

## Fabrication and performance evaluation of oil –fired crucible furnace using locally sourced materials

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### Abstract

The technological advancement of any nation have been influenced and uplifted by the extent to which it can usefully harness and convert its mineral resources. The production of metal in foundries and in all human lives have become a general practice. This paper deals with the design, fabrication and performance evaluation of an oil-fired crucible furnace using locally sourced materials. The components of oil fired crucible furnace were furnace casing, crucible, furnace cover, burner housing, furnace cover stand, base stand and burner. Design drawings were produced and mild steel sheet was used for the fabrication of the furnace, while the other components needed for the design were selected based on functionality, durability, cost and local availability. Experimental tests were performed to evaluate the performance of the furnace. The results showed that the furnace has a heating rate of 43.9°C/min and attained a temperature as high as 1386 °C. The furnace also had a melting rate of 333.3g/min for Aluminum and 115.8 g/min for Copper. The efficiency of the furnace was determined to be 10.34%. The low value was as result of the large energy wastage due to the open nature of the furnace.

**Keywords** - Crucible furnace ,fabrication , heating rate , melting rate ,oil fired, , performance evaluation.

### I. INTRODUCTION

For a nation to advance technologically, it must be able harness, convert its mineral resources and fabricate most of its equipments and machines locally. In the production of mineral resources the melting of metals has become one of the tremendous industrial practices in the forefront. This is because metals are versatile elements whose field of application are very wide in human lives [1]. The melting and heat treatment of metal in foundries is very importance in manufacturing process [2,3]. One of the most widely used furnace is the oil fired crucible furnace. The oil fired crucible furnace uses the combustion of diesel as a fire source to heat the crucible and melt the solid metal inside it. Some of the advantages of oil fired crucible furnace are low investment costs, easy operation and maintenance ability, capable of melting small batches of various alloys, the melt can be treated directly in the crucible and the alloy can be quickly and easily replaced as necessary [4].

Oyawale and Olawale, [5] designed and constructed a Mini-Electric Arc Furnace to melt 5kg of steel/cast iron scraps, using locally produced Soderberg electrodes. Tests carried out on the furnace showed that it required 60 minutes to heat up the furnace to the melting temperature of cast iron (1150C – 1400C). Furthermore, it took about 95 minutes to melt the first charge of 2kg resulting in a melting rate of 21.05g/minute. Alaneme and Olanrewaju, [6] designed and fabricated a diesel fired heat-treatment furnace using locally sourced

materials which was aimed at eliminating the use of heating elements requiring electric power which is poorly supplied in the country. The performance of the furnace was observed to have a fast heating rate of 61.24°C/min to attain a pre-set temperature of 900°C and a fuel consumption rate less than 1.41litres/hr. Ramazan, [7] designed and constructed an electrical furnace with an automatic control to fire ceramic products. Eman, [8] manufactured a gas furnace using locally sourced materials which had a heating rate of 25°C/min and attained temperature in the burning zone as high as 1000 C° in the burning chamber and 700 C° in the inner pot, while Bala, [1] carried out the design analysis of an electric Induction furnace for melting of aluminium scrap.

As important as oil fired crucible furnaces to the the foundry and manufacturing process, its availability seem to be limited in Nigeria and when available most of them are imported and this is costing the country huge sum of foreign exchange. The aim of study therefore was to carryout the design, fabrication and performance evaluation of oil fired crucible furnace using locally sourced materials.

### II. Methodology

#### 2.1. Materials

The materials utilized for the design of the oil fired furnace were 4mm thick mild steel, stainless steel rod, fire brick, castable refractory (Durax) and sodium silicate.

## 2.2. Components of the furnace

The oil fired crucible furnace consists of the following components: furnace casing, crucible, furnace cover, burner housing, furnace cover stand, base stand and burner.

## 2.3. Component Design

### 2.3.1. Furnace casing

The mild steel sheet was selected for the fabrication of the furnace casing because of its relative light weight, good strength, excellent formability, weldability, availability and low purchase cost. The furnace casing houses all the components of the furnace including: fire bricks and lining, the burner and the crucible.

### 2.3.2. The Crucible

The crucible is a cylindrical shaped container placed in the inner cavity (heating chamber) of the furnace. Its function is to accommodate the charge to be melted in the heating chamber of the furnace. The design is made to ensure that the charge to be melted is not in direct contact with the combustion gases but to serve as a medium to conduct heat generated from the combustion chamber which is transferred by convection to the charge. For this reason, the pot is made from chromium based steel which has high heat resistance, high strength and good thermal conductivity since it is exposed to direct heating. The pot has the following dimensions 10mm thickness, 140mm diameter and 200mm height

### 2.3.3. Furnace cover

The cover was made from the 4mm thick steel it was rolled into a cylinder of 485mm diameter, 65mm height with a hole of 175mm which serves as the exhaust.

## 2.4. Design considerations

The following design considerations were made while designing the furnace:

### 2.4.1. Emergency spout

This is a circular opening designed at the base just above the base thickness. It is to allow for molten metal to flow out of the system if the crucible eventually fails (breaks). This was designed with a diameter of 70mm and is centrally located 150mm from the base.

### 2.4.2. High attainable temperature (combustible rate)

During the design of the furnace, a stainless steel pipe of diameter 55mm was used for the oil pipe to enable the introduction of large volume of air from the blower to the oil from the oil-pipe for a higher

air-fuel ratio that enters the furnace which will lead to an improved combustion rate.

## 2.5. Fabrication Procedure

### 2.5.1. Furnace Casing and Burner Housing

#### 2.5.1.1. Marking Out and Cutting

This is the first fabrication stage which involved the marking out and cutting out of the required dimension of 3770mm by 620mm from the mild steel for the furnace casing. The burner housing was also marked out and cut from steel metal plate to produce two flat plates of dimension 240mm by 230mm and 230mm by 230mm and a hole of diameter 51mm was marked out and cut on the 240mm by 230mm plate. The furnace base was also cut from the steel plate to produce a circular sheet plate of diameter 600mm.

#### 2.5.1.2. Rolling and welding Process

This process was used to produce the casing of the furnace by rolling the cut sheet metal in rolling mill to produce a cylindrical housing for the furnace frame of diameter 600mm and height 620mm. The rolled sheet metal was then welded to the required shape and the burner part is also welded to the furnace casing. Stainless steel of diameter 50mm was cut to a length of 305mm and was aligned with the burner housing hole. This was welded together to form the burner housing completely.

#### 2.5.1.3. Refractory lining

The refractory lining for the furnace was made by mixing Refractory cement (Durax) was mixed with sodium silicate  $\text{Na}_2(\text{SiO}_2)$  in the proportion of 1 Litre of  $\text{Na}_2(\text{SiO}_2)$  to a bag of Durax of weight 25kg. The thoroughly blended mixture was used in lining the furnace which involves three stages:

#### 2.5.1.4. Flooring.

This was done by first making the surface of the base of the furnace wet with a mixture of water and sodium silicate before pouring a very thin layer (2mm thick) of the refractory mixture before arranging fire bricks into the base of the furnace. The mixture of the Castable refractory and sodium silicate then poured on it and allowed to set.

#### 2.5.1.5. Setting of bricks

The wall was also damped with sodium silicate before the surface is plastered with the mixture of the refractory cement and sodium silicate to form a layer of 10mm thickness before the 60mm thick bricks was glued to the first layer while it is still wet before a final layer (26mm thick layer of the refractory and sodium silicate) is used to cover the bricks and the final thickness of the wall is 100mm leaving us with the furnace internal diameter of

400mm. A total number of 40 bricks were used to produce the wall.

#### **2.5.1.6. Drying.**

The furnace body is then allowed to dry for 28 days and any crack was duly observed and repaired as it dried.

#### **2.5.2. Furnace cover and stand**

The fabrication of the cover was based on the internal diameter of the furnace and a cover of diameter of 485mm and height of 60mm was made from steel rim using purely the same mixture of Durax and sodium silicate with a hole in the rim which serves as the exhaust. The furnace cover support was fabricated from steel plate cut out to a

dimension of 560mm by 30mm and another of 460mm by 30mm which was inclined at an angle of  $37^{\circ}$  to form the support.

#### **2.5.3 Assembly**

The parts assembled include: The casing, cover, the crucible stand, crucible, the cover stand and the burner. The cover stand which has a support for the cover and serves as a holder for the cover is first welded to the body of the furnace body before the cover is carefully placed in an anchor and it is held in place using a pin. Then the burner is placed in the 50mm hole drilled in the burner housing at an angle  $45^{\circ}$  on the horizontal plane. The assembled oil fired crucible furnace and its drawings are shown in Fig. 1 and 2 respectively.



Fig 1: The produced oil fired crucible furnace

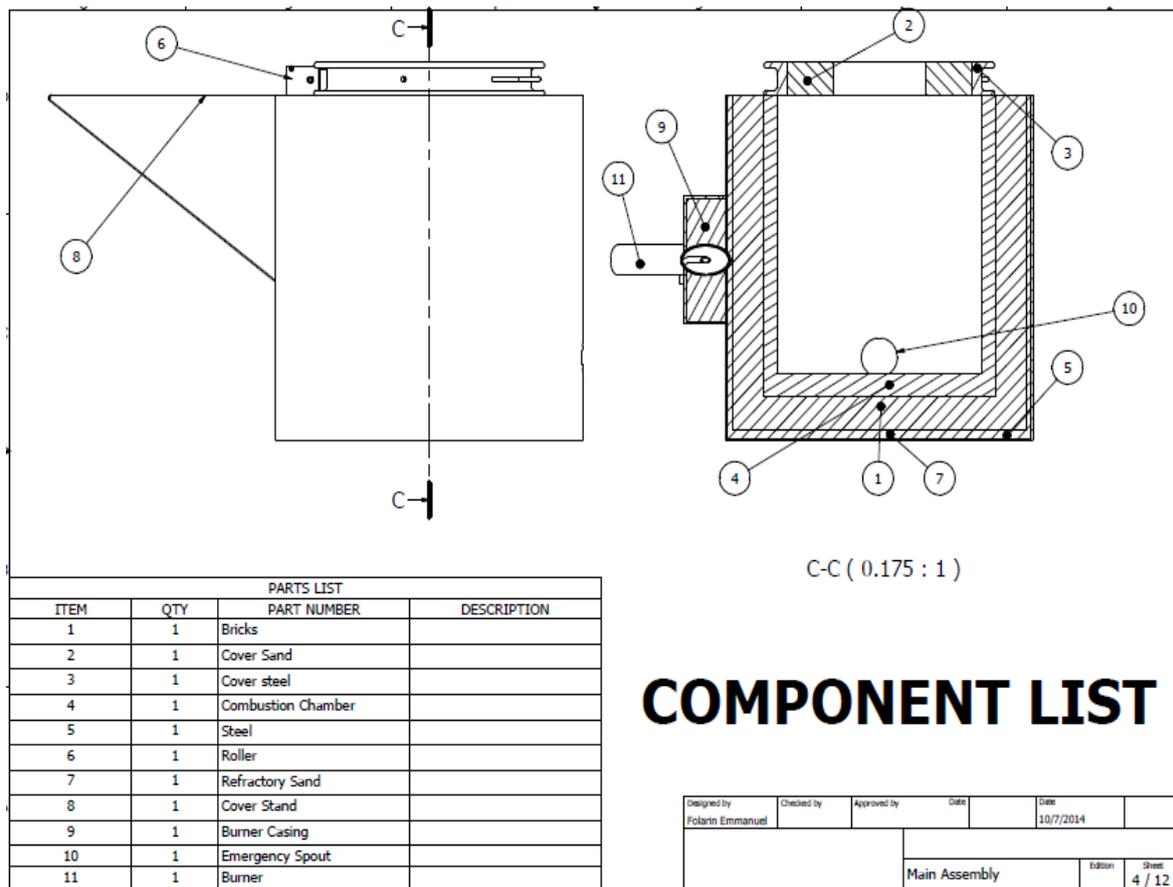


Fig 2: Drawing of the Furnace

### 111. Performance evaluation

#### 3.1. Test procedure.

An electric blower was connected to the oil pipe of the furnace and properly sealed to avoid leakage of air. The necessary diesel for firing the furnace was placed in the fuel container and the blower which supplies air is powered. Scrap metals of Aluminum and copper of mass 5Kg and 3Kg respectively were charged into two separate crucibles placed carefully side by side into the combustion chamber. The furnace was ignited and was covered. The oil valve was gradually opened to enable fuel flow into the flame that was already created inside the furnace and the blower was powered and valve was adjusted until the desired air-fuel ratio was obtained that gave complete combustion. A thermocouple was used to obtain the temperature in the combustion chamber of the furnace through the opening on the cover of the furnace. The temperature in the combustion chamber was recorded at a time interval of 3 minutes .The result is shown in Table 1. The furnace was observed to have an average heating rate of 43.9<sup>0</sup>C/min and attained a temperature as high as 1386 °C (Table 1). The melting time for Aluminum was 15 minutes while the one for Copper was 26 minutes. Melting rate was determined with equation (1) [9]:

$$Melting\ Rate = \frac{Total\ mass\ of\ charge\ (grammes)}{Total\ time\ taken\ to\ melt\ charge\ (mins)} \dots\dots\dots (1)$$

Melting rate for aluminium was determined as 333.3g/min while that for copper 115.38g/min.[10]. The furnace melting rate of 333.33g/min for aluminium and 115.38g/min for copper was relatively high compared to a mini-electric arc furnace of melting rate of 21.05g/mins for steel/cast iron scraps obtained by Oyawale and Olawale [5].The difference may have be due to the fact the density of steel/cast iron is higher than that of aluminium [3 ].

Table 1: Furnace temperature – time results

Time (min.)	Temp. attained (°C)	Heating rate (°C/min)
3	126	42.00
6	270	45.00
9	401	44.56
12	520	43.33
15	660	44.00
18	780	43.33
21	913	43.48
24	1076	44.83
27	1245	46.11
30	1328	44.27
33	1386	42.00
	<b>Average</b>	<b>43.90</b>

### 3.2. Efficiency of the furnace.

Efficiency ( $\eta$ ) of the furnace was determined using equation ( 2) [9,11]:

$$\eta = \frac{\text{heat required to melt aluminum}}{\text{heat used to melt aluminum}} \dots\dots\dots (2)$$

An efficiency of 10.34% was obtained for the furnace [10] and this was found to compare favourably with 11.5% obtained by Ighodalo *et al*, [11] for Local Charcoal-Fired Furnace for Recycling Aluminum .The low efficiency obtained was as a result of large energy wastage due to the open nature of the furnace.

### IV. Conclusion

An oil fired crucible furnace using diesel as its fuel has been designed and fabricated using a locally sourced materials .It was found to have a working efficiency of 10.34% which was relatively low as a result of the considerable energy loss due to the opening at the top which has been a characteristic for most gas and oil fired furnaces.The furnace was also observed to have good melting rate and a fast heating rate of 43.9°C/min and attained a temperature as high as 1386 °C.. This implies that most metals including cast iron can be melted and heat treated using this furnace.The furnace can therefore be used for small scale foundry workshop, hence providing employment opportunities in the Nigeria.The local production of this furnace will help save the country of huge foreign exchange used for its importation.

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