ENERGY CONSERVATION IN AN INDUCTION FURNACE: A NEW APPROACH

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ABSTRACT

Steel is an essential material for sustainable development for people to satisfy their needs and aspirations. It is a part of people's everyday life, in both the developed and developing world. It is used for various purposes like transportation, enabling healthcare, supplying water, delivering energy etc. Now-a-days demand of steel is increasing due to increased in infrastructure and globalization. And to meet this demand we are looking for such foundry process which will produce high quality steel with minimum time.

The aim of this paper is to improve the overall performance of induction furnace and to improve melt rate with optimum use of electricity. This paper mainly put attention on induction furnace as these are main consumer of electricity in foundry. In case of induction furnace efficiency is sensitive to many controllable features lie in operational practices ,coil height, charge mix, furnace utilization etc. So with the help of recommendation ,it is easy to find out the ways to lower the specific energy consumption in this furnaces.

Keywords: Coil height, Control label , Energy, Optimum , Utilization

I. INTRODUCTION

The iron and steel industry presents one of the most energy intensive sectors within the Indian economy and is therefore of particular interest in the context of both local and global environmental discussions. Increases in productivity through the adoption of more efficient and cleaner technologies in the manufacturing sector will be effective in merging economic, environmental, and social development objectives.

But now a day's the demand of steel is increasing because of increase in infrastructure and globalization .That's why steel industries are looking for such a furnace which can produce good quality steel with high production rate, and controlling quality, composition, physical and chemical properties. This can be achieved by using "INDUCTION FURNACE" and hence it comes into picture. So, in this paper, we are trying to develop certain relationship between input and output parameters to improve the Whole process.

The energy efficiency of any foundry largely rides on the efficiency of the melting process a multi-step operation where the metal is heated, treated, alloyed, and transported into die or mould cavities to form a casting. The melting process is not only responsible for the energy consumption and cost-effectiveness of producing the castings (Exhibit 3), but it is also critical to the control of quality, composition, and the physical and chemical properties of the final product.

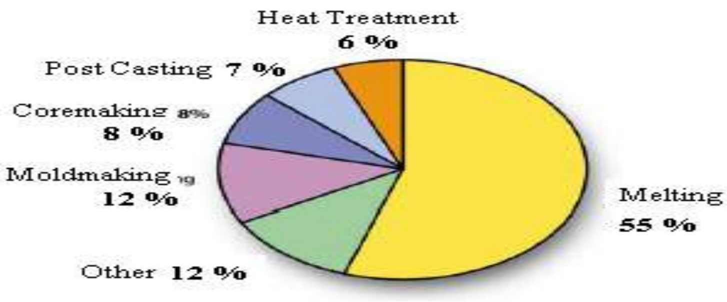

Figure 1: Report Source: 2004 Metal Casting Annual

The industry spent $1.2 billion in fuels and electricity purchases alone in 1998. The concern over the energy efficiency of processes has been growing with the recent rising costs of energy. Factors like increasing energy demands, compounded by spikes in energy costs from world events will continue the upward trend in energy costs, pressing the need for developing energy-efficient solutions for the melting process.

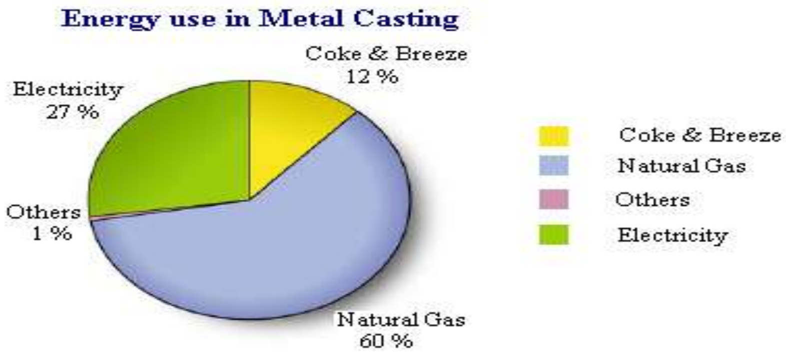

Figure 2: Source 2004 Metal Casting Annual Report

Although the energy consumption in the melting process has been a significant concerning foundry operation. Studies have shown that by Implementing best practice technologies, iron and aluminium melting can save approximately1.2 and 3 million per ton respectively. In summary, striving to reduce energy consumption in melting ferrous and non-ferrous metals shows a promising path to lowering operating costs in foundries and in turn cutting down the production costs for the entire U.S. manufacturing sector.

II. FORMULATION OF THE PROBLEM

2.1 .MELTING PROCESS

The melting of any industrial metal used in manufacturing involves the following steps:

2.11. Preparing and Loading Metal for Melting

Removing dirt and moisture and sometimes, preheating the charge material, such as scrap metal or ingot; and introducing solid charge into the furnace system

2.1.2 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

2.1.3. Refining and Treating Molten Metals

Introducing elements or materials to purify, adjust molten bath composition to provide a specific alloy chemistry and/or affect nucleation and growth during solidification.

2.1.4 Holding Molten Metal

Maintaining the molten metal in molten state until it is ready for tapping

2.1.5. Tapping Molten Metal

Transferring the molten metal from the furnace to transport ladle

2.1.6 .Transporting Molten Metal

Moving the molten metal to the point of use and keeping the metal in molten state until it is completely poured. Which increase the costs of melting operations?

III. METHODOLOGY

3.1. Principle of Induction Furnaces

The working of induction furnaces is based on the principle of electromagnetic induction and basic concept is same as that of a transformer but with a concept is same as that of a transformer but with, a single turn short circuited secondary winding. The charge to be heated and melted forms the secondary while the hollow water cooled copper coils excited by the A. C. supply from the primary.The coil is surrounded by a laminated magnetic yoke to provide a return path for the flux to prevent stray losses and improve the pf. The whole furnace is contaminated in a mechanically rigid structure and mounted so that it can be tilted for pouring.

3.2. Experimentation

Date	Heat No	F/C-No.	Planned Grade	power on	Power Off	Tap to tap time, Min.	Melt Rate, Kg/Min	KWh Cons, F/C	Molten Steel (MS), MT	KWH/ MT MS	Slag
01/10/09	4522	A	M.S	0.3	18.45	1089	16.6941	15664	18.28	856.89	3.65
02/10/09	4527	B	M.S.	21.2	6.45	381	34.4912	16828	19.66	855.95	2.32
06/10/09	4549	B	M.S.	11	0.35	255	22.6994	16294	18.5	880.76	2.75
08/10/09	4561	C	M.S.	11	0.15	327	22.9308	16096	18.23	882.94	1.86
11/10/09	4581	D	M.S.	8	23.25	273	21.0811	16414	19.5	841.74	2.23
15/10/09	4608	B	M.S.	13	2	270	23.8205	15968	18.58	859.42	1.71
19/10/09	4616	D	M.S.	8	16.4	192	43.4091	15968	19.1	836.02	2.24
20/10/09	4623	A	M.S.	17	2.1	546	33.2182	15276	18.27	836.12	11.46
27/10/09	4646	D	M.S.	17	1.45	202.2	34.4952	15606	18.11	861.73	8.45
28/10/09	4648	D	M.S.	21.5	2	192	74.1961	16830	18.92	889.53	5.64

Above parameters in the table are critical variable parameters to the furnace. Input (Affecting) Variable parameters to the furnace are Raw material in ratio (Scrap, Direct reduction iron and Hot briquettes iron alloys) Power supply on & off time, Thickness of Refractory lining (partition between raw material and induction coil) Output (affected) parameters to the furnace Molten metal quantity in MT/Heat ,Waste heat Slag (containing erosion of lining & integrated slag with raw material),Time per heat.

During the data analysis it was found that, the furnace is not utilized up to the full capacity. specific energy consumption is very high for a little tap quantity with a high tapping temperature. Even restricting power input levels or causing power to be switched off increases specific energy consumption. From the table values, It was also found that for the same metal tap quantity, there was a marked difference in specific energy consumption due to more heating, As the heat losses from coreless induction furnace represent an energy consumption that is proportional to the time metal is held at that temperature and hence more the heating time more is the consumption. Hence, care should be taken to avoid dead time by developing efficient operational practices.

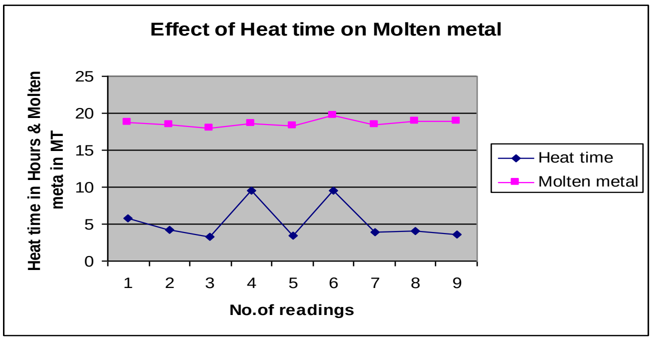

Figure 3: Time Vs Molten Metal

Above fig. shows adverse impact on the specific energy consumption.

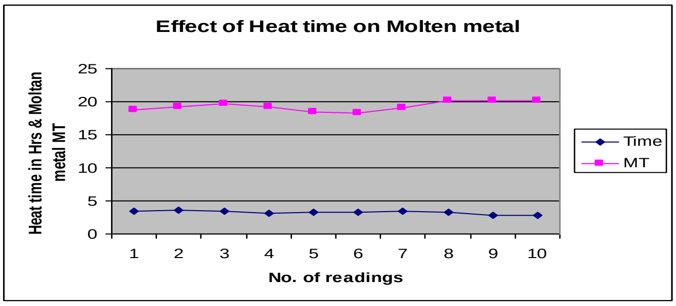

Figure 4: Time in Min Vs Molten Metal in MT

It was found that after few heats, the time required for the Molten metal reduces and so the specific energy consumption. Also due to erosion of lining, the tap quantity increases along with lining life number, which has reduced specific energy consumption (Fig. 4).

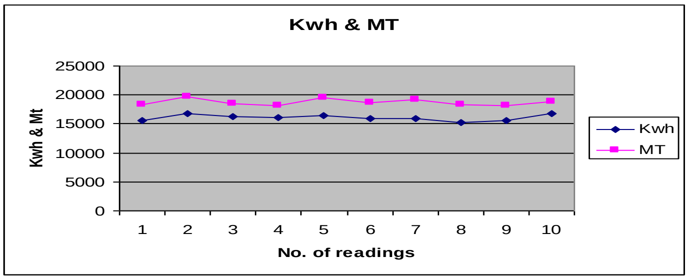

Figure 5: Showing Kwh and Molten Metal in MT

It is seen from the above figure 5 that for less molten metal, the power consumption is very high.

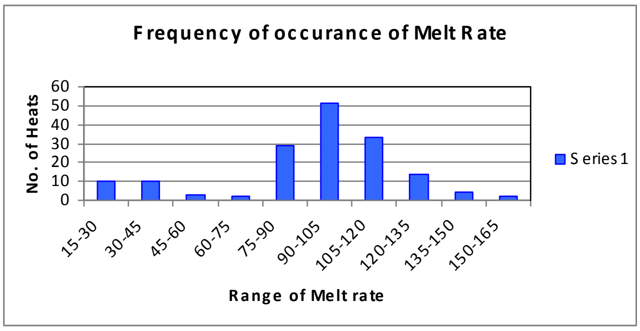

Figure 6: Frequency of Occurrence of Melt Rate

This regression analytical clearly suggests that nearly 76 % of heats were taken at the melting rate of 75-135 Kg/min and relative SEC is nearly 752 KWh/MT was achieved.

The effect of lining no. of crucible of induction furnace on specific energy consumption and melt rate is also important to analyse. Lining no. has the considerable effect on melt rate and SEC.

IV. RESULTS AND DISCUSSION

After studying all the Input and Output parameters , we have suggested some of the modifications during the operation of the Induction Furnace.

4.1 Furnace Utilization

The Furnace should be utilized at its full capacity, so that more metal can be tapped, at low temperature and the specific energy consumption can be reduced with increase in production.

4.2 Metal Tapping Temperature

The Metal tapping temperature should be as low as possible. Different heats should tapped at nearly similar tapping temperature so that optimum specific energy can be consumed. Heat capacity of molten metal increases with increasing the tapping temperature, and furnace heat loss is fully proportional to melting temperature. Heat capacity of gray iron increases about 20 kWh/t as its temperature rises per 100°C.

Heat conduction loss (Qc) and radiation loss (Q_R) are calculated as follows

$Qc = (T\text{-}t)/R10\text{-}^{3}$

Qc**:** Conduction loss (Kw) ,t: Cooling water temperature (°K),T: Molten metal temperature (°K),R: Heat resistance of furnace wall (kW/°K),$Q_R = 5.67 . 10^{-3} . A . (T/100)^4$),Q_R**:** Radiation loss (Kw),Emissivity : ε,A: Surface area of molten metal (m^2)

From the above mentioned equations it follows that conduction loss and radiation loss of high-frequency furnace with 500 Hz and 900kW at tapping temperature of 1500°C come to 50 kW and 35 kW respectively, and these losses can be reduced approximately by 10 kW each at tapping temperature of 1400°C. To keep the tapping temperature lower, it is necessary to take carefully thought out measures in practice, for example inoculation, laddle traveling distance, preheating and covering of laddle, etc. The tapping temperature employed by a foundry will be determined primary by the type of raw material being used.

4.3 Molten Metal Should be Held at Low Temperature and in Short Time

Rated power should be turned on to heat up again. Chemical analysis of molten, preliminary furnace test and temperature measurement should be performed quickly. Preparatory operations should certainly be performed so that there is no unmatching with mould assembly or waiting for crane.

4.4 Effect of Tap Quantity on Specific Energy Consumption

Due to erosion of lining, the tap quantity increases along with lining life number, which has reduced specific energy consumption in later heats. For a given liquid metal quantity maintain the maximum possible speed charging to reduce heat time and thereby to reduce specific energy consumption Optimum the lining thickness with increased no. of line sintering so as to tap higher quantity and minimize specific energy consumption. Along these, it has been recommended to charge the raw material by bucket/ compact bundle arrangement and to use the cover during initial heating period on the furnace surface.

4.5 Preheating of Material

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 furnace consumes 87% of the total power consumption required for melt down. Remarkable power saving may be realized if raw material is preheated up to 500 - 600°C by any method more effective than induction heating.

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 wall damaged by erosion should be repaired to maintain the standard diameter in respect to thermal efficiency of the furnace.

4.6 Furnace Lid and Charging

The furnace lid has to be opened every time the furnace is charged. Enormous heat losses occur if the molten meta1 is exposed and any delays in charging of low bulk density scrap or failure to re close the furnace lid result in decreased furnace efficiencies.

The important energy conservation opportunity found is preheating the scrap, so that the moisture from the scrap can be removed which reduces the heat time and specific energy consumption. It is observed that for the first 10 minutes of a heat the total quality of scrap in the crucible consist of pressed bundles (15-20 no's) and there total weight does not exceeds 3000-3500 Tons .The percentage losses in this period are higher as heat is being carried away by cooling water and also being dissipated by radiation and convection losses. The amount of metal that is being heated up is small. The time taken to melt this initial charge is also more because of low bulk density of the charge.

The bottom hinged doors of the bucket are tied by rope and open after the rope and gets immediately burnt because of the heat from the furnace. In this way well-packed scrap is initially charged into the furnace. Scrap is put at the bottom to prevent escape of any heavier pieces of Scrap during transportation.

The MS scrap has high bulk density. This enables the crucible to be packed with this scrap ensuring quick transfer of heat. It is estimated that by this method of initial charging nearly 5-7 minutes of total heat would be reduced resulting in corresponding energy savings. No capital investment is required as the bucket can be fabricated in the plant.

4.7 Slag Removal

Normal practice is to remove the slag manually with hand spoon or tilt the furnace forward and take off the slag through the pouring spout into a crane held slag box. A similar solution is to tilt the furnace backward like arc furnace and drain the slag in slag-box. Another method is to use a crane suspended pneumatically operated slag -grab which will perform the task in **a** very short time.

4.8. Control of Slag

The incorporation of 0.5 to 2.0 pounds of Redux EF40L flux per ton of metal has significantly improved the inductor life of pressure pour furnaces, coreless induction and vertical Channel furnaces. Redux EF40L has been successfully used in the production of gray and ductile irons as well as high alloy irons and steels to minimize slag build up on furnace sidewalls and ladles. Using recommended addition rates, Redux EF40L flux effectively combats slag build up without the adverse effects of aggressive refractory attack or emissions of fluorine or chlorine gases. Flux additions can significantly improve furnace performance and prolong useful ladle life.

V. CONCLUSION

So, in this paper, we are focusing on improving the efficiency of steel melting processes. After actually watching all the steel melting process, we came to know that what are the various losses and where heat is lost. Hence for improving its efficiency and for reducing the losses we have made recommendation, if this comes in regular practice obviously it helps to increase its efficiency. The heat loss in the furnace is major due to open mouth of furnace, due to transmission of molten metal through transfer media, and mostly we are concentrated in this paper to avoid such loss, so that maximum power is saved.

Material and energy losses during these process steps represent inefficiencies that waste energy and increase the costs of melting operations. It is, therefore, important to examine the impact of all proposed modifications over the entire melting process to ensure that energy improvement in one step is not translating to energy burden in another step.

Although these technologies require little or no capital for deployment, engineering assistance is needed for the facility to reap its maximum benefits. The study concludes that to achieve energy reduction goals, renewed R&D efforts must target the current technical barriers in the melting technologies and pursue multiple paths as recommended (Result & Discussion). Advances from such efforts will not only save substantial energy in the overall melting process, but also provide high-quality molten metal that will reduce the cost of the casting process and enhance the quality of the final casting product.

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