DEVELOPMENT OF A CRUCIBLE FURNACE FIRED WITH LIQUEFIED PETROLEUM GAS - BUTANE GAS

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ABSTRACT

This research work focuses on the development of a crucible furnace that runs on liquefied petroleum gas (LPG) LPG-butane gas. The refractory material (aluminosilicate) used for the construction of the furnace wall was harvested from Ilaro, Ogun State, Clay deposit. Other materials used not limited to crucible pot, 6 mm mild steel angle iron, household gas cylinder, 60 mm rubber hose, and mild steel with a thickness of 5 mm were sourced from a local market in Lagos. The performance evaluation of the constructed crucible furnace was ascertained by charging aluminium scrap and other ferrous metal into it with complete melting occurring at a furnace temperature of 750°C

Keywords: crucible furnace, refractory material, non-ferrous, melt, LPG-butane

1.0 INTRODUCTION

The crucible furnace is among the oldest and most fundamental kinds of melting devices used in foundries. In this furnace, the metal charge is stored in a refractory crucible pot. The charge receives heat from the crucible through its walls. The heat sources normally used ranges from heating fuels, coke, gas, electricity, and oil. When it is necessary to produce low melting point alloys in small batches, crucible furnaces are frequently utilized. The capital outlay of these furnaces makes them attractive to small non-ferrous foundries. A range of furnace types, such as crucible, induction, electrical resistance, and reverberatory furnaces, are used to melt aluminum (Chukwudi & Ogunedo, 2017). Crucible furnaces are commonly characterized according to their manner of removal which are the bale-out furnace, tilting furnace, lift-out furnace (Musa, 2012).

A crucible is a pot used to store metals before they are melted in a furnace. Furnace crucibles are made to withstand the greatest temperatures found in metal casting operations. Fundamentally, the materials used to construct the crucible should have a melting point that is far higher than the materials that will be melted. It should remain strong even in very hot conditions. The components of crucible furnaces include silicon carbide, clay graphite, and metal structures (Okey, 2017). These materials can resist extreme temperatures in typical foundry operations.

Nigeria foundry practice

Foundry technology are used by Nigerians in both rural and urban areas. The man who works as a foundry in the area makes a hole in the ground that looks like an oven and uses charcoal or coal as fuel. The crucible is then made of clay or a metal container. Fan (blower) is used to generate the air needed for combustion in the chamber.

The crucible furnace is used by the local foundry professionals to cast a variety metal items, including frying pans, serving spoons, machine parts, and pots and pans of various sizes for the home.

Challenges facing foundry practice in Nigeria

According to Ighodalo et al. (2011), foundry practices faces difficulties when using the local type of crucible furnace due to high fuel consumption, high operator heat radiation, labor-intensive operation, and high heat loss in the system. An effort has been made to enhance the traditional melting technique used by foundry men in Nigeria, taking into account the accessibility of materials, the great demand for their products, the need to lower production costs, and the attraction of young people to the field of foundry work.

Komolafe (1992) made improvements to the labor-intensive melting process used by foundry workers by creating a gas-fired furnace that used locally sourced materials. From the assertion of Kulla (2004) due to ineffective burning and inadequate heat transfer, fuel wood that would have been sufficient for 10–33 years is consumed annually. For these and other reasons, he studied ways to cut down on the amount of wood used for cooking at home. Due of this, the efficiency of the crucible furnaces used in the surrounding foundries must be increased, resulting in reduction of the quantity of charcoal consumed. Another significant problem is the emission of combustion pollutants, which can lead to respiratory ailments (Kulla, 2004) cited by (Okey, 2017). As a result of the emission of gases which leads to air pollution, gas fired crucible is preferred. Gas is readily available and can be stored.

The earliest type of foundry technology that has been in use and has changed over time is the crucible furnace. There are regional variances and the designs correspond to the intended application. According to (Eman, 2013), the oldest known crucibles date back to the fifth or sixth millennium B.C.

Aluminium foil, beverage cans, doors, engine and body parts for automobiles, and pistons are the main products of aluminum smelting and refining. Additionally, it can be utilized as door frames, windows, aircraft components, rods, bars, and wires, as well as sheet metal and aluminum plate (Chukwudi & Ogunedo, 2017). Aluminum is completely recyclable and doesn't lose any of its qualities or attributes when being recycled. Recycling aluminum requires less energy than extracting and refining its ingots (Herbert, 2001).

Every day, more and more aluminum scraps are produced, posing a significant environmental threat. It is imperative that aluminum waste be recycled and used as raw materials to create new goods. This cannot be stressed enough. It is against this basis that the development of a crucible furnace fired with LPG butane gas emanate.

2.0 MATERIALS AND METHODOLOGY

Materials

The materials utilized in this research were sourced from the local marketplaces in Lagos and Ilaro Clay deposit. Mild steel of 6mm thickness, rubber pipe of 60mm diameter, 10kg gas cylinder, industrial burner, angle iron, refractory material, and crucible pot where purchased in Lagos. The refractory material used was particularly harvested from Ilaro, Ogun State, Clay deposit.

Equipment

The equipment used in this project work includes: measuring tape, grinding machine, Hacksaw, and electrical arc welding machine Denver d12.

Methodology

The following methods were adopted for this project work:

Engineering design of the Furnace

An industrial gas burner, gas cylinder, high-pressurized standard regulator, hose, nozzle, and crucible furnace unit make up the main configuration and profile of the furnace. The furnace is made up of a burner that burns the gas, a crucible lid, and a pot into which the charge to be melted is introduced.

Design Consideration:

During the design process, considerations were given to the cost of production, the type and availability of fuel (domestic gas), the availability of materials, their selection, flexibility in fabrication, ease of maintenance, durability, cost of the chosen materials, availability of tools and equipment for fabrication, height and width of the furnace, and the shape of the furnace.

Crucible and Furnace specification

The furnace with it cover is 520 mm high, the furnace lining form an inner diameter of 250 mm. Because of its portability and small size, the furnace may be easily transported from one location to another. The five parts of the intended crucible furnace assembly are as follows: crucible pot, gas cylinder, furnace body, refractory material (lining), burner and its hose.

Design Calculations

i. Calculations of Furnace Height

The internal height of the furnace = height of crucible + height of refractory bricks coupled with lining

Therefore, = 400 + 410 = 810 mm

External height = internal height of the furnace + thickness of the baselining

Therefore, external height = 810 + 80 = 890 mm.

ii. Area of the furnace

The area of the furnace = l × b

Hence, area = 441 × 368 = 162, 288 mm

iii. Calculating weight of the crucible

Since the crucible to be used is 5kg

Hence, its weight = 5 × 9.81 = 49.05N

iv. Calculating of weight of the molten Metal

Let the mass of charged materials equal the mass of the molten metal let's say = 6kg

Therefore, its weight = 58.56N

Fabrication of Furnace

A 6 mm mild steel was cut into dimensions using a cutting machine. It was put together by welding with an electric arc machine to create a 441 mm by 368 mm rectangular shape that acts as the rectangle's body. A burner seat of dimension 268 mm × 268 mm was constructed in the furnace to fit into the burner which is of diameter 172 mm. A reinforcement bar of diameter 12mm and 220 mm long was welded across the sections of the square-shaped burner seat to carry the weight of the crucible during melting operation. Additionally, a 400 mm by 400 mm cylindrical crucible lid made of mild steel plate was constructed, with a 120 mm hole to act as an exhaust for fumes and gasses. To facilitate the removal of the crucible cover from the furnace body when feeding charges into the furnace and removing the crucible pot from the furnace, handles were affixed to the cover.

Refractory Lining

The raw refractory material (alumino silicate) was crushed into a uniform size about 26 mm, which was further grinded into the size of 200 mm mesh, then the undesirable materials were removed from the refractory materials through hand screening. The materials was tampered with water and binder was added which enhances the plasticity of the refractory material. Thereafter, it was pounded or rammed into the joint of the lined refractory blocks of the furnace, forming a joint-less lining, then dried and heated to obtain high strength, high density and chemical resistant. The constructed lined crusible furnace is as shown in figure 1

Plate 1: Fabricated Crusible Furnace

3.0 RESULTS AND DISCUSSION

The performance of the constructed furnace was verified by melting of 7kg of non-ferrous metal (aluminuium sheet) which was utilized to produce spoon and pot via the processes above. A pattern of a spoon and pot was created using the clay floor moulding process and left to dry for 24 hours. The furnace was started and the crucible was placed in it and left to preheat for 5 minutes. About 7kg of aluminium sheet was charged into the crucible and the furnace was covered, the aluminium scrap turned liquid after 50 minutes into the commencement of the heating at a temperature of 750ºC. A tong was used to deliver the crucible containing the liquefied metal from the furnace, after which it was charged into the pattern mold and left to harden.

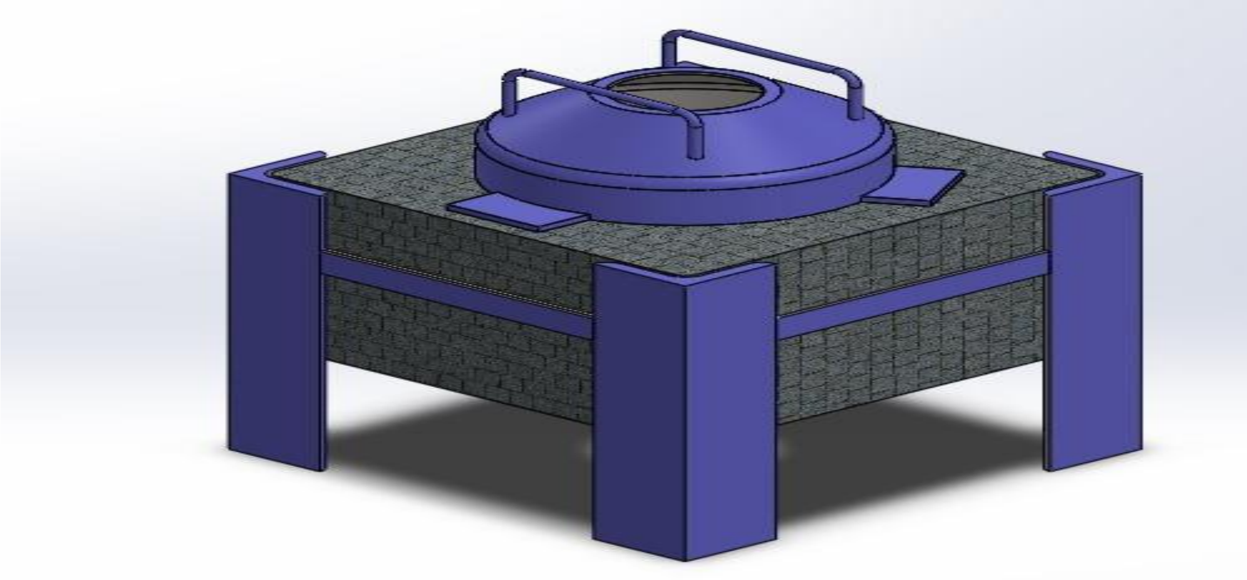

Plate 2: Assembly view of fabricated Crucible Furnace

4.0 CONCLUSION

A crucible furnace fired with LPG-butane gas was designed and constructed. Its performance evaluation was confirmed by melting aluminum scrap, utilized to cast some test specimen. Other research objectives, which include fuel efficiency, reducing health hazards, and operating time, were met based on the furnace's performance test findings. Heat was transferred to the aluminum scrap with little loss due to the high heat conductivity of the furnace. The configuration of the furnace allows for the easy pouring out of molten metal without spilling out. Further research work is advised to ease the operation of the system. An awareness campaign should be undertaken to encourage the use of the crucible furnace.

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