Electric Melting Furnace - A Review

Sneha P. Gadpayle, Rashmi N. Baxi

Abstract— Electric furnace is used for heating purpose in various industrial production processes. Electric furnaces are used where more accurate temperature control is required. Melting of metals, glass, and other materials has been a vital manufacturing process for several thousand years, producing molten liquids that can be poured and solidified into useful shapes. Although the basic process continues to be the same, the utility of cast products has come a long way. The productions of metal in foundries and in all human lives have become a general practice. Different melting techniques are in practice with different energy sources. This topic deals principally with the mechanical and electrical requirements for furnace production. The electrical aspect deals with the furnace power requirement to make it functional.

A blast furnace performs basic melting (of iron ore) operation to get pig iron, cupola furnace is used for getting cast iron and an electric arc furnace is used for re-melting steel.

Index Terms— electric heating, mechanical components, electrical components, melting, heat distribution.

I. INTRODUCTION

A furnace is an equipment used to melt metals for casting or to heat materials to change their shape during the processing of the product (e.g. rolling, forging) or to enhance properties of the processed components (heat treatment). Electric furnace is used for heating purpose in various industrial production processes. Electric furnaces are used where more accurate temperature control and relatively cleaniliness is required. There are three types of electrical furnaces namely:
(1) Induction Heating Furnace (2) Resistance Heating Furnace and (3) Arc furnace depending upon the method of heat generation.
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 fields of application are very wide in human lives.Of all metals, iron production has developed substantially, such that different types of furnaces ranging from blast furnaces, open-hearth furnaces, to converters and electric furnaces for steel production are in use today worldwide.

II. CLASSIFICATION OF DIFFERENT FURNACES

Based on the method of generating heat, furnaces are broadly classified into two types namely:
Combustion type (using fuels) and electric type.
In case of combustion type furnace, depending upon the kind of combustion, it can be broadly classified as oil fired, coal fired or gas fired.

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1. Based on the mode of charging of material furnaces can be classified as (i) Intermittent or Batch type furnace or Periodical furnace and (ii) Continuous furnace.
2. Based on mode of waste heat recovery as recuperative and regenerative furnaces.
3. Another type of furnace classification is made based on mode of heat transfer, mode of charging and mode of heat recovery as shown in the Figure below.

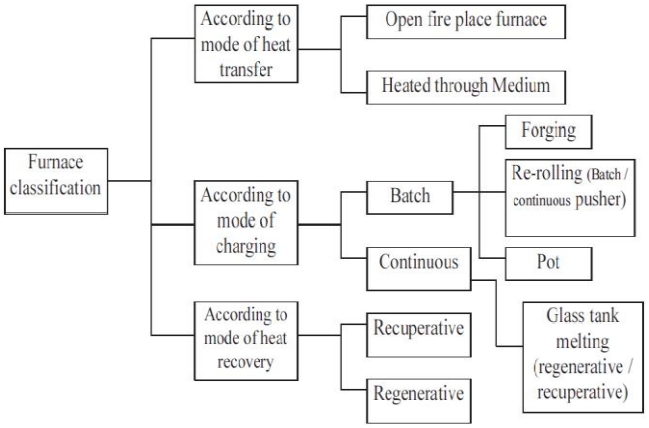

Figure 1: classification of furnace

III. CHARACTERISTICS OF AN EFFICIENT FURNACE

- Determination of the quantity of heat to be imparted to the material or charge.
- Liberation of sufficient heat within the furnace to heat the stock and overcome all heat losses.
- Transfer of available part of that heat from the furnace gases to the surface of the heating stock.
- Equalisation of the temperature within the stock.
- Reduction of heat losses from the furnace to the minimum possible extent. [1]

IV. TYPES OF ELECTRIC FURNACE

A. Induction Heating Furnace :

- A current is passed through a water cooled coil near or around the charge
- Eddy currents are produced in the charge material in response to the coil current
- Heat is generated through ohmic heating in the material

- BASIC COMPONENTS:

The induction furnace consists basically of a crucible, inductor coil, and shell, cooling system and tilting mechanism.
The crucible is formed from refractory material. The furnace coils are lined within it. This crucible holds the charge material and subsequently the melt.
The inductor coil is a tubular water cooled copper coil with specific number of turns. An alternating current (A.C) passes

through it and magnetic flux is generated within the conductor.

The shell is the outer part of the furnace. This houses the crucible and the inductor coils, and has higher thermal capacity.

The cooling system is a through-one-way- flow system with the tubular copper coils connected to water source through flexible rubber hoses.

Tilting of the furnace is to effect pouring of the melt as a last operational activity before casting. [2]

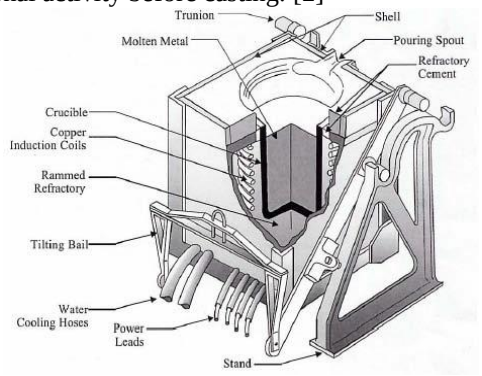

Figure 2 : Schematic of induction furnace

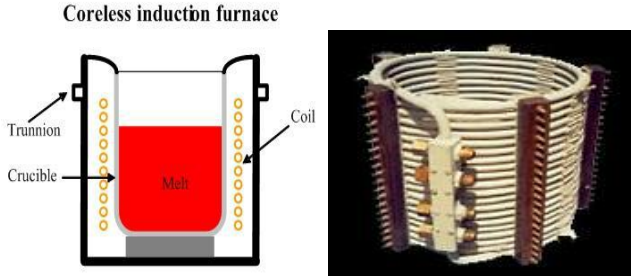

FIGURE 3: TYPES OF INDUCTION FURNACE

- **PRINCIPLE OF INDUCTION FURNACE:**

The principle of induction furnace is based on Induction heating. Induction heating is a form of non-contact heating for conductive materials.

The principle of induction heating is mainly based on two well-known physical phenomena:

1. Electromagnetic induction
2. The Joule effect [3]

B. Resistance Heating Furnace:

- A current passed through a material resulting in ohmic
- Heating Radiation heats charge material
- Some convection and conduction occurs

In resistance heating furnaces, the resistance heating elements are used to generate the heat in a heating chamber. The heating elements used are Nichrome wire, Kanthal wire or Graphite rods depending upon the temperature requirements.

An electric furnace in which the heat is developed by the passage of current through a suitable internal resistance that may be the charge itself, a resistor embedded in the charge, or a resistor surrounding the charge. Also known as electric resistance furnace. an electric furnace in which heat is generated by conductors that offer resistance to the passage of a current through them. Resistance furnaces are widely used in heat treatment, for heating prior to pressure shaping, and to dry or melt materials. Most resistance furnaces are of the indirect type. In indirect-heat resistance furnaces, electric energy is converted into heat when a current flows through the heating elements. The heat is transmitted to the articles to be heated by radiation, convection, or conduction. Such a furnace consists of a working chamber formed by a lining composed of a layer of firebrick that supports both the articles to be heated and the heating elements and that is insulated from a metal casing by a layer of heat insulation. [4]

Electric resistance furnaces offer a safe, efficient, reliable and clean method for heat treating, melting, heating prior to forming, and brazing metals.

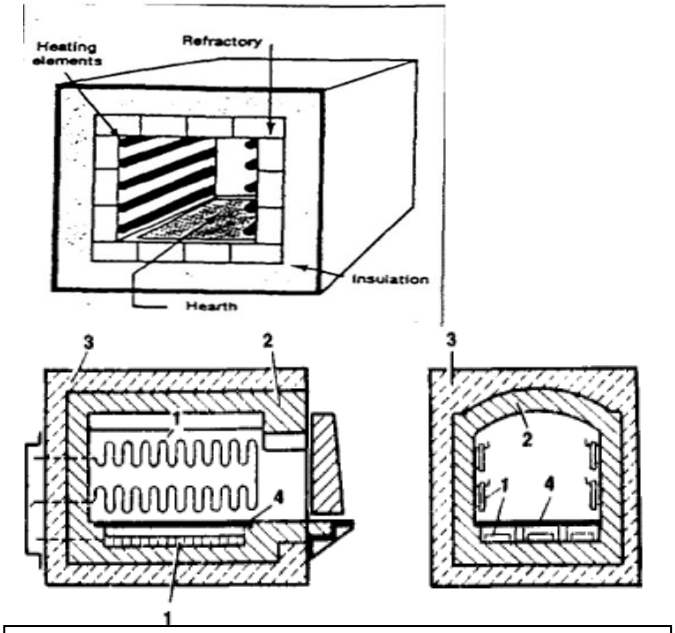

Figure 4: Diagram of a batch-type indirect-heat resistance chamber furnace: (1) heating elements, (2) refractory lining, (3) heat insulation, (4) refractory hearth plate

This furnace can be described as a furnace heating charged materials by the way of an electric arc. The first electric furnaces came into being in 1907, at the hands of ***Paul Heroult*** of French origin. The commercial part of these furnaces was established in the USA. [5]

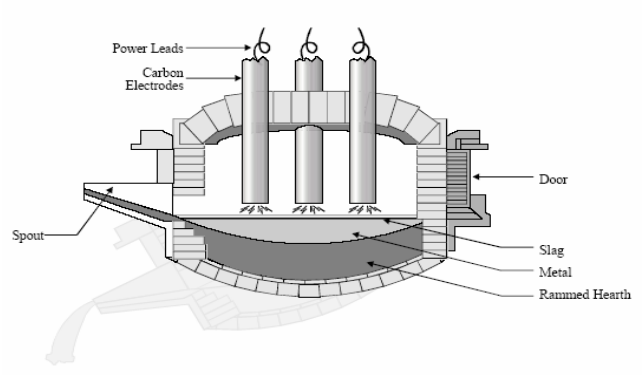

Figure 5: Electric arc furnace

- ***CONSTRUCTION :***

An electric arc furnace used for steelmaking consists of a refractory-lined vessel, usually water-cooled in larger sizes, covered with a retractable roof, and through which one or more graphite electrodes enter the furnace. The furnace is primarily split into three sections:

i. The shell, which consists of the sidewalls and lower steel 'bowl';
ii. The hearth, which consists of the refractory that lines the lower bowl;
iii. The roof, which may be refractory-lined or water-cooled, and can be shaped as a section of a sphere. The roof also supports the refractory delta in its center, through which one or more graphite electrodes enter.

- ***HEAT ENERGY SOURCE:***

Furnace can be described as a furnace heating charged materials by the way of an electric arc. [6]

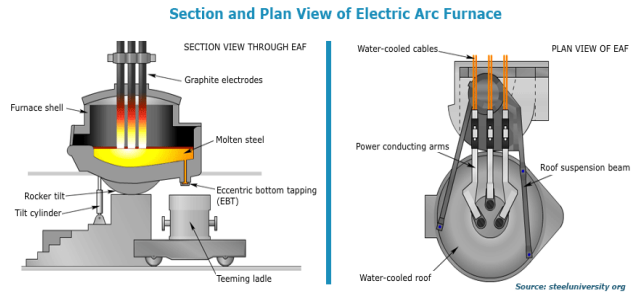

Figure 6 : Section and plan view of electric arc

V. PRINCIPLES OF ELECTRIC HEATING

When a current (I) flows through a conductor of resistance(R), heat is produced and there is temperature rise of conductors in electrical circuits. Temperature rise is undesirable and must be limited by design to avoid overheating of the conductor or its electrical insulation. This is often termed as permissible surface loading of a conductor. The conductor could be in the form of wire, strips or any other shape.

VI. REQUIREMENTS FOR A HEATING ELEMENT

1. It should have melting point greater than furnace temperature.
2. It should not react with the atmosphere of the furnace. Commonly furnace atmospheres are oxidizing, reducing and may contain water vapour.
3. It should be resistant to thermal and mechanical shock.
4. It should have enough resistivity. Resistivity is the ability of a material to inhibit flow of current in presence of applied voltage.

VII. MELTING PROCESS

1. **Preparing the Metal and Loading** – removing dirt and moisture and sometimes, preheating the charge material, such as scrap metal or ingot; and introducing solid charge into the furnace system
2. **Melting the Metal** – supplying energy from combustion of fuels, electricity or other sources to raise the metal temperature above its melting point to a pouring temperature
3. **Refining and Treating Molten Metal's** –introducing elements or materials to purify, adjust molten bath composition to provide a specific alloy chemistry and/or affect nucleation and growth during solidification
4. **Holding Molten Metal** – maintaining the molten metal in molten state until it is ready for tapping
5. **Tapping Molten Metal –** transferring the molten metal from the furnace to transport ladle
6. **Transporting Molten Metal –** moving the molten metal to the point of use and keeping the metal in molten state until it is completely poured. [7]

VIII. HEAT TRANSFER IN FURNACES

- Radiation from the flame, hot combustion products and the furnace walls and roof.
- Convection due to the movement of hot gases over the stock surface. [1]

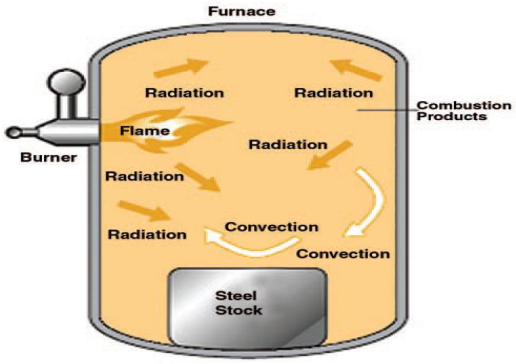

Figure 7: Heat Transfer in Furnace

IX. PERFORMANCE EVALUATION OF A TYPICAL FURNACE

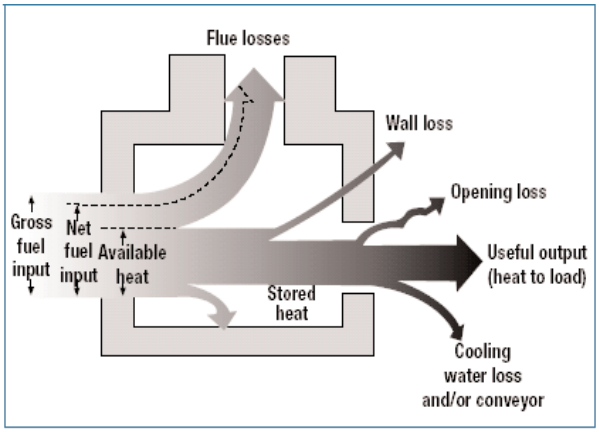

Figure 8: Heat Losses in Industrial Heating Furnaces

These furnace losses include:
• Heat storage in the furnace structure
• Losses from the furnace outside walls or structure
• Heat transported out of the furnace by the load conveyors, fixtures, trays, etc.
• Radiation losses from openings, hot exposed parts, etc.
• Heat carried by the cold air infiltration into the furnace
• Heat carried by the excess air used in the burners. [1]

X. MARKET POTENTIAL

Electric furnaces find its application in Engineering Industries, Food processing industries, Chemical processing Industries, Laboratories etc. The furnace is designed and constructed as per the requirement of the customer. The various parameters such as maximum attainable temperature dimension of the heating chamber, automatic or semi - automatic controlling of temperature etc. depends upon the requirement of the customer.
The demand for this item depends upon the growth of industrialization. The present day growth in demand for this product is approximately 10% per year. There are 15 to 20 SSI units manufacturing this item in Kerala and Tamil Nadu. Since this is industrial machinery, quality assumes prime importance. [8]

XI. CONCLUSION

Several advancements in melting technologies have been made over the last few decades, but significant opportunities still exist for the metal casters to improve the melting efficiency and reduce the metal loss.
The Induction furnace design and subsequently its fabrication should be promoted considering the abundant power sources, less maintenance cost and labor requirements.
It is observed from the study that resistance heating is appropriate and energy efficient for a variety of heat treating, preheating processes in terms of cost of the furnace. As the furnace for melting of metals require different set ups due to the purpose of use, the integration of the furnaces can be done to meet various requirements such as melting of metals. Various purposes can be achieved using the same furnace.

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