A Review on Energy saving in Induction Furnace using Hydraulic Lid

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Abstract

Foundry is one of the most energy intensive industries. A significant amount of energy is required in operations like melting. Since energy cost is a significant contributor to the overall production cost due to high and rising energy cost in current scenario. In general, the melting process consumes the maximum amount of energy in a foundry. Hence, foundries can cut costs by reducing energy consumption during the melting process. Energy intensity in foundry can be reduced with adoption of technologies which will improve energy efficiency and produce financial benefits. We focus on identifying the best operating practices and energy efficiency measures and implementing the same at low capital investment.

***Keywords*:** Foundry, Energy Efficiency (EE), Melting, Induction Furnace, Losses.

1.Introduction

Energy is a multiplying factor which allows man to translate various raw material and resources into useful items to meet the daily demands and necessities of human beings. Foundry technology involved casting from molten metal transferred into a mould and permitted to harden under varying conditions depending on the purpose. Foundry is the most basic input industry stringent demands of quality and quantity are being placed on it with rapid industrialization and growth in other fields of production. This sector faces several critical issues that require immediate attention. One such factor that falls in the ambit of this paper is the prevalence of age-old technologies across the sectors and inherent inefficiencies associated with resource utilization, including, energy. [1]

Most coreless induction furnaces consist of a robust steel shell that is mounted on trunnions and fitted with a mechanism for tilting, usually by hydraulic power; however, some furnace bodies are of open frame or concrete block construction. The furnace normally comprises a cylindrical refractory, the top of which is open for charging and de-slagging operations. A spiral, water-cooled electrical coil is mounted within the body shell. On all but the smallest furnaces, a refractory-lined swing lid is provided to reduce heat losses from the surface of the liquid metal; many units employ this facility to extract the fume and particulate generated. Molten metal is transferred from an induction furnace into ladles, launders, etc., by tilting the furnace on its trunnions. The trunnions are normally fitted at the front of the furnace body in line with the pouring lip. The tilting mechanism is usually hydraulically powered. [2]

Typical foundry work includes pouring melted metal into molds, transferring the molds, breaking metal parts from their molds (degating), and sanding/deburring the final parts - all applications robots excel in. Like many other industries, foundries are constantly on the lookout for new ways to boost their productivity, cut costs and increase quality. The benefits of employing automation with robot technology are lower production costs and scrap rates, increased up-time and consistent, superior quality.

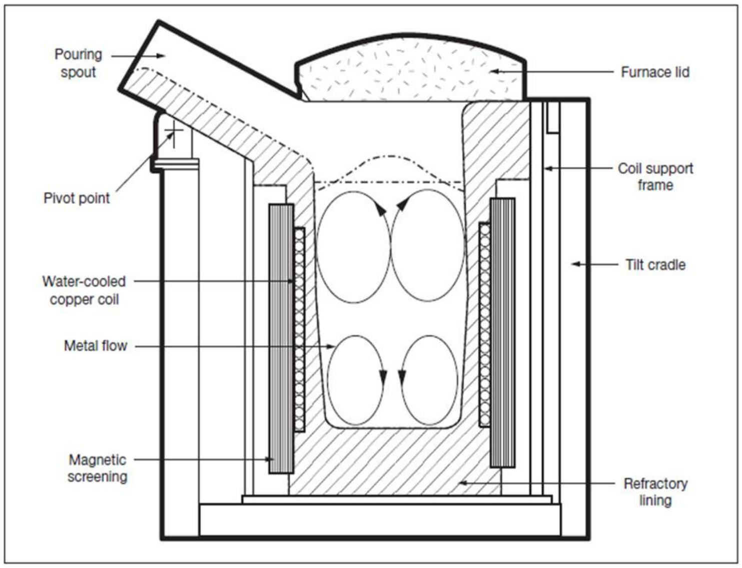

Fig.1. Typical arrangement for a coreless induction melting furnace.

2. Literature Review

The literature review reveals that a great deal of work has been carried out in the field of process improvement in the industries using Induction furnace for steel melting, it is observed that there is lot of work has been done on the parameters which are responsible to reduce energy consumption and reduce the production cost of steel.

J. Powell has analyzed in his paper presented at the institute of British foundries that in case of coreless furnaces, full power should be applied to the furnace for the maximum possible time to ensure maximum output and minimum energy consumption, and holding periods should be kept to a minimum .The use of medium frequency furnaces started from cold and emptied completely immediately after each melt can have better energy consumption figures, since there are few if any holding periods. In addition, the increased power densities available with such furnaces and their increased melting rate capability further reduce energy consumption. The type of refractory construction employed in channel furnaces can also affect energy consumption and lining wear has an adverse effect. With all furnaces, it is important to minimize heat losses by proper attention to linings and the use of lids and covers. [3]

W. A. Parsons has shown that Electric Furnaces which are operated with molten heel practices are vulnerable in a reduced output situation since the holding component to the total electrical energy consumption tends to increase. The adverse effects of this type of operation may be overcome in mains frequency coreless furnace melting where it is possible to produce the lower output by working at optimum furnace melting rate and decreasing the number of working days. Apart from the liquid metal quantity, variation in charging practice also affects the heat time. It has been found that similar liquid metal quantity has taken with variation in heat time. This has an adverse impact on energy consumption. Also, due to erosion of lining, the tap quantity increases along with lining life number, which has reduced specific energy consumption. [4]

S. K. Dutta has investigated the main problems faced by steelmakers are short supply, fluctuating prices together with extremely heterogeneous nature and the presence of tramp elements of steel scrap. Use of direct reduced iron (DRI) as a partial replacement to scrap, to some extent does help in overcoming this hurdle. However, unlike scrap and even pig iron, DRI is characterized by high porosity, low thermal and electrical conductivities which, in turn, pose problems in its melting. Attempts were made to study melting of DRI in a laboratory size induction furnace using molten steel bath as hot heel. The induction stirring accelerates the transfer of heat and promotes the melting of DRI. The effect of partial replacement of scrap by DRI on various melting parameters has been studied. Also, kinetic studies were made to evaluate net melting rate. It was revealed that since melting and refining are taking place simultaneously, the increasing proportion of DRI in the input charge increases net melting rate and metallic yield. It was concluded that higher proportion of DRI, as a replacement to scrap, contributes to improve mechanical properties with no segregation of carbon content and the decrease in sulphur and tramp elements in the product that improves steel quality. [5]

L. Smith has concluded that it is essential that consideration be given to energy costs both at the purchase stage and throughout the useful life of a furnace. It is through awareness of salient factors such as charge materials, charging practices, linings, temperature measurement and keeping that minimum energy costs can be attained. These costs should not be divorced from other factors such as recovery, flexibility and environment. The environmental impact is very difficult to quantify in terms of energy efficiency, although for a large number of operations the absence of fumes offers additional energy savings by virtue of elimination of extraction facilities. [6]

Seminar report by **The Energy conservation Center, Japan (ECC) (1998)** focused on energy saving opportunity in induction furnace few of them are, rated power is supplied to the furnace only when thickness of furnace refractory remains normal. Furnace power may be lowered when its inner diameter changes due to erosion of furnace wall or slag attached to the wall. Furnace walls damaged by erosion should be repaired to maintain the standard diameter in respect to the thermal efficiency of the furnace. Before charging the material, it is necessary to remove sand, rust and other foreign matters causing slag formation. Quantity of heat required for cast iron melting process up to its melting point (about 1150°C) accounts for 65% of the total heat consumed for heating cold material of room temperature (20°C) to tapping temperature (1500°C). Induction furnaces consume 87% of the total power consumption required for meltdown. Remarkable power saving may be realized if raw material is preheated up to 500 -600°C by any method more effective than induction heating. [7]

The advancement of any nation technologically has been influenced and elevated 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 also become a general practice. Different melting techniques are in practice with different energy sources. The cleanliness and availability of electrical energy sources in Nigeria is of paramount importance to its use in foundries, hence the need for this design. The mechanical aspect gives consideration to the geometrical components, cooling system, and the tilting mechanism. The electrical aspect deals with the furnace power requirement to make it functional. The design was achieved through consideration of relevant theories and their practical application. [8]

Study by **R. L. ROD** shows that during the past 30 years, the melting methods and associated molten metal handling systems used by the U.S. foundry industry have changed significantly. During the same period, while ductile iron production has experienced continued growth, the quality of metallic scrap and other iron unit feed stocks has steadily deteriorated. The result: slag related melting problems have become widespread issues in recent years. Yet, a search of the foundry technical literature from the past 30 years about slag control and buildup will result in only a handful of articles. A new flux, Redux EF40L, has been developed that controls and minimizes buildup in pouring ladles, melting furnaces, pressure pour furnaces and magnesium treatment vessels with minimal to no adverse effects on refractory linings. [9]

The higher temperatures required for the melting of steel results in significantly higher energy losses in comparison with melting other industrial cast alloys. The energy costs associated with heat losses during melting are significantly higher for steel foundries than foundries melting other cast alloys. Today's steel foundries use both induction furnaces (IF) and electric arc furnaces (EAF) for melting steel. [10]

Extensive heat losses in the ladle could be associated with excessive superheating of the melt before tap which increases energy consumption, promotes oxidation of the melt and increases refractory consumption. A high cooling rate of the liquid metal in the ladle could also cause casting quality instability. [11]

3. Areas in which improvements are possible in a foundry

- Melting – cupolas, Induction furnaces.
- Compressed Air System
- Heat recovery
- Electrical utilities – Motors, DG Sets.

From the energy balance sheet, areas of high energy consumption ―energy centers‖ were considered as potential areas for energy saving. However, other areas could also be considered to improve the overall energy utilization. There may be many options to reduce energy consumption. For example, better housekeeping, behavioral changes, preventive maintenance, installation of energy efficient equipment etc. are a few of the options available. [12]

- ***Energy savings in cupola & Induction furnaces:***
  In general, the melting process consumes the maximum amount of energy in a foundry. Hence, foundries can cut costs by reducing energy consumption during the melting process. Cupola, which is the most commonly used melting furnace in the Indian foundries accounts for up to 50 % of a foundry's total energy consumption. Don't hold the molten charge inside the cupola. It consumes energy as well as changing the metallurgical properties of different batches.

  In induction furnace, the only factor that needs to be controlled in order to save energy during induction melting, is cycle time. Keep the size of charging material to about one third of the furnace crucible size. Don't superheat the metal. Don't uncover the furnace unnecessarily.
- ***Melting furnace cooling or heat recovery system:***
  All electrical melting furnaces need to be equipped with cooling systems to avoid surplus heating causing damage to induction furnace coils or the steel structures in electric arc furnaces.
- ***Energy savings in the compressed air system:***
  Energy savings of up to 30 % can be realized in a compressed air system by regular simple maintenance measures. The compressor should be placed away from equipment which may add moisture to the atmosphere, for example, rinsing lines, cooling towers, dryer exhaust etc. If the compressed air is moist the components of the compressed air system will corrode. The specific power consumption will also increase.
- ***Energy savings in electrical utilities:***
  Oversized motors should be replaced with motors according to load requirement. Using variable speed drive (VSD) with the motor. Ensure that the air intake to the generator is cool and free from dust.

Modernization of foundries include: (1) changing over to better and newer foundry equipments; (2) employing newer, better and more economical moulding, melting and casting techniques; and (3) creating conditions which do not make a foundry dirty, dusty and smoke-filled, i.e., improving working condition in foundries, providing adequate illumination, air circulation, dust extraction etc. [13]

Energy efficiency improvement will have firm level as well as economy level benefits. At the firm level, energy intensity reduction due to efficiency improvement will reduce the cost of production of individual small-scale industries and at the aggregate level it will bring down or curtail the growth of industrial demand for energy. [14]

By demonstrating a commitment to Cleaner Production, companies can also improve their public image and gain the confidence of consumers. It aims at avoiding the generation of waste and emissions, by making more efficient use of materials and energy, through modifications in the production processes, input materials, operating practices and/or products and services. [15]

The TERI-designed pot furnace reduced energy consumption by nearly 30% compared to the other 'retrofitted' gas-fired pot furnaces that came up in the cluster. The gasfired pakai bhatti design helped in reducing particulate emissions and thereby greatly improved the environment in the workplace. [16]

In collaboration with The Energy and Resources Institute (TERI), New Delhi, SDC India selected the foundry industry as one of the prominent areas in which to introduce environment-friendly technologies. [17]

Table *1.* Suggested Energy Efficiency improvement technologies in Foundry. (Courtesy of BEE)

Equipments	**Old Technologies**	**New Technologies**	**Saving Potential**
Copula	Blast Copula	Dividing Blast Cupola	15% (Coal Consumption)
Oil Fired Rotary Furnace	Rotary Furnace	Induction Furnace	25% Energy Saving (Approx.)
Power Factor Improvement	Manual Control	APFC with Additional Capacitor for maintaining PF 0.99	!0-15% Electricity Saving
Insulation & Lid cover to avoid radiation losses	Open lid/poor insulation	Good insulating material/ lid cover	2% saving
Insulation Paint for Rotary and Cupola Furnace	No Insulation over surface	Insulation paint over surface of furnace	5-7% Fuel saving
Excess in Air Blas no	Flue gas	Gas	Gas 5-7%
Copula	Monitoring system	Monitoring with damper control	Electricity saving
Excess Air in Blast Copula	No Flue gas Monitoring System	Flue gas monitoring with damper control	5-7 % Electricity saving
Energy Efficient motors for blowers	Old re-winding motors	Use of energy efficient motors	3-5% savings
Lighting System	40 W with conventional choke	T/5 28 W Tube Light	40%

4. Energy saving in Induction Furnace - Hydraulic Lid:

Achieving efficient operation of coreless induction furnaces depends largely on the implementation of good operating practices. In an induction furnace the radiation losses are estimated at about 3 to 5%. This radiation loss can be minimized by providing closed hood for the furnace and a cover. A well-fitted furnace lid in closed position limits radiation losses to about 1% of power input against 7-10% in open furnace. [18]

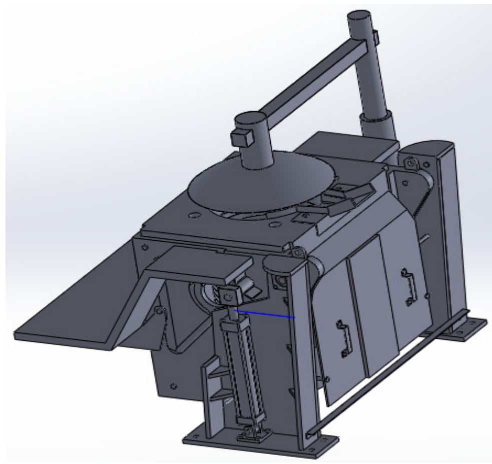

Fig.2. Design of Lid for energy saving.

A. Heat radiation from crucible body

Table 2. Heat radiation from crucible body.

App. Size (mt.)	App. Area in Sq. Ft.		Avg. Body Temp.	Ambient Temp.	Total Losses (KCal / hr)	Energy loss (Kcal/ hr) Total Operation Time 3 Hours
1.6 M Dia, 2.8 M height	151.3		60 - 80	25-45	2837	8510

B. Heat radiated from open crucible

Table 3. Heat radiated from open crucible.

Sr. No.	Temperature on Average Deg. Centigrade	Energy loss (KW/m^2)	Energy loss (KW/hr) Total Operation Time 3 hours	Energy loss (KCal/hr) Total operation time 3 hours
1.	1050	125	375	42785

*In the above calculations, crucible diameter has been taken as 1.3 Meters and average emissivity as 0.5.

5. Conclusion

There are mainly four sources of energy used in small and medium scale foundry shops and these include used oil, diesel, electricity and biomass. Biomass in the form of charcoal is used for baking the molds and diesel/electricity is used to run the blower motors. [19] Several measures can be employed to reduce on energy use including installation of energy metering, monitoring and control systems, monitoring the quality and size of scrap charged into the furnaces, investment in energy efficient technology, fitting furnaces with sufficient insulation and proper maintenance, implementation of an effective communication system, seeking external help on technical issues and motivation of workers. Reducing this loss will save considerable amount of energy which while leading to immediate improvement in profitability and economic viability of foundry.

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