CHAPTER 5

MODIFICATIONS IN ENERGY OPTIMIZING FURNACE

The 35 MT EOF operating in India at Hospet Steels Ltd and SISCOL are successful on commercial scale since the total steel produced by these units up to 31st March 2008 has been 4.42 million ton (Figures 1.2 and 1.3).

The steel produced through respective EOF was meeting the safety, quality and norms for cost of production. There have been a number of modifications carried out in the EOF to make it suitable for the local conditions in India. Simplification of certain design parameters have been made in order to ensure repeatability of the process for consistent production. The inputs consisting of hot metal and scrap for any melting furnace is location-specific in order to achieve economic production. Keeping the local inputs in mind, certain changes in the design have been incorporated to achieve successful operation of the EOF.

5.1 SCRAP PRE-HEATING SYSTEM

In a conventional EOF, scrap charge for the subsequent heat is heated to about 900º C by the off-gases of the running heat. The scrap is stored on the water-cooled fingers and the hot gases evolved at about 1200º C pass through the scrap and thereby heating the same. The scrap pre-heating arrangement is provided in the EOF in order to have flexibility to charge up to 50% scrap and balance 50% hot metal. This facility was provided to suit the EOF operation in various locations and depending on availability and cost of hot metal vis-à-vis scrap, which is location-specific, EOF can still be operated
economically. Under Indian conditions, scrap availability is very poor and the scrap price is very high. Hot metal is the cheapest source of metallics for the EOF.

Hence, it was found that under Indian conditions, the EOF is best operated with 80% hot metal and 20% solid charge. Under this situation, the EOF melting process is autothermic where, by the time Carbon is oxidized to the desired level, the scrap melting and bath temperature reaching the tapping temperature takes place in a balanced manner. Trials were conducted by pre-heating 20% scrap in the charge in the conventional manner in EOF. Since scrap was present in the gas passage, two numbers ID fans were operated to maintain negative pressure inside the EOF. Moreover, significant reduction in the blowing time or tap-to-tap time was not found while pre-heating only 20% scrap. The water-cooled fingers used for holding the scrap were very maintenance prone and lot of down time was observed due to water leakages. There was no by-pass system provided for the off-gases in the SPH area. Since the scrap percentage was only 20%, a lot of times, it was found that the scrap had actually started melting which resulted in blockage of the passage for exhaust gases. This was a very unsafe thing to happen since positive pressure start building inside the EOF that resulted in flame shooting out of the EOF which is very dangerous. Moreover, molten metal caused stickers on the fingers that reduces service life. The control of off-gases using dilution air through forced draft fans was not really very effective. Hence, it was concluded that under Indian conditions, the scrap pre-heating arrangement was giving more trouble and there was very little benefit derived from the same. Therefore, steps were taken to remove the fingers from the scrap pre-heating arrangement of the EOF, which was major change in the design parameter of the basic EOF. After removal of the scrap pre-heater, it was found that the oxygen blowing time of 30 to 35 minutes could be maintained and therefore, productivity was not hampered. The EOF could be run with one
ID fan in place of two numbers which has reduced the power consumption by 10 KWH per MT (20%). The down time of the EOF got reduced since the fingers were removed from the scrap pre-heating system. This also gave a lot of simplification in the hydraulic system as well as water system in the scrap pre-heating area.

Removal of the scrap pre-heating system gave rise to higher temperature of the off-gases into the gas cleaning system. This resulted in solidification of the fumes in the gas cleaning inlet. In order to reduce the off gas temperature from 1200º C to below 1000º C, additional spray was put in the post-combustion area using water and air spray nozzles.

Water spray box was added in the off gases outlet of the scrap pre-heating area. Lastly, further water jets were added in the down-comer of the EOF in order to bring down the temperature of the off gases which helped in proper working of the EOF.

The scrap charging bucket has been modified when fingers were removed from the EOF, in order to discharge the scrap into the EOF from the same level as the fingers before. This was done to ensure that the hearth of the furnace does not get damaged due to discharge of solid scrap pieces from a greater height.

The modifications carried out after removal of water cooled fingers, addition of water sprays and modifications of the scrap bucket is shown in Figure 5.1.

This was one of the major modifications carried out in the EOF basic design that ensured good availability of the equipment without
sacrificing productivity. In fact, there was a saving in the energy consumption to the extent of 20% and overall increase in productivity.

Figure 5.1 Furnace with water cooled fingers and furnace after modification

1. Water spray nozzles
2. Water spray box in off gas outlet
3. Spray nozzles in downcomer
4. Water / air spray nozzle in Scrap Pre-Heating
4. Modified Scrap Bucket
5.2 DOUBLE SHELL PRACTICE

Originally EOF had two bottoms, rail mounted, on the respective trolleys and having common shell and roof. In the EOF there are 49 water cooled elements in each shell and roof. Proper maintenance of the water cooled panels is most important for safe operation and controlling the down time. It was found that with common shell and roof, the bottom change over time was at least 12 to 16 hours and time was never available for attending the water cooled panels. At times, there was failure of water cooled panels during EOF operation which caused water leakage inside the furnace on top of the liquid metal. Such situations are very dangerous and they can cause serious accidents. Hence, steps were taken to fabricate one more shell and roof. Thus, we had two complete furnace bottom shell and roof placed on their respective trolleys. While one shell was in operation the refractory relining work on the stand-by shell could be carried out off line. The maintenance of water cooled panels in the spare shell could be carried out with ease. The shell and roof were cleaned 100%, painted and were made ready for operations. The down time and safety of operations improved significantly after double shell practice was introduced as shown in Figure 5.2 (a and b).

This also helped in reducing the bottom change over time to eight hours. This was also a major step towards ensuring safe operations and high equipment availability of the EOF. With the help of this modification, the EOF availability per year improved from 330 to 345 days, which is quite comparable or better than other steel making process routes.
1. Scrap bucket
2. Top sliding door
3. Scrap pre-heater
4. Water cooled panel
5. Supersonic lance
6. Atmospheric injector
7. Submerged tuyer

Figure 5.2(a) Running bottom car with stand-by bottom

1. Scrap bucket
2. Top sliding door
3. Scrap pre-heater
4. Water cooled panel
5. Supersonic lance
6. Atmospheric injector
7. Submerged tuyer

Figure 5.2(b) Running bottom car with stand-by bottom and shell
5.3 INCREASING THE FURNACE CAPACITY

The furnace capacity was increased from 35 to 45 MT by modifying the hearth refractory lining (Figures 5.3 and 5.4). The volume of the hearth was increased from 5.7 m$^3$ to 6.8 m$^3$ by changing the diameter of the hearth. Modified refractory bricks were placed and the quality of the back up lining was improved. This was done to ensure safety of operation and to minimize the loss of heat to the hearth refractory, which would cause over heating of the bottom shell. The bottom refractory is most critical for safe operation of the EOF. In order to have 100% safety in this area, the working lining of the bottom was changed in every campaign. The back up lining (second layer) was changed after every alternate campaign. The EOF refractory was purchased only from approved and reliable sources. Moreover, EOF bottom and shell was strengthened in order to withstand additional load. In order to ensure 30 to 35 minutes blowing period along with the increase in the furnace capacity, second supersonic lance was installed and the oxygen blow profile was also modified. However, this also increased the dust load on the gas cleaning system. This was taken care of by putting additional water spray nozzles in the down comer area. The venturi size was increased to the next standard model in order to take care of the increased off gas volume and ensure proper functioning of the Gas Cleaning System. More care was taken for frequent cleaning and maintenance of Gas Cleaning system.
Figure 5.3 EOF (35 MT) refractory bricks

Figure 5.4 EOF (45 MT) refractory bricks
Increase of the furnace capacity to 45 MT per heat also demanded modifications of other upstream and downstream equipment as listed below:

1. The hot metal ladle capacity was increased from 35 to 40 MT
2. The hot metal transfer car was strengthened.
3. New set of steel ladles were ordered having a capacity of 45 MT
4. The steel ladle transfer car was modified to handle the additional load
5. The wheels and wire ropes of the steel ladle handling EOT cranes were checked for safe operations. The wire rope was changed to height and size quality to ensure safe operations.
6. The continuous casting structure was strengthened to handle the additional load.

The increase of heat size to 45 MT in the EOF was a very important step, which gave 20% increase in productivity. Amongst the existing EOFs operating in the world, after due consideration of all aspects, this was the first to increase the EOF capacity to 45 MT. After seeing the success of this EOF, the other plants are now planning for the same. Hence, this was a pioneer work done in the field of EOF. Now we are working on the project how to increase the EOF capacity to 50 MT.

5.4 MANAGEMENT OF WATER-COOLED PANELS

The shell of the EOF above the slag line has two layers of pipe-to-pipe construction water cooled panels. It was found that failure of the water
cooled panels next to the slag line was very frequent due to higher thermal load. Same feedback was received from the other plants where the water cooled panels in the lower level failed very frequently and this led to excessive down time in the EOF. To overcome this problem, brick lining was done inside the EOF shell up to the first level of water cooled panels. To save the cost, normally used bricks from the previous campaign were used for such purpose. Within a couple of heats the slag layer was formed on these bricks and thus enabled it to last the entire refractory campaign. This has almost eliminated the failure of the first layer of water cooled panels which was very frequent earlier. The water cooled panels were procured only from approved sources. Each water cooled panel was checked for continuity of water flow and also pressure tested before putting into use. All temperature sensors and display in the control room screen were kept in healthy condition to ensure that the outlet water temperature is monitored continuously. In case of any malfunctioning and thereby increase in the outlet water temperature of any panel, there would be alarm on the computer panel such that immediate steps for rectification could be taken. The specified negative pressure (-200 mm water column) inside the furnace shell was maintained to form a slag / metal coating on the EOF water cooled panel in the shell and roof which reduce the thermal load on the water cooled panels and thus prolonged their service life. The double shell practice provided opportunity for good inspection and maintenance of the water cooled panels. After studying the previous data, life of the water cooled panels for different areas was fixed as under:

(a) Shell panel (lower) 10000 heats  
(b) Shell panel (upper) 10000 heats  
(c) Roof panel 7500 heats  
(d) Roof upper piece and sliding skirt 2000 heats  
(e) Scrap pre heater lower piece 2000 heats
The position of the atmospheric injectors, which was accommodated in the upper portion of lower panels of the shell was shifted to lower part of the upper layer of water cooled panels in the shell. The post-combustion of the gases from EOF were still taking place very efficiently and this did not affect the thermal balance or the blowing period in the EOF.

5.5 SUBMERGED TUyERES

Originally there were four numbers submerged tuyeres in the EOF having internal diameter of the copper pipe of 18 mm. The four tuyeres (T2, T1, T3 and T4) were placed at 45°, 135°, 225° and 315° respectively with tap hole as 0° position. It was found that the erosion of the refractory near the tuyeres was very high resulting in short refractory life of 400 to 450 heats. Loss of liquid metal while deslagging through the slag door was also high due to two tuyeres (T1 and T3) being very close to the slag door. In order to take care of these problems, extensive trials were conducted and finally the inner diameter of the copper pipe was reduced from 18 mm to 16 mm and finally to 14mm, while keeping the oxygen quantity through the tuyeres as before. This increased the oxygen velocity in the tuyeres and shifted the flame away from the furnace refractory. This gave a very significant improvement in the refractory life from 450 heats to 900 heats per campaign. There was reduction in the gunning material consumption as well.

The blowing time of the furnace is a function of the amount of oxygen injected. this also increases the amount of turbulence created inside the steel bath, which promotes mass transfer as well as formation of small droplets of the steel bath which speeded up the de-carburization process as per Hirata (1992).
After extensive trials the position of the tuyere no.1 earlier at 135° was shifted to 90° and tuyere no.3 earlier at 225° was shifted to 270°. This improved the overall processing of the melt in the EOF while containing the blowing time. Moreover, the visibility of tuyere no.1 and 3 through the slag door also improved, which facilitated proper maintenance of these tuyere areas.

Now we are working on the project to use ceramic tube holding the copper tuyeres. This would reduce the consumption of the tuyeres and also expected to reduce the refractory erosion in the tuyere area.

The modifications listed above helped in big way to achieve stable operation of the EOF under Indian conditions. Rated productivity was achieved through control of down time. Cost of production was achieved by using locally available metallic inputs.