Improving availability of EAF by avoiding mechanical delay

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Abstract-The EAF is a highly energy intensive process used to convert scrap metal into molten steel. The aim of this project is avoid the mechanical delays in EAF of Steel Melting Shop. This paper has main contribution to avoid delay due to adverse effect of EAF cooling system. Adverse effect of EAF cooling can be avoided by providing pressure reducing arrangements. Avoiding these major mechanical delays results with improved availability of the Electric Arc Furnace, and fulfill the objective of the project in order to increase productivity.

Index Terms—EAF cooling system, Maintenance practices, Adverse effects of EAF cooling systems, Application of QC tool, Finding root cause, Development of solution, and Improving availability of EAF.

1. INTRODUCTION

Electric arc furnace (EAF) uses electric arc to heat the charged material. Usually in industries the arc furnaces ranges from 1Ton to 400Tons capacity are installed to produce cast iron products.

EAF used in secondary steelmaking includes water-cooled refractory lined large vessel which is covered by roof. In the roof up to 3 numbers electrodes are fixed in the furnace those electrodes are made of graphite material. The furnace is divided into 3 parts as follows,

- The shell, it includes sidewalls with lower steel "shell";
- The hearth, made by the refractory and the lower shell is line by the hearth
- The roofhaving shape of sphere and water cooling arrangements. A refractory delta is placed in center of the roof in which electrodes are fitted

EAF is placed on tilting platform to transfer metal from furnace to a ladle after converting pig iron to liquid steel. The process to rotate the furnace to transfer molten liquid steel is named "tapping". The tapping point is formed by using refractory so that all the metal will be removed completely by tilting the furnace, furnace has eccentric bottom tapping (EBT) to decrease slag and nitrogen in liquid metal.

2. LITERATURE REVIEW

The manufacture of iron for tools, implements, and constructionmaterial goes back to 4000 BC. From 1850 until 1960, the Coke-Blast Furnace became the leading reduction process. The OHF and pneumatic air blowing – processes were for mass-production of steel.

Most of the arc furnace use air cooling system for structural elements of shell and roof, but larger capacity furnaces requires water cooling system to maintain the EAF structure to operate within safer operating conditions. The upper shell and roof cooling takes place by a panel of water circulation piping system. The pipe leakages are immediately found in the operating systems by continuous monitoring of pressure losses in the cooling systems. An alarm system is provided to take immediate actions on normalizing the pressure drop and avoiding abnormal operations. These actions help in hiding the major accidents like hearth breakouts and molten metal explosion.

Carbon injector burners are combined with oxygen injection burners in the form of single housing and these are installed on upper shell side wall. These create a jet so they are called as jet burners; it has functions of decarburization of steel bath, gives thermal energy as input and forms a foaming slag with reduced carbon requirement.

Effective maintenance is needed to reduce refractoriness cost and improving the life of the furnace. Long time gunning maintenance of side wall practice is necessary. Usually the water cooled panels cover the gunning materials and improves the life of it. Dolomite injection improves the life of shell by acting as a slag conditioner agent and minimizes the replacement of carbon injectors. Water leakage of roof can also be arrested by bypassing the cooling water with reduced pressure in the system.

3. PROPOSED APPROACH

Shrouding is a process of pre heating the refractory to maintain the internal temperature; for shrouding 3 oxygen injection systems are used, these injection systems are made of copper material and needs continuous cooling. Whenever water leakage occurs in roof of EAF, need to reduce the water pressure to arrest the leakages by isolating the roof cooling system with maintained cooling in other systems. There is no arrangement to reduce the pressure, so presently stopping the pumps manually. Manual stopping of pumps cannot be started in auto mode, to start in auto mode need to stop all the pumps. At this time continuous cooling stops in shrouding process, due to this the copper material of oxygen injection system melts and causes major delay.

Objective is to avoid mechanical delay due to adverse effect of EAF cooling system to improve availability of EAF in order to increase productivity.

4. ANALYSIS OF THE ADVERSEEFFECTS OF EAF COOLING SYSTEM

There are 4 number of SIS (SIEMAG Injection Systems) are installed in EAF which is made of copper material and running at 1000^{0}C and it needs continuous cooling system with 6.4bar pressure.Whenever leakage occurs in roof or panel of EAF we need to reduce the line pressure to 6.4 to 5bar. To reduce pressure we need to stop one motor in manual mode and to take again in auto mode we need to stop all 3 motors.While taking in auto mode we observed that SIS copper materials melts due to high temperature and cause delay about 3-5 hours.

Also observed that there is hammering effect due to sudden impact on pipeline during starting of EAF cooling pumps in auto mode.Due to hammering effect there are chances of damaging Hose pipes, gaskets and leakages through flange joints.

A simple technique used to define the problem is 5W+1H analysis. This provides the simplest way to get the all the information related to problem and the responsibilities related to it. By applying 5W+1H analysis the problem is defined as follows,

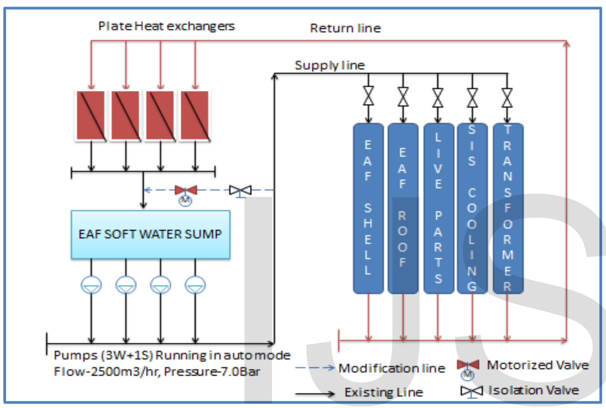

Fig 4.1 EAF cooling system circuit diagram

- **What is the problem?**
  - ➢ Adverse effects of EAF cooling system.
- **Who is responsible?**
  - ➢ Water system shift in charge.
- **Where does it happen?**
  - ➢ In EAF cooling systems.
- **When does it happen?**
  - ➢ During starting pumps in auto mode after arresting roof water leakages.
- **Why does it happen?**
  - ➢ Delay during starting pumps in auto mode.
- **How does it happen?**
  - ➢ During continuous operation of systems.

Definition of the problem indicates that the adverse effect of EAF cooling system during mechanical maintenance activities causing the major delay. Adverse effects includes, roof leakages, delay during starting of pumps, burning of copper burners, live parts hose damages, gasket failure and hammering effect of pipeline during starting of pumps. Delay due to all these problems are interlinked to each other by a common root cause which results in causing major delay.

To avoid this delay, analysis of the problem is required to find out the root cause.

A best tool for finding the root cause is cause and effect diagram which shows the different causes in its major bones and root causes in its sub branches. Such a root cause analysis is been carried out using cause and effect diagram below.

5. FINDING ROOT CAUSE OF THEADVERSE EFFECT

To find out the root cause for the adverse effects of EAF cooling system the main problem is related to man, method, machine and material using cause and effect diagram as shown in fig 4.2.

From the analysis it is observed and selected the repeated cause. Found that there is no bypass line in cooling water supply header pipeline is the root cause for all the type of adverse effects of EAF cooling system.

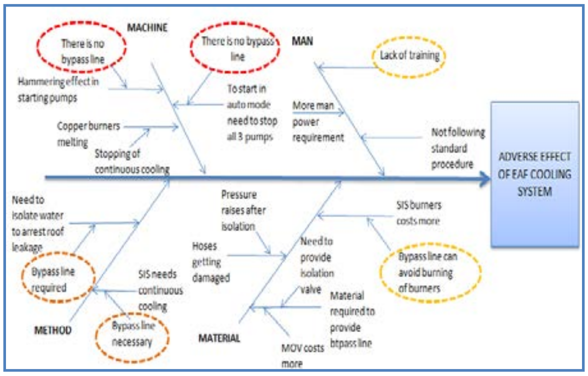

Fig 4.2 Cause and effect diagram for finding root cause

Here selection of the cause plays an important role, so that root cause is one which is affecting to most of the sub branch problems. From the above cause and effect diagram a root cause is selected to as ''There is no bypass line in cooling water header pipeline''. By attacking to a single root cause most of the problems can be avoided and this results in avoiding major mechanical delay during maintenance activities.

5.1 Suggestions

- A bypass line can be provided from EAFcooling header pipeline to EAF cooling water sump through the Heat Exchanger outlet line.
- A manual butterfly valve to be provided for isolation
- A motorized butterfly valve to be provided in bypass line to avoid adverse effect during operation
- A Local Control Station to be provided in WCS control room for regular operation during starting of EAF cooling pumps.
- Based on the above suggestions, initially discussed about what all the material required for the completion of the modification work. Made a list of required materials and checked for the availability of those materials at site. It is found that most of the materials are available at site and a piping contract is allotted for completion of the project.

6. DEVELOPMENT OF SOLUTION

About 10 meter piping done with DN 300 pipe, a manual butterfly valve provided for isolation and a motorized valve is provided for continuous operation. Electrical cable connections are made to take feedback of this valve in the control room HMI screen for continuous monitoring.

Whenever the leakage occurs in roof or panel we can bypass the flow of water to reduce pressure from 6.4bar to 5bar and after arresting leakage by closing bypass valve we can attain the 6.4bar pressure without disturbing the SIS system. Provision of bypass line with motorized valve smoothen the operation of EAF cooling pumps during start up.

Continuous cooling of SIS and smooth operation avoids the delay and it makes the safe working environment.

7. RESULTS

Availability is well established in literature of stochastic modeling and optimal maintenance. The simplest representation for availability is as a ratio of the expected value of the uptime of a system to the aggregate of the expected values of up and down time.

i.e Availability(%) = Uptime / (Uptime + Downtime) * 100

Availability of EAF before completion of project is calculated by considering average delay in 6 months from April 2016 to September 2016.

The results are as follows,

- Delay due to other maintenance activities = 44 hours
- Delay due to adverse effects of cooling systems = 38.11hours
- Total delay during EAF maintenance in 6 months = 82.11 hours
- Average Delay during each EAF maintenance activity (Down time) = 16.4 hours or 984 minutes
- Calendar time available for production of steel = 24*60*30 = 43200 min
- EAF Up time = 43200 – 984 = 42846 min

Availability = Uptime / (Uptime + Downtime) * 100

= 42216 / (42216 + 984) * 100

= 97.72 %

Due to this 16.4 hours non availability of EAF, production of liquid steel was affecting and unable to achieve monthly production target. This delay is avoided from the project work and improved availability of EAF to achieve monthly target.

After completion of the project, availability of EAF is calculated by considering average delay in 6 months from October 2016 to April 2017.

The results are as follows,

- Delay due to other maintenance activities = 8.5 hours
- Delay due to adverse effects of cooling systems = 0 hours
- Total delay during EAF maintenance in 6 months = 8.5 hours
- Average Delay during each EAF maintenance activity(Down time) = 1.7 hours or 102 minutes
- Calendar time available for production of steel = 24*60*30 = 43200 min
- EAF Up time = 43200 – 102 = 43098 min

Availability = Uptime / (Uptime + Downtime) * 100

= 43098 / (43098 + 102) * 100

= 99.76 %

Improved availability of EAF is the difference between availability of EAF after completion of project and availability of EAF before completion of project.

i.e Improved availability = 99.76 – 97.72

= 2.06 %

Available time for more liquid steel production is calculated by taking the availability and the calendar time,

i.e Uptime = (Availability * calendar time) / 100

= (2.06 * 43200) / 100

= 864 minutes.

Availability of electric arc furnace from is improved by14.4 hours and the major problem during EAF maintenance activities is completely avoided.

The results are compared using pie chart by considering the six month data before starting project and six month data till completion of the project.

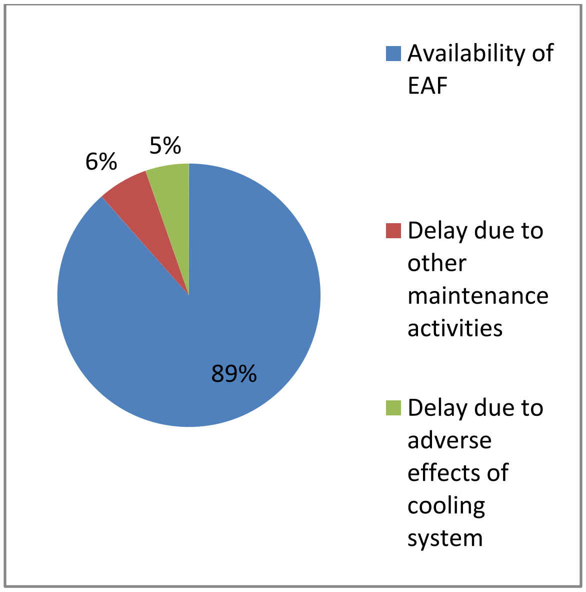

Fig. 7.1 Availability of EAF before starting project

From the above graphs it is observed that, before starting project there was 6% delay during shell changing maintenance activity and 5% delay due to adverse effects of EAF cooling systems.

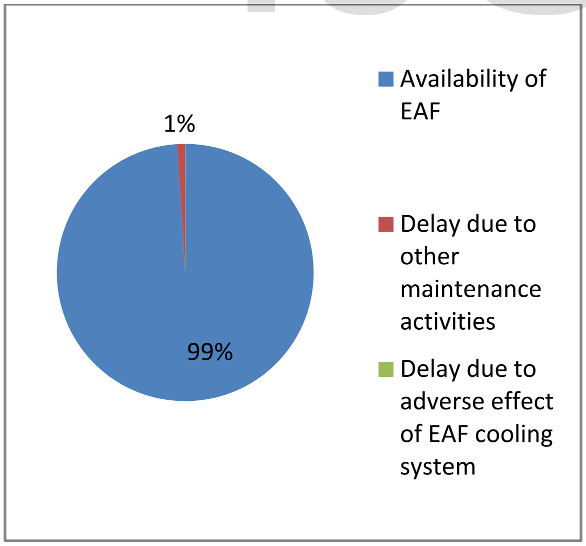

Fig. 7.2 Availability of EAF before starting project

After completion of the project the delay due to other maintenance activities is reduced by 5% and the delay due to adverse effects is completely avoided.

8. CONCLUSION

- Clearly defined the requirement of a bypass line in the cooling system which can avoid all the adverse effects of EAF cooling system.
- Burning of copper burners is completely avoided by providing continuous cooling for SIS.
- Damage of live parts hoses and water leakage due to gasket failure is been avoided by reducing pressure by using bypass line instead of closing the roof cooling line.
- Hammering effect is avoided by standardizing operating procedure of starting EAF cooling pumps

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