

CONSTRUCTION AND TESTING OF AN OPEN-PIT CHARCOAL FURNACE FOR MELTING NON-FEROUS METALS

¹Aghete Ewomazino Goodluck and ²Engr. Adidi O. David

Email: operationalresearch138@gmail.com

¹Department of Mechanical Engineering, ²Department of Welding and Fabrication Engineering, ^{1&2}The Delta State Polytechnic, Ogwashi-Uku, Delta State, Nigeria

ABSTRACT

In this work, the open-pit charcoal furnace was successfully constructed using locally available materials. Both laboratory and field test were conducted and the efficiency was found to be 85%. The furnace comprises of some major parts which are as follows: the heating chamber, blower, electric motor and air pipe unit. The open-pit furnace operate on the principle by which air is required for combustion is supplied by the blower to blow air through the air pipe to the heating chamber of the furnace so that temperature of about 2000°C could be attained as a result of burning charcoal in the heating chamber. Non-ferrous metal like zinc (Zn), Brass (Br), Aluminum (Al) and lead (Pb) etc could be melted in order to produce cast products. The machine was tested and approved. It can be useful in the workshops or factory.

INTRODUCTION

Owing to technological development and advancement of engineering in this nation (NIGERIAN), there is the need to develop a system which is purely from locally sourced materials. The achievement of the designing system based on a local material is of paramount important. Due to high cost of constructing furnaces, this work is to improve the traditional method of constructing furnaces, and to enhance the utilization of raw materials within the vicinity of an area. It was designed to help our blacksmiths to overcome the shortcoming that accompanied the traditional method i.e. tedious labour, time consuming and heat lost. The furnace can be used as an apparatus in our technical/vocational institutions in enhancing practical work in foundry technology and practice as the machine is portable and has an ability to melt non-ferrous metals.

STATEMENT OF PROBLEM

Locally used furnaces have lots of lapses and shortcomings that needs to be modified, and that is the main purpose of this research work. The problems are: intensive labour, high cost and time wastage associated with the usage of locally made furnaces.

AIMS/OBJECTIVES

- 1) To construct a low cost furnace from locally available materials that can withstand temperature up to 2000°C.
- 2) To produce furnace that can be used as teaching instrument.
- 3) To develop an easier means of constructing furnaces from locally sourced materials.
- 4) To open up the viability of our local sand for furnaces applications

DESIGN CONSIDERATION

The factors that were considered for this work are:

- i. Availability of the material
- ii. Property requirement for the material
- iii. Environmental friendliness
- iv. Fabricability

i. **AVAILABILITY OF THE MATERIAL**

All the materials that were used where available in the market and they are less expensive.

i. **PROPERTY REQUIREMENTS OF THE MATERIALS**

The properties require for a furnace lining refractory materials are:

1. Structural stability, thermal and expansion characteristic, during heating and cooling
2. Resistance to impact of charged materials.
3. Resistance to erosion(i.e. by dust laden gases)
4. Refractoriness or resistance to elevated temperature under the load required including any external stress
5. Low capacity and transmittance for fuel economy.
6. Resistance to attach by slag and metal that is resistance to chemical.
7. Resistance to spelling, cracking and flaking under the effect of rapid temperature changes thermal expansion characteristic and hot strength which mean mineralogical structure especially of grain boundaries.

ENVIROMENTAL FRIENDLINESE

The furnace should have efficient means with which transfer of heat energy to the crucible and material to be melted are by direct radiation from the hot wall of the furnace. The furnace frame should be made of steel metal round the refractoriness materials (clay), this is to minimize gas leakage and allow temperature insulations appropriate to its size and weight of the refractoriness materials (clay).

FABRIVABILITY

The component or materials used in constructing the open-pit furnace are fabric able which make the work to be easy.

1. Calculating the dimension of the various parts of the furnace and determining their suitability for research work.
2. Carrying out refractoriness test on the clay material intended to be used in constructing the furnace.
3. Dimensioning and cutting of sheet metals for the construction of the hearth wall.
4. Welding of sheet metals.
5. Preparing the refractory for lining the furnace hearth.
6. Finishing the hearth internal and external surface.

1.4 BASIC COMPONENT PARTS

1. Blower, 2) Furnace base, 3) Air pipe, 4) Electric motor.

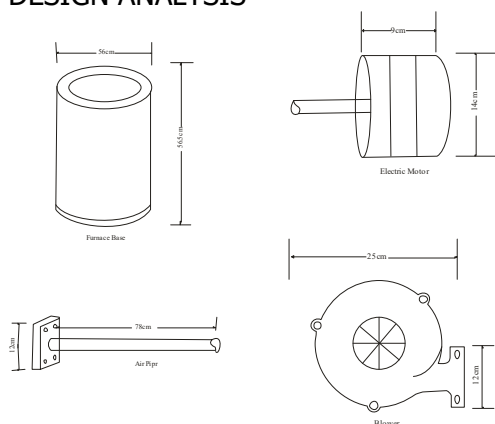
The function of the component parts are as follows:

1. Blower: the furnace blower is the unit that provides air for the system for constant heating process.
2. Furnace base: is a cylindrical rim shape lined with brick and clay, it ensures heat from the charcoal is utilized without heat loss in the surroundings. The base has hole at the centre above the brick
3. Air pipe: serves as a connection to the blower and also as a passage to the air from the blower to the furnace.

TABLE 1

ITEM	NAME	QUANTITY	DISCRIPTION	MATERIAL
1	Furnace base	1	Cylindrical	Low carbon steel
2	Blower	1	220mm	Aluminum
3	Air pipe	1	Cylindrical	Middle carbon steel
4	Impeller	1	220mm	Aluminum

DESIGN ANALYSIS



The design analysis of the open-pit charcoal furnace and formulae used are as follows:

$$\text{Volume of a cylinder} = \pi r^2 h \dots \dots \dots (1)$$

$$\text{Area of a cylinder} = 2\pi rh \dots \dots \dots (2)$$

$$E = \frac{\text{input}}{\text{Output}} \times 100 \% \dots \dots \dots (3)$$

DESIGN CALCULATION

The design calculation for the closed pit furnace is as follows:

DATA

Radius of the hopper = 28cm

Diameter of the hopper = 56cm

Height of the hopper = 56.5cm

Area = $2\pi rh$

Where the volume is = $\pi r^2 h$

$$= \frac{22}{7} \times (28)^2 \times 56.5$$

$$= 3.142 \times (28)^2 \times 56.5$$

$$\text{Volume} = 13978.032 \text{cm}^3$$

$$\text{Efficiency} = \frac{\text{input}}{\text{Output}} \times 100$$

Where input = 5.1kg of charcoal

Output = 6.0kg of aluminum

$$\text{Amount of fuel consumed} = \frac{\text{input}}{\text{output}} \times 100$$

$$\text{Amount of aluminum consumed} = \frac{5.1 \times 100}{6.0}$$

$$0.85 \times 100$$

= 85%

Energy dissipated is = mass of fuel consumed x calorific value

Calorific value of fuel (charcoal): it is defined as the amount of energy dissipated by burning unit mass of volume of fuel (charcoal).

Calorific value of charcoal = calorific value of 7.0cal

1kcal = 4.18kj

(Source: <http://www.utafoundation.org>)

Therefore 1.0kcal= 4.18kj

7.0kcal= x kHz

By cross multiplying

$$\frac{7.0 \times 4.18}{1} = \frac{1.0 (x)}{1}$$

$$X = 29.26\text{kj}$$

Therefore if 2.34kg of charcoal = 29.26

1kg = x kJ

Still cross multiply

$$2.34x = 29.26$$

$$X = \frac{29.26}{2.34}$$

$$X = 12.5\text{kJ/kg}$$

CLOSED PIT CHARCOAL FURNACE

DATA

Mass of fuel (charcoal) used/hour = 14.0kg/2hour.50minutes

Calorific value of fuel charcoal = 12.5kj/kg

Energy dissipated = mass of fuel consumed x calorific value

Conversion of 2hours.50minutes = 170 x 60 = 10200sec

Energy dissipated by the fuel (charcoal)

$$= 14.0 \times 12.5$$

$$170 \times 60$$

$$= 0.001372549 \times 12.5$$

$$= 1.71 \times 10^{-2}\text{kJ.kg/s}$$

Thus only 75% is transferred in to power output.

Power output = energy dissipated by fuel x efficiency

$$\text{Power output} = 0.017156 \times 0.75$$

$$= 0.012867 \times 10^{-3}\text{kw}$$

The total heat that the open-pit charcoal furnace can withstand is 650 – 2000°C (by: Igor-kiznetsor).

CONSTRUCTION AND FABRICATION

The method used in constructing the component parts of the open-pit charcoal furnace is indicated or stated below:

FURNACE BASE

The furnace is welded with a low carbon steel rod, which serve as a retaining strap for brick and lining material with a rim shape. The base of the furnace is laid with bricks and clay mortar.

The layer consist of bricks which are laid to face in the mortar of the rim shape base before the lining of wall furnace, a hole of the right size is created at the centre.

Drain hole is also created opposite the centre hole the air is loosely inserted through the centre hole created on the base and first layer of the wall lining is build around it.

The lining of the furnace with clay mixture now begin.

Brick/grog is now mixed to the basic mortar in proportion of approximately twenty (20 percent) by volume. So starting at the wedge shape recess left by the over lapping of the brick rows. A second layer of mortar with fire grog is applied to produce a round smooth lining for the bottom to the rim shaped base.

The top inside edge of the lining is round into a small curve after a few hours for drying complete smoothly with the palm of your hand.

BLOWER (CASTING PROCESS)

The process use in producing the blower was sand casting. The flat face of the blower pattern is placed on a tumor board and a molding board drag is full and if the sand is to loose, a bad impression is obtained.

If too tight are the gasses generated when metal is poured cannot escape resulting in refractive casting, the drag is inverted and joint surface is sprinkled with parting sand, the top(cope) is place in position above the drag and two boxes are registered by locating pins. Moulding sand was added to the cope box rammed; two pipes formed the down gate.

Therefore the two boxes are separated and the pattern choosened into the impression by tapping. After rapping the pattern is carefully withdrawn from the cope which is replace in position on the drag the molten (liquid us aluminum) which is then poured into the mould and allowed to solidify when cooled the two boxes are separated and casted is removed.

ASSEMBLING THE FURNACE COMPONENT PARTS

When the lining of the base of the furnace have dried out, the next stage is to insert the long air pipe, and then the blower is attached to the air pipe with the help of four bolts and nut. The blower is first connected to the electric motor which supplies the air and some quantity of charcoal is poured on the centre hole on the furnace. The fastest way of lighting the furnace as follows:

First and foremost, light a ball of paper and placed it with charcoal at the centre of the furnace hole after two to three minutes switch on the electric motor to blow air t the fuel (charcoal).

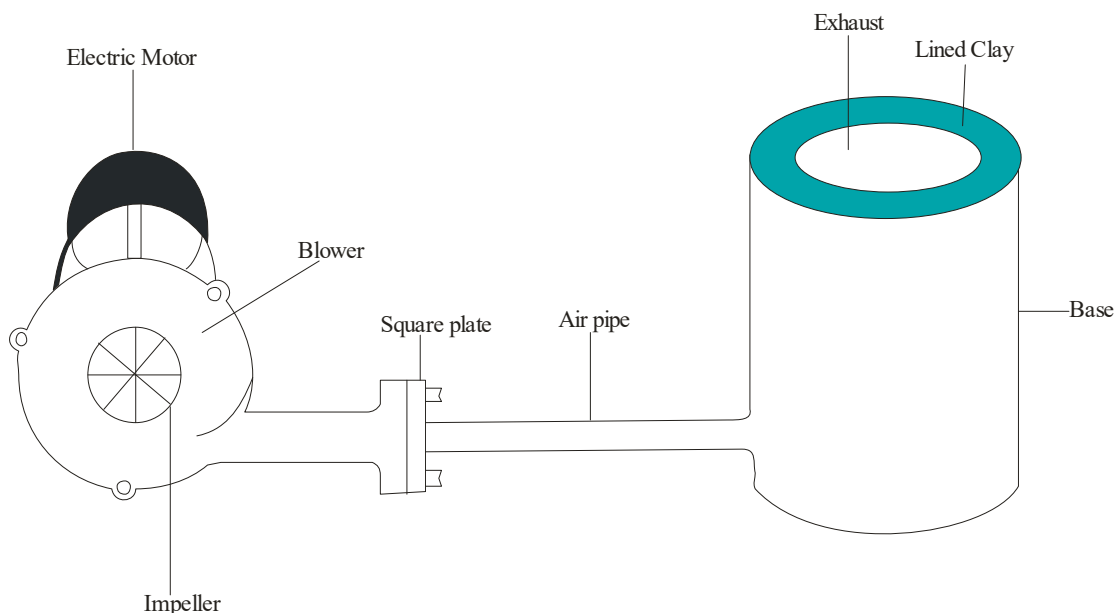
RESULT AND DISCUSSION

The table in figure (i) shows that 1kg of aluminum was melted with 2.2kg of charcoal in 24minutes in open- pit furnace.

The second test was conducted using 2.0kg with 1.4kg of charcoal and the same aluminum was melted in 25minutes with open- pit furnace.

While the same 2.0kg was melted in 60minutes using 5.0kg of charcoal with open-pit furnace.

And finally the third test was conducted using 3kg of aluminum was melted in 88minutes with 6.8kgof charcoal using closed pit furnace.



THE ASSEMBLE OF OPEN-PIT CHARCOAL FURNACE

PERFORMANCE EVALUATION STEP

- I. We weigh the fuel (i.e. charcoal).
- II. We weigh the aluminum (i.e. ingot).
- III. prepare the crucible pot
- IV. poured the weight fuel (charcoal) into the furnace
- V. placed the crucible pot into the furnace
- VI. light the furnace
- VII. And finally timing starting and ending.

OPEN – PIT FURNACE (CHARCOAL)

S/N	NAME OF FUEL USED	AMOUNT OF CONSUMED FUEL (CHARCOAL)	AMOUNT OF ALUMINUM USED	TIME
1	Charcoal	2.2kg	1.0kg	24mins
2	Charcoal	5.0kg	2.0kg	60mins
3	Charcoal	6.8kg	3.0kg	88mins
4	Charcoal	14.0kg	6.0kg	2hr.50mins

Figure (i)

E=Input

Output
Therefore
= $\frac{\text{Amount of aluminum used}}{\text{Amount of fuel consumed}} \times 100$
 $\frac{5.1}{6.0} \times 100$
= 0.85×100
= 85%

Therefore the efficiency of the open- pit furnace = 85%

The evaluation of those refractory properties required investigation and test. Those test are well known and describe in standard procedure issued (ASTM) (i.e. American society for testing and materials) they are adopted worldwide.

COST ESTIMATE/BILL OF ENGINEERING MEASUREMENT

ITEM	NAME	QUANTITY	DESCRIPTION	MATERIAL
1	Sheet metal	1	Rectangle	Mild steel
2	Blower	1	220mm	Aluminum
3	Air pipe	1	Cylindrical	Middle carbon steel
4	Electrode	1 package	Gauge 12	Carbon
5	Impeller	1	220mm	Aluminum
6	Charcoal	1	-	-
7	Hand wheel	1	Cylindrical	Mild steel
8	Rod	1	Full length	Mild steel
9	Clay	-	For lining the base furnace	Clay sand

CONCLUSION

The test result was successfully and the objective of the work was achieved. It is more efficient than the previous local method. Saves time and less consumption of fuel (charcoal). The efficiency was found to be 85% which shows that the open-pit furnace has positive result that it can be used in work shop as practical teaching instrument.

REFERENCES

Gilcris J. O., (1994) Metallurgical furnace

University of Newcastle- upon-tyne, England p. 193-194

Needham J. (1986), The beginning of furnace technology in central Europe, Cambridge University press, p. 370

Ibadode A. O. (2001), Introduction to Manufacturing Technology Ambik Press, Benin City.

Grum Grzhimailo V. E. (1905 - 1911), principle of Theory of Furnace

Internet (www.utafoundation.org)