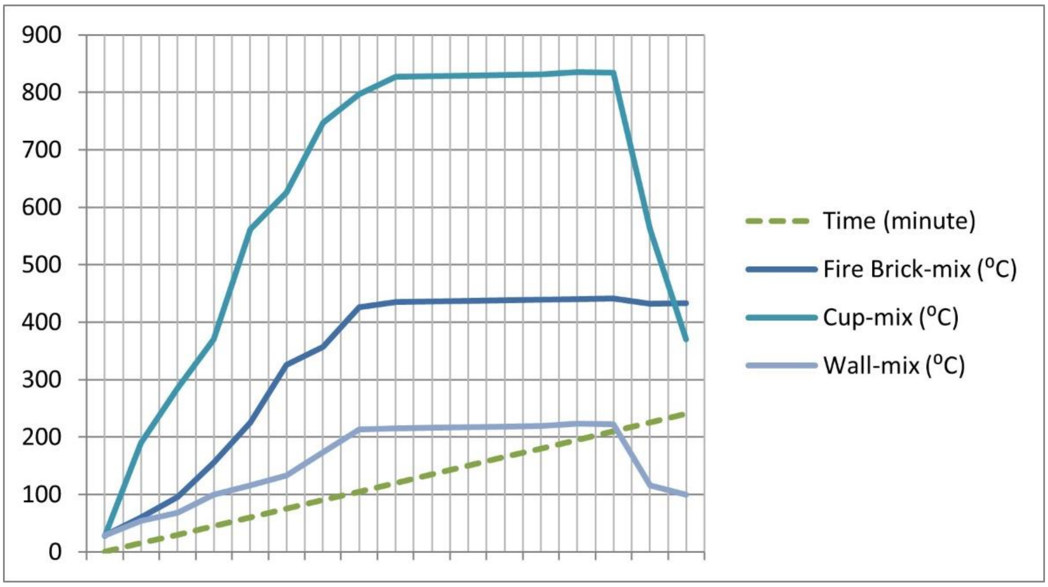

Fig. 4. Graph of distribution of temperature rise for 240 minutes.

Based on Table 2, the calculation of heat energy consumption is carried out in the following sections.
The heat is used in smelting 50 kg of aluminium for 120 minutes (Q1). Calculated by equation 1:
Q1 = (50*0.215*652)+(50*95)+(50*0.26*202)
Q1 = 14,385.00 kcal
Q1 = 22,788.20 kJ
The heat absorbed by the refractory bricks (Q2) has a specific heat of 0.84 kcal/kg°C. Calculated by equations 2 and 3:
.mb = 0.25*3.14*0.80*1600*(1^2-0.64^2)
.mb = 593.23 kg

Q2 = (593.23*0.84*406)
Q2 = 202,315.16 kcal
Q2 = 849,723.67 kJ
The heat absorbed in the cup (Q3) has a specific heat of 0.46 kcal/kg°C. Calculated by equations 4 and 5:
.mc = 0.25*3.14*0.3*7833*(0.64^2-0.6^2)
.mc = 91.50 kg

Q3 = (91.50*0.46*799)
Q3 = 33,629.91 kcal
Q3 = 141,245.62 kJ
With the calculation data that has been done, it is known that the total heating rate absorbed by the components at the time of casting is;
Qtotal = Q1+Q2+Q3
Qtotal = 1,013,757.49 kJ
The use of pellets is 200 grams x 120 minutes x calorific value. Obtained data;
Q pellets = 0.2 kg x 120 x 18.478 kJ/kg.
= 443,472.00 kJ/kg
The theoretical amount of diesel fuel (after deducting Q pellets) that should be used in the smelting process is as follows;

.mfuel = 570,285.49 kJ / 45113 kJ/kg
.mfuel = 12.65 kg

With a diesel density value of 0.83 kg/litre, the total theoretical fuel used is around 15.24 litres. In actual circumstances, the natural energy used is as much as 25 litres or 20.75 kg of fuel. The difference in the amount of raw power is 8.1 kg, equivalent to the calorific value of diesel fuel of 365,415.3 kJ. If the heat transfer to the wall is neglected, the combustion chamber has a potential heat energy of 365,413.3 kJ.

Simulation of temperature measurement on the exhaust channel.
In the temperature measurement process, a thermocouple is installed in a hole on the top side of the furnace. In this measurement, additional devices, such as prototype reactors, were not used because there was a large fire in the exhaust gas channel, as shown in Figure 5.

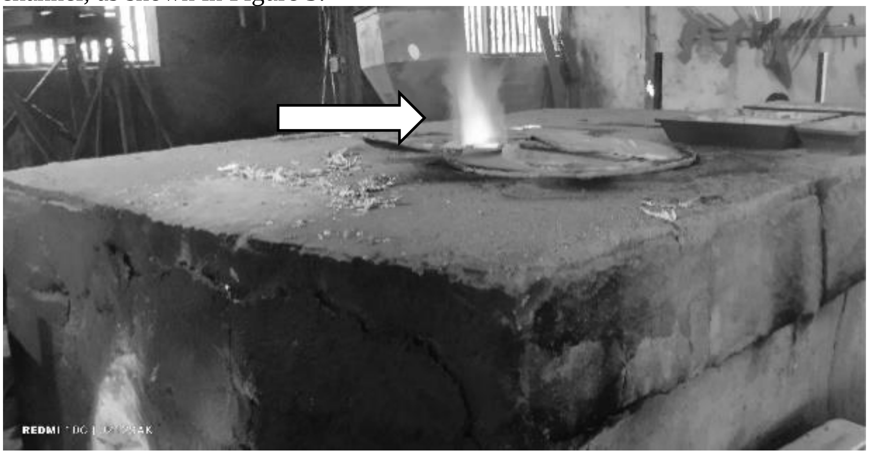

Fig. 5. Fire escaping from the furnace exhaust.

Based on these measurements, the temperature in the exhaust channel is known to be able to reach numbers above 450ºC. Based on Figure 6, it is known that in the 105th minute, the temperature got 550ºC, provided that the tip of the measuring instrument does not come into direct contact with the fire. Measurements are placed in the hole area where there is no spark with the aim of finding a location with a stable temperature.

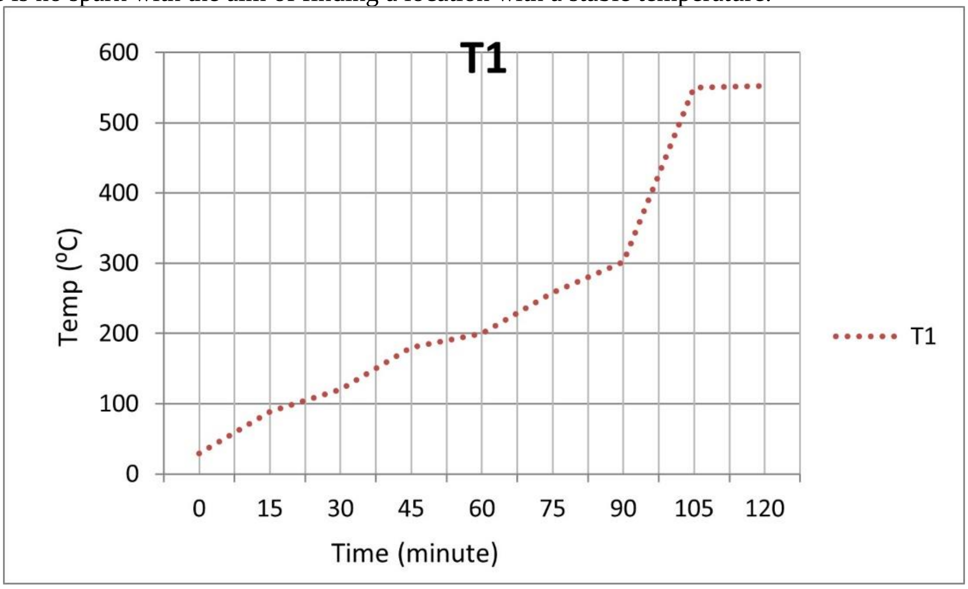

Fig. 5. Furnace exhaust gas temperature

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4. CONCLUSION

The analysis results show that in the case studied; there is a heat energy of 365,413.3 kJ which is wasted from the total point required for smelting. The flames sometimes coming out of the furnace flue gas channel indicate that some heat energy is smashed into the free air. The exhaust gas temperature is measured at 500-550ºC, and you can see flashes of fire coming out frequently. This indicates that there is energy potential for the working process of the pyrolysis reactor; apart from that, the moments of fire that often appear indicate an excess of the combustion process in the furnace.

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