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Construction and Performance analysis of Pit furnace by using Biodiesel

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Abstract

From the past years coal is used as major fuel source for melting nonferrous metal in many foundry industries which is hazardous. The coal should be replaced by environmental friendly or reduced pollutant fuels. Biodiesel is derived from non-edible oil seeds, contains calorific value is almost equal to 90% diesel. Biodiesel emits low carbon, sulfur emissions during its combustion. This research concentrates on utilization of biodiesel as a fuel in pit furnace to melt aluminum scrap. An attempt is made to study the performance of Karanja biodiesel on pit furnace. The developed furnace melts 20 kg of aluminum in 40 minutes and attains a maximum temperature of 1000^{0}C. The thermal efficiency of furnace is found to be 18.71%. Normal thermal efficiency of pit furnace lies between 4-19 %. The furnace is fitted with medium exhaust pipe for easy escape of combustion gases. The blower is used to supply air and to atomize the fuel into the furnace chamber. The top surface of furnace is closed to avoid conventional and radiation losses. An air gap is provided as insulation of furnace. This furnace can effectively be used in academic laboratories to melting of nonferrous metal.

Keywords: Aluminum, Biodiesel, Performance, Pit furnace, Thermal Efficiency

1. Introduction

In recent days the underground carbon resources are dwindling at faster rate. Rising world fuel prices, growing demand for energy and global warming are the main reason for implementation of advance technologies in foundry industries[1]. Nonferrous metal has been melted in crucibles for thousands of years. These crucibles are place in a furnace and heated by coal. As the charge melts and attains the required pouring temperature, crucible is brought out of furnace with help of tongs. Crucible furnaces are generally employed in melting nonferrous metal. They are pit furnace, pot furnace, oil fired furnace etc[2]. Average capacity of these furnaces lies between 30 to 150 kgs[3]. In India coal is the major source of fuel in melting nonferrous metals for large number of small scale foundry industries. Numerous attempts were made to reduce the consumption of coal by replacing it with oils and electrical sources in modern foundry technologies. The other reasons includes low melting rate, handling of ash, re-coking reduces a drop in temperature of melt and labile to contamination by smoke. At present days foundries looking for different oil sources for heating furnaces and heating by electrical source is quite expensive[4]. A. A. Olalere (2015) developed a crucible furnace fired by spent engine oil. This furnace melts 30 kg of Al-Si alloy in 20 minutes and consumes 7 litres of used engine oil. The flow rate of oil was found to be 5.833 x 10^{-6} m^3/sec. Thermal efficiency of furnace was 46.74% on its performance evaluation[4]. The furnaces fired by diesel reported thermal efficiency of 10.34% and 11.45%[5,6] and it was noticed that the low value in efficiency is because of heat loss due to open nature of furnace. In general crucible furnaces fired with petro oils, diesel, lubricating oils, kerosene and mixture of different oils results in good heating but also results in emission of high nitrogen oxides, carbon, and sulphur emissions. The cost, availability of petrol and its derivatives and also due to its non-renewable nature and

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environment hazards of these fuels has encouraged focus on bio-fuels as alternative fuels by many researchers[7].

Biodiesel is produced from non-edible seed oils and animal fats[8]. In past years its application can be found in boilers, diesel engines without major modifications but has noticed small reduction in its performance[7]. Biodiesel has about 90% energy content compare to diesel fuel. Hence alternative ways is needed to improve its effective utilization but there is limited use of biodiesel in burners for melting nonferrous metals. Hence utilizing biodiesel in pit furnace for melting of nonferrous metal is a value addition for the biodiesel. Thus this will enhance value for non-edible oil seeds and intern it helps in cultivation of non-edible seeds yielding trees. Maintenance of oil seed plants will lead to reduction of carbon foot print in the atmosphere.

The proposed work constructs a pit furnace and fabricates an oil burner. Melting of aluminum scrap that is collected in the college premises. Scrap may be tins, beverage cans, medicine bottle caps etc. Study on performance of biodiesel fired pit furnace is made.

2. Materials and Methods

The pit furnace is constructed by using locally available materials. The development is based on the engineering material properties such as weldability, toughness, thermal conductivity high temperature resistance. Since aluminum melting point is around 660°C so that the crucible should be have a higher temperature to melt aluminum. Hence cast iron crucible is selected. Mild steel plate of thickness 2 mm, galvanized iron pipes were selected for construction of burner.

2.1 Construction of Pit Furnace

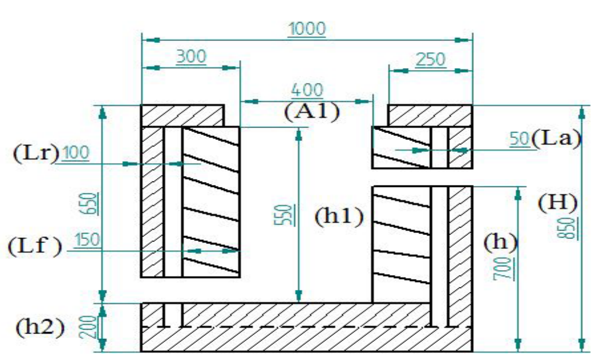

Figure 1. Pit furnace.
Note: Dimensions are in mm.

The pit furnace constructed was bale out type lies above the ground level. Figure 1 shows the design specifications of pit furnace. Locally soured clay and fire bricks are used for its construction. The major materials used for the development of the furnace were: 2 mm mild steel plate, fire bricks, 20 mm iron rods, 5 mm angle iron bar. The furnace has overall dimensions of 1000*1000*850 mm (L*B*H) and constructed in square shape. It has a combustion chamber of 400*400 mm. The lining of the developed crucible furnace was carried out using an aggregate mixing of lime stone power, clay, betonite and water. The lining materials was made up of refractory bricks materials embedded in the refractory paste to form a thickness of 150 mm left behind a diameter of 400 mm as the combustion chamber. Furnace cove is fabricated by mild steel plate of 2 mm thick and has a dimension of 400 mm*400 mm. A 310 mm diameter hole is cut exactly at the centre of sheet and fixed it to the furnace chamber it allows the crucible in to the furnace chamber.

Figure 2. Pit furnace provided with air gap.

Figure 3. Pit furnace assembled with burner unit.

The chimney was rightly positions at the right side of furnace at a height of 700 mm. 50 mm air gap is provided between the fire brick and the red brick shown in Figure 2. It acts as insulation to the furnace[9]. The burner is developed by fabricating parts such as nozzle, adapter and cap, GI pipes and assembled all together. Blower is used for primary atomization of fuel. The burner head is attached to blower perpendicularly shown in Figure 3. This forms the burner unit. It is positioned perpendicular to the left side of the furnace. Burner is fabricated from galvanized iron pipe of diameter 40 mm and length 600 mm. The nozzle is fitted to steel pipe of length 600 mm and it is made out of brass. The out let diameter of nozzle is 2.4 mm.

Table 1-1. Specification of pit furnace

Sl. No.	Parameter	Symbol	Dimensions
1	Total height of the furnace from ground level	H	850mm
2	Height of exhaust pipe from ground level	h	700mm
3	Height of combustion chamber	h_1	550mm
4	Surface area of combustion chamber	A_1	400 x 400mm
5	Height of burner inlet from ground level	h_2	200mm
6	Thickness of fire brick	L_f	150mm
7	Thickness of red brick	L_r	100mm
8	Thickness of air gap	L_a	50mm

Table 1.1 shows the detailed dimensions of pit furnace. The combustible volume of furnace after laying bricks was (Lx B x h1) = 400 x 400 x 550 mm = 0.088 m^3.

3. Experimentation

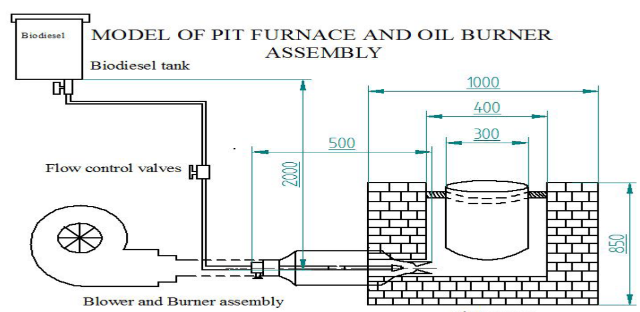

Figure 4. Model of pit furnace and oil burner assembly.
Note: Dimensions are in mm.

Figure 4 shows the experimental setup of biodiesel fired pit furnace. It consists of crucible, blower, burner head and biodiesel tank. The experiment is carried to melt scrap of aluminum weighing 20 kg. Initially scrap of tins, cans, bottle caps that are collected is charged into crucible made up of cast iron. K type thermocouple is incorporated to measure the flue gas temperature, stock temperature and combustion chamber temperature. Digital thermocouple is used to measure the surface temperature (T_a) of the furnace. Tank is charged with 10 litres of biodiesel. Initially furnace chamber is ignited by small quantity of coal and wood pieces; time is noted till the pre heating of combustion chamber. Air is blown into the furnace at the inlet provided simultaneously inlet valve of biodiesel is opened slightly, biodiesel feed into the furnace through nozzle and primary atomization fuel takes place cone like arrangement provided at out let of the burner. Blower and burner inlets are provided with control valves to regulate air furl flow.

3.1 Melting Operation

Figure 5. Initial charging of furnace with scrap.

Figure 6. Melting of aluminum scrap.

The following figures show the melting operation of pit furnace. Figure 5 shows aluminum scrap charged in the crucible, it is pre heated by igniting small amount of coal in the furnace chamber. The continuous heating process is carried out by allowing biodiesel into the furnace chamber. Slowly the aluminum scrap started to melt as shown in Figure 6, the stock is raised to its pouring temperature. Then it is poured to a metal mould box as shown in Figure 7 and the casted metal is removed from mould shown in Figure 8. The duration of melting process noted and tabulated by stopwatch. The operation completes within 40 minutes with biodiesel consumption of 5 litres. The developed furnace attains a maximum temperature of 1000°C. The thermal efficiency attains by the furnace is calculated based on this experimental results and standard values.

Figure 7. Pouring of molten metal to mould.

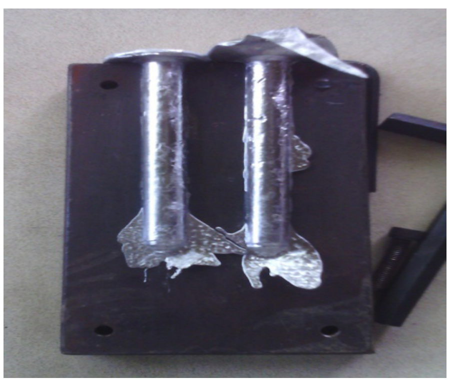

Figure 8. Casted metal part.

4. Results and Discussion

The efficiency of the furnace can be calculated by direct method considering the amount of heat required to melt the scrap to the amount of fuel energy supplied to melt the scrap. Furnace's efficiency increases when the percentage of heat that is transferred to the stock or load inside the furnace increases. It is also determined by measuring the amount heat absorbed by the stock and dividing this by the total amount of fuel consumed. Theoretically it is given by[5].

$$\eta_{The} = \frac{\text{Total heat required to melt the stock } (Q_s) \times 100}{\text{Total heat supplied by the fuel } (Q_f)} \quad (1.1)$$

Where;

η_{The} = Thermal efficiency of furnace (%).

Q_s is the total amount of heat required to melt the stock (KJ).

Q_f is the amount of heat supplied by the fuel to melt the stock (KJ).

The total heat required melt the stock Q_s is given by:

$$Q_s = M*C_p*(\Delta T) \quad 1.2$$

Where;

M is mass of metal (kg).

C_p is specific heat capacity of Aluminum (KJ/Kg K).

ΔT is temperature difference ($T_a - T_f$) (°C).

T_a is ambient temperature (°C).

T_f is maximum furnace temperature (°C).

The total heat supplied by the fuel is given by Q_f [5]

$$Q_f = L_f*S_g*T_t*C_v \quad 1.3$$

Where;

Q_f = Amount of heat supplied by the fuel (KJ).

L_f = Quantity of fuel consumed (liters).

S_g = Specific gravity of fuel.

T_t = Time taken to melt the stock (hr).

C_v = Calorific value of fuel (KJ/Kg K).

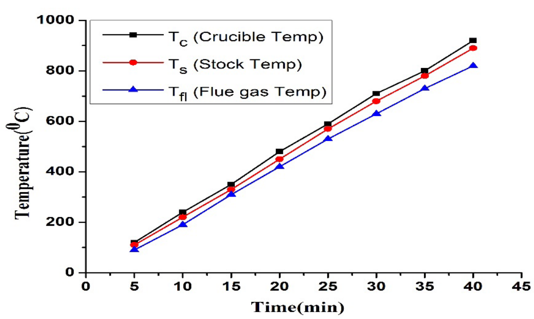

Figure 9. Aluminum melting time vs. temperature.

Figure 9 shows aluminum melting time vs. temperature, during the melting process it was noticed that with respect to that time, the stock temperature and flue gases temperature increases. The time taken to melt aluminum is 40 minutes (T_t) and ambient temperature was 28°C, flue gas temperature was 820°C. The performance of furnace is analysed by the experimental results gotten and from the ASTM standards, Karanja biodiesel have the calorific value of 36000 KJ/Kg and specific gravity is 0.885. The specific heat capacity of aluminium scrap is 0.920 KJ/Kg K[10].

From the Equation 1.2 the heat required to melt the aluminium is Q_s = 20*0.920*(1000-28) = 17884.8 KJ.

From the Equation 1.3 the heat supplied by the fuel, heat input Q_f = 5*0.6*0.885*36000 = 95580 KJ.

From the Equation 1.1 the thermal efficiency of furnace is $\eta_{The} = Q_s/Q_f$ = 17884.8/95580 = 18.71 %.

5. Conclusion

The developed furnace has η_{The} of 18.71%. Normally pit furnace efficiency lies between 4%-19%. After the complete experimentation it can be concluded that the furnace may be effectively used for melting non-ferrous metal. It enhances the technical skills of the students by using as an academic laboratory experiment to produce the aluminum castings. Moreover, this research work is a value addition for bio-diesel. It also encourages the farmers to cultivate the much more amount of non-edible oil seed yielding plants that may balance carbon foot print in atmosphere.

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