Experimental Characterization of Graphite Electrode Electric Arc Furnace

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Abstract
In this project work, a deep and precise study has been carried out on the working of different electric furnaces and an electric arc furnace using mainly graphite electrode and refractory materials has been designed and fabricated. Different materials have been melted in the furnace and the optimization of process parameters has been carried. The application of electricity ensures conservation of fossil fuels and reduce pollution by decreasing the emission of harmful gases.

Keywords: Electric arc furnace, Specific energy, Design of an electric arc furnace, Use of graphite as an electrode, Experimental characterization

1.Introduction

Nowadays the need for molten metal to make very complex shapes has been increased and the best name that can be taken to satisfy the high need for molten metal is an electric arc furnace (EAF). The main advantages of EAF are the considerable drop in specific energy i.e. energy per unit weight needed for steel production, the second benefit is the quick start/stop and its versatility. EAF is pollution-free and has outstanding metallurgical control [1-3].

These are so complex/intricate in design and need high input cost that it is not possible to afford these arc furnaces by a small scale industry, educational institute or organization. Due to this in most of the places, only prototype EAFs are found for experimental purposes [4]. EAFs have several metallurgical advantages essential for research, oriented towards obtaining high impact results. Such features include close temperature and heat regulation, precise melt analysis, a definite sequence of metal refining, high thermal efficiency (as high as 70%), and production of steel directly from pig iron and steel scrap [5-6].

The objective of this research work is to design and develop an electric arc furnace for different materials and their alloys.

2. Electric Arc Furnace Design and Fabrication

In this chapter, we are going to discuss the material required and the construction of the furnace

2.1 Aluminum box preparation: An aluminium box is made and used as a shell in furnace construction and by using a metal cutter and some nails aluminium box is made with dimensions (25×25×17cm).

2.2 Mold preparation: A mixture of plaster of Paris, sand, and water are mixed in proper fractions and mixed properly to form a paste which is called a refractory material and this is properly spread in the aluminium box to form as shown in the below figure 1.

2.3 Shell, Hearth: Shell is the outer most cover of the furnace and this is made up of aluminium sheets and the thickness of the shell is very less (1mm), and the dimensions of the shell are (25×25×17 cm).The sidewalls and lower steel "bowl" consists of a shell in case of industrial furnaces.

Hearth consists of molten metal this is made of plaster of paris and the slot where metal melts is having a dia of 11cm and a groove is made such that that the molten metal can be easily, safely poured out from the furnace. And the gap between the melting slot and the shell is completely filled with the refractory material i.e Mixture of plaster of paris, sand, and water [7].

2.4 Roof or Lid:

Roof or lid is a covering from the top while the furnace is on work so that it prevents the heat liberated in the hearth to surroundings. The lid mold is also made up of refractory material with a 3-4cm thickness. It will be having two holders to lift it when there is a need to remove it. And three holes are made at the center of the lid through which electrodes are passed.

Figure:2-Lid

2.5 Electrode:

The electrodes used here are made of graphite, the main reason for using electrodes is due to their excellent thermal properties. The dimensions of the graphite rods considered here are of dia 0.5-1.0cm and length is of 6inches.In general A.C EAF needs 3 electrodes but we can use the furnace with two electrodes also [8-9].

Figure:3 – Graphite electrodes and Set up of electrodes with electrode holders

2.6 Tilting Mechanism and Assembled Set-up

The tilting mechanism is a mechanism that is used for lifting and tilting the furnace to some angle so that it will be easy for collecting molten metal. The tilting mechanism is made up of wood and a casing is further provided which is holding the furnace-mold. The dimensions of the casing are 30×30×19cm.

Figure: 4 – Tilting Mechanism

The casing mentioned in preceding lines is the same as the square structure that is shown in figure 5. Circular wooden rods are placed on either side of the casing as shown in the figure. The radius of the wooden logs is 8cm and the length of each log is 17-18 cm.

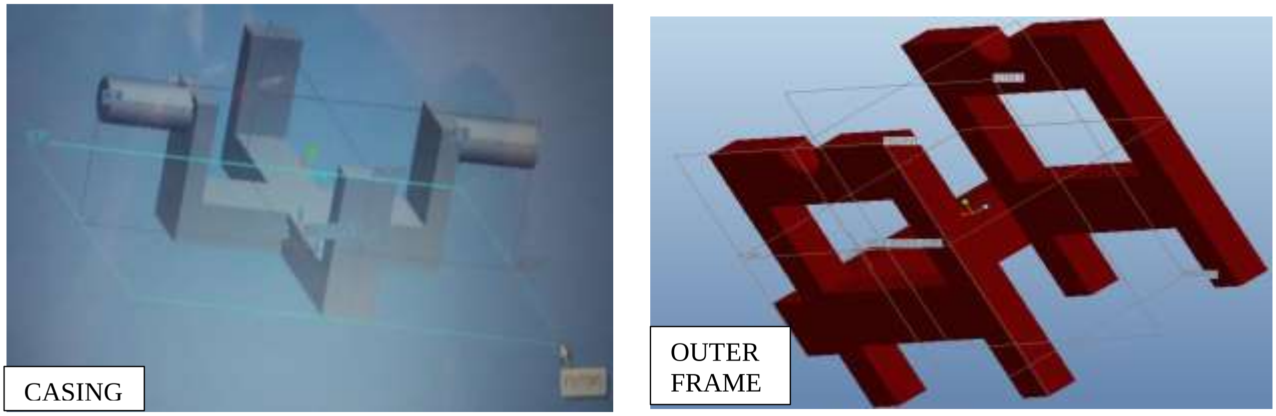

Figure:5- PRO-E models

Figure:6-Fabricrated outer frame and final assembled Set-up

And the whole wooden casing along with the electrodes are placed on the base and the mold is rotated with the help of the wooden rods fixed on either side of the casing according to our convenience and safety, such that the molten metal is collected properly. The structure which was described in preceding lines is shown in the figure. The dimensions of the base are 45 x 35 x 35 cm. The whole assembled setup with the casing is as shown in figure 6.

2.7.Power Source:

The Power supply can be of A.C or D.C.In the case of A.C Electric Arc Furnace, there is a need for a transformer and the input given to it will be of 220-230v and 60-80 amps. Incase of D.C supply there is a need for rectifier to convert A.C to D.C.

3. Experimental Work

3.1 Experimental Set-up

The transformer used for arc welding which has a power output as 440 V and a maximum of 500 A was utilized to provide the electric input. We can alter the amount of current we needed like 100A,200 A etc.Graphite electrodes are connected to a transformer with the help of cables which can withhold voltage up to 1100 V through electrode holders as shown in the figure below.

Figure:7-Experimental Set-up

3.2 Selection of Process parameters:

To ensure proper melting of materials, different currents were used and results observed and tabulated below

Voltage	Current	Result
440 V	100-150 A	Uneven electric arc
440 V	200 A	Continues electric arc and proper melting of the material
440 V	230 A	A reduced melting time with an increase in current.

4. Result and Discussion

After doing the experimental work the following results/outcome have been extracted.

- The fabricated electric arc furnace is capable to meet its purpose i.e. to melt a material with melting point approx 800^0C.
- All the selected design parameters like the dimensions of the hearth, electrical connections wherever required and the tilting mechanics are appropriate to meet the purpose.
- The optimum process parameter for the melting of aluminium in the furnace is 440 V and 200-250 A.
- With an increase in current i.e. power input to the graphite electrode, the melting time can be decreased.
- The material melted in the furnace can be easily cast and it depends on their castability.

Figure:8-Melted Aluminium

5. Conclusion

An electric arc furnace has been produced capable of producing small quantities of melted materials for research. The tests show that the performance is satisfactory. The heating rate, melting rate, and electrode consumption rate is comparable to existing standard furnaces attaining a temperature of well over 1000^0 C within an hour and melting the first charge in about a few minutes.

The design changes in EAF included the use of HP transformers for feeding power at a much faster rate for enhancing the melting rate and adoption of Oxygen refining of hot metal charge. It also uses jet-box or co jets for supplying extra thermal energy, besides the arc energy, for hastening melting and refining of solid metallic charges. Further, a modification can be incorporated in designing of hearth and tilting mechanism. We can also use bearings, gears or chains to provide the proper tilting of the frame.

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