Design and Fabrication of Crucible Furnaces by using Black Smithy Setup

S.S. Bhandari[1], S.B. Badadal[2], V.G. Kinagi[3], H.S. Tuljapurkar[4] and Prof. S.H. Bansode[5]

[1]Student, Department of Mechanical Engineering, Solapur University, Maharashtra, INDIA
[2]Student, Department of Mechanical Engineering, Solapur University, Maharashtra, INDIA
[3]Student, Department of Mechanical Engineering, Solapur University, Maharashtra, INDIA
[4]Student, Department of Mechanical Engineering, Solapur University, Maharashtra, INDIA
[5]Assistant Professor, M. Tech in Process Metallurgy, Department of Metallurgy and Material Science, College of Engineering, SBFPU, Maharashtra, INDIA

[1]Corresponding Author: bhandarisiddh@gmail.com

ABSTRACT

The main aim was, to design Pit Furnace from the setup of black smithy. As the Smithy setup was not in use so it is converted into Pit Furnace setup. The purpose of using Pit Furnace is to melt nonferrous material. The Nonferrous materials such as Aluminum, Aluminum alloy, Copper, Brass, etc. The Aluminum has less melting point (680° C, 1218^oF) and cheaper than other. The thermal efficiency of furnace is 13.72% which is obtained by melting 2 kg of Aluminum for 75 minutes. Normally thermal of pit furnace is between 4-19%. The blower is used to supply the air into the furnace chamber to burn the coal. For melting the Aluminum, Crucible should sustain higher temperature so Graphite Crucible is used. This Crucible has thinner wall and have more refractory properties.

Keywords— Pit Furnace, Aluminum, Thermal Efficiency, Crucible

I.   INTRODUCTION

Furnace is a device which is used in industries for many things such as, the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns. Pit furnace is most utilized furnace in manufacturing industry because it is easy to control, high efficiency and cleanliness. There are two types of Pit furnace horizontal and vertical. And in the most of industry vertical type pit furnace is used. In this type of pit furnace most of nonferrous materials are melt. Hence these materials are melted by using Subsector (Crucible). Graphite crucibles are widely utilized for such application because graphite has high melting temperature, easy machinability, and high thermal stability. [1] Pit furnace method is easy phenomenon and for each different applications, detailed study and analysis is required that includes,

1. Bricks design as per size of crucible and thermal property.
2. Suitable blower pressure to achieve maximum heat for burn.
3. Space for ladle lifting.
4. Coal size and its heating property.

Fire clay refractories are commonest of all refractories. Fire clay refractories containing less than 40% alumina are classified into:

1. Medium heat duty, and
2. High heat duty fire clay refractories. [2]

Fireclay refractories are made into bricks and blocks of various standard sizes and shapes and also as per specific requirement of user industries. [3] Fire clay refractory products are used by almost every industry, which has heat processing in the production process Iron and steel, cement, petrochemicals, sugar, non-ferrous metal, glass and ceramic industries are some of the user industries.

A typical prior pit furnace apparatus is shown and described in U.S. Pat. No. 2,264,740, issued to Brown on Dec. 2, 1941 for a Melting and Holding Furnace. With the intrusion of the crucible into the melting chamber, the volume of the melting chamber is reduced, thus requiring a larger furnace for a given volume of melt, with a correspondingly higher cost of construction. Correspondingly, with the smaller housing, for efficient heat transfer through the walls of the housing, the chamber

size must be smaller. In either furnace, the crucible or housing is subjected to physical and thermal, as well as chemical abuse from the direct contact with the solid or molten metal thus requiring replacement and consequent higher operating costs and downtime. [4]

II. CONSTRUCTION

For the construction of pit furnace fire clay and fire bricks are used. The thickness of fire bricks is 75mm with dimension 220mm x 110mm. With the help of bricks, the hexagonal structure (Side length 400mm) is made and circular shape is provided by covering the sheet metal to its surrounding and it act as insulation. At the bottom of furnace from the height of 110mm approximately, 5 rods of 500mm each are placed horizontally. Two rods of 350mm are also placed at the both side of 500mm rods respectively as shown in figure no. 2. The distance between each rod is kept 1 inch exactly. The purpose of this arrangement is to provide air supply from the blower, which is placed backside of pit furnace and to burn coal properly. The chimney is placed above the furnace at the height of 1250mm. To supply the air to the furnace, blower is used, with help of assembly of galvanized iron pipe and pressure control valve. One pipe is of diameter 25mm and length 100mm. and pressure control valve of diameter 25mm and length 300mm is attached to the blower.

Figure 1.Fire Bricks

Figure 2.Blower pipe and Rod

Figure 3. Circular Metal Sheet

Figure 4. Melting Aluminum

Table no.1 Specification of Pit Furnace

Sr. no	Parameter	Dimension
1.	Total height of furnace from ground level.	1000mm
2.	Height of Furnace structure.	350mm
3.	Height of Chimney from Furnace.	1250mm
4.	Height of Blower from ground level.	600mm
5.	Diameter of furnace.	720mm
6.	Thickness of Fire bricks	75mm

2.1 Crucible

A crucible is a container that can withstand very high temperatures and is used for metal, glass, and pigment production as well as a number of modern laboratory processes.

1. Material- Graphite Crucible
2. Grade No- B16
3. Dimensions- Height: Top diameter: 250mm, bottom diameter: 150mm.
4. Quantity- 10 to 12 Kg

Figure 5. Graphite Crucible

2.2 Ladle

The Ladle is used for lifting the crucible and to pour molten metal into mold to produce casting.

1. Material: Mild Steel
2. Total length: 950mm
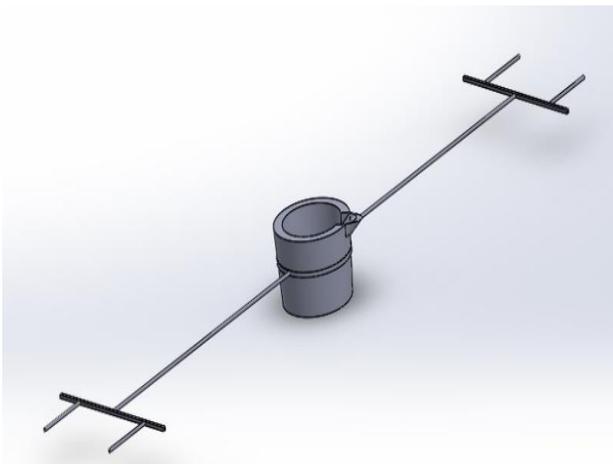3. Ring diameter: 220mm
4. Handle length: 400mm

Figure 6. Ladle with Crucible

III.   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 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]

$$\eta_{Thermal} = Q_s \times 100/Q_f \qquad \text{(Eq 1.1)}$$

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:

$$Q_s = M \times C_p \times (\Delta T) \qquad \text{(Eq 1.2)}$$

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:

$$Q_f = L_f \times S_g \times T_t \times C_v. \qquad \text{(Eq 1.3)}$$

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 (hrs.).

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

The time taken to melt aluminum is 75 minutes (T_t) and ambient temperature was 30°C, maximum furnacetemperaturewas1000°C.Theperformanceoffurnaceis analyzed by the experimental results gotten and from the ASTM standards, Coal has the calorific value of 8000 KJ/Kg and specific gravity is 1.3. The specific heat capacity of aluminum scrap is 0.920 KJ/Kg K [6] [7]

From the Equation 2 the heat required to melt the aluminum is

Q_s = 2 x 0.920 x (1000-30) = **1784.8 KJ**.

From the Equation 3 the heat supplied by the fuel, heat input

Q_f=10 x 1.3 x 1.25 x 8000=**13000KJ.**

From the Equation 1 the thermal efficiency of furnace is

$\eta_{The}=Q_s/Q_f=1784.8/13000=$**13.72%.**

IV. METHOD APPLIED TO GET RESULT

The crucible is placed in a pit below the floor level, and it is fired with coke. The charge to be melted is placed in crucible, and coke is packed around the crucible. Natural draft is provided by tall chimney. After the metal is melted, the covers are removed; the crucible is lift out with the help of ladle. The laser type digital pyrometer is used for measuring the temperature of melting metal and taken to the pouring. And after cooling of poured molten the cope and drag are removed.

Figure.7. Pouring of molten metal into mold

V. CONCLUSION

The developed furnace has $\eta_{Thermal}$ of 13.72%. 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. This paper presents the design and fabrication of pit furnace to melting the aluminum metal. Only mechanical requirement for pit furnace is considered. The geometrical parameters of the furnace such as diameter of melt, height of melt, were determined directly by the furnace capacity. The digital pyrometer is used to measure melting point of aluminum (Range -32°c to 950°c).

REFERENCES

[1] B. Patidar, M. M. Hussain, S. Jha, A. Sharma, & A. P. Tiwari. (2016). Transient numerical analysis of induction heating of graphite crucible at different frequency. *International Journal of Electromagnetics, 1*(1), 35-46. Available at: https://airccse.com/ijel/papers/1116ijel04.pdf

[2] Gbasouzor Austin Ikechukwu & Philip N. Atanmo. (2018). Development of an improved crucible furnace using locally sourced materials for teaching and learning purposes in metallurgical laboratory. *Current Journal of Applied Science and Technology, 26*(1), 1-14. Available at: http://www.journalrepository.org/media/journals/CJAST_67/2018/Feb/Ikechukwu2612017CJAST37249.pdf

[3] E.O. Eze, S.A. Onabanjo. (1995). Heating effects on physical and strength characteristics of fireclay from the Nigerian Coal Measures Formation. *Elsevier Applied Clay Science, 9*(5), 397-406. Available at: https://www.sciencedirect.com/science/article/pii/016913179400024K

[4] M. Thirugnanam. (2013). Modern high pressure die-casting processes for aluminium castings. *Transactions of 61st Indian Foundry Congress*, 1-7. Available at: http://www.foundryinfo-india.org/images/pdf/2A2.pdf

[5] Ekpe E. E, Yahaya B. S, Achema Felix, & Fabiyi M. O. (2016). Design and Fabrication of Aluminium Melting Furnace Using Locally Available Materials. *American Journal of Engineering and Technology Research, 16*(1), 12-20. Available at: https://www.scribd.com/document/339810255/Design-and-Fabrication-of-Aluminium-Melting-pdf

[6] R. Suresh, M. G. Nagarjun. (2016). Construction and performance analysis of pit furnace by using bio-diesel. *Indian Journal of Science and Technology, 9*(45), 1-5. Available at: file:///C:/Users/DST/Downloads/104587-234985-1-PB.pdf

[7] Kothandaraman CP & Subramanyan S. (2014). *Heat transfer data hand book*. (8th Edition). Ned Delhi, India: New Age International (P) Limited. Available at: https://www.abebooks.co.uk/book-search/title/heat-and-mass-transfer-data-book/author/kothandaraman-c-p-and-subramanyan-s/