REMEDIAL FORENSICS TO IRON FOUNDRIES

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ABSTRACT

The present paper highlights the practical problem or danger of electric induction furnaces and preventive measure to be taken during melting of iron/metals in foundries that can avoid catastrophes. During the course of investigation it was found that improper lining of refractive materials that provide the thermal insulation between the direct contact of hot molten iron (~ 1500°C-2000°C) and hollow copper pipes through which water/ coolants flow of the induction furnace could cause accident similar to volcanic eruption. This paper is concerned with the vulnerability of induction furnaces in foundries and hence seeks the attention of technicians and induction furnace makers and also engineers and supervisors of foundries in order to avert such untoward incident.

I. INTRODUCTION

The present piece of work consisted of five sections. The first section would introduce to various sections of this paper. The second section would focus on the incident and the background of this investigation. The third would highlight on the technical aspects of induction furnaces and refractory materials in iron foundries. The fourth section presents the results of our investigation that led to the accident. The fifth section concludes the paper giving possible remedies to such occurrences.

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THE BACKGROUND OF THE INCIDENT

In an iron foundry named ‘Vision Sponge Iron Private Limited’ at Rakta, in the rural belt of the district of Purulia under Santuri Police Station, West Bengal, India, a blast took place at a furnace on 26.12.11 at about 10.30 hrs. Fortunately, there was no one close to the site at the time of blast. But the impact of the blast was so immense that seven workers who were few hundred yards away center of blast were severely injured, asbestos sheds at a height of 100 feet above the head of the furnace flew away apart and glass panes of the windows of the office at a distance of about 200 meters from the epicenter of the blast, banged and broke off into pieces.

On the basis of the complaint lodged by the local residents a case was registered against the owner of the said foundry at Santuri P.S. of Case no. 58/11 dated 26.12.11 under section 287/336/337/338 of Indian Penal Code. The State Forensic Science Laboratory (SFSL), West Bengal was asked to visit the spot to ascertain the cause of the incident and their views. The authors of this paper visited the site on behalf of SFSL on 06.01.12 to diagnose the incident.

II. THE INDUCTION FURNACE AND REFRACTORY MATERIALS

In the present day the induction furnaces are widely used as clean, energy efficient and controllable way to melt metals and are fast replacing cupolas [1] from the foundries. The capacities of induction furnace range from few kilograms to hundred tones. There are two main types of induction furnace firstly, the coreless induction furnace [2] and secondly the channel-type induction furnace. In the present case we found the furnace to be coreless type of induction furnace (Fig.1). The coreless induction furnace works on the principle of a transformer where the hollow copper pipes acts as the primary and the charge material (iron/metal) behaves as the secondary. When a high frequency electric current is passed through the primary coil, a much heavier secondary current is induced in the charge. Thus heat is generated, (Joule’s law of heating, $H=i^2Rt$) [3] due to the resistance of the metal causing it to melt. The liquid metal undergoes a stirring action due to the ‘*eddy currents*’ [3] induced by the EMF (Electromagnetic Force) [3] that is concentrated in the center of the circular primary coil. When the molten metal has reached the desired temperature, the metal is deoxidized and tapped into ladles for pouring into moulds to cast into various shapes. The operating frequency of the coreless induction furnace varies from 50 KHz to 400 KHz, depending on the type of the material to be melted (charge), the quantity of the charge and the melting speed. Generally, larger the volume of charge lower the frequency of induction furnace is required. This is due to the '*skin depth'* [3], which is the measure of the distance that an alternating current can penetrate the surface of any metal/ conductor. This distance falls off exponentially with the frequency of the current. The input power supply coreless induction furnace ranges from 10 KW to 15 MW depending on the quantity of the charge or melt. In coreless induction furnace the crucible [4] is lined with refractory material [5] that contains the charge which rests on the brick work and surrounded by circular coil made of hollow copper tube. The copper tube having high thermal conductivity of heat [6] requires active cooling to keep it below the melting point (~1084°C) during the melting process of iron (melting temperature of Fe ~1540°C) which is achieved by passing a flow of water through the hollow space of the copper tubes.

III. THE INVESTIGATION AT THE PLACE OF OCCURENCE

We found the furnace was kept in dismantled condition (Fig.2) inside the foundry. It had a height of about 217 cm and internal diameter of about 172 cm. The thickness of the refractory lining of the crucible along the inner side of the furnace was about 23 cm.

It was found that from about 57 cm up to 107 cm of height from the ground level, the hollow copper pipes melted and sheared off, bent outward (Fig.3 and Fig.4) with molten iron flux sticking to it (Fig.5) at about 3'O clock position with respect to inlet/ outlet of water jet (Fig.6). The inner crucible part inside the furnace at this position suffered major damage. More over it was observed from the remnants of the molten flux that the crucible was one third filled at the time of blast.

The aforesaid observation suggested that the lining of refractory material of the inner side of the furnace making the crucible part happened to have bore damages (development of cracks/ fissures) (Fig.7) at the affected position and therefore copper pipes came in contact with the molten flux at the furnace temperature which is much higher than the melting point of copper. As a result the copper pipes melted and water circulating through the hollow copper pipes came in physical contact with molten iron. The molten iron flux being at a much higher temperature than the steam point of water (100°C at 76 cm of Hg) the circulating water immediately vaporized and underwent expansion that caused the blast.

IV. THE REMEDY

The remedies to such type of incidents are manifolds. It starts from the makers of induction furnaces. The thickness of the refractory lining of the crucible should be optimum. The choice of refractory material should be governed by the nature/ type of melt. The nature of the refractory material should strictly be acidic or alkaline or neutral in accordance as the slag material and the atmosphere of the charge is acidic or alkaline or neutral respectively. Depending on the operating environment, they need to be resistant to thermal shock [7], chemically inert and or have specific thermal conductivity and their coefficients of thermal expansion [6] as well.

Furthermore, perhaps the most important role to be played actively in prevention of such accidents at all the times; right from the installation of the induction furnace to its disposal is by the technical supervisors and maintenance staffs of the foundries. They should regularly check the condition of each and every part of the furnaces.

Moreover, during the course of investigation another pertinent point which surfaced out is the '*alarm*' system. The alarm system should be such that it would create alert the people/ workers who are at the vicinity of the furnace when certain critical temperature is attained and thereby the circuit of the furnace should automatically snap off by use of thermocouple [6, 8, and 9] or by any other type of circuit-breakers or thermostats [10]. The alarm did not work in the present case. Had it worked the fatality of such incidents could have been avoided.

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FIGURES:

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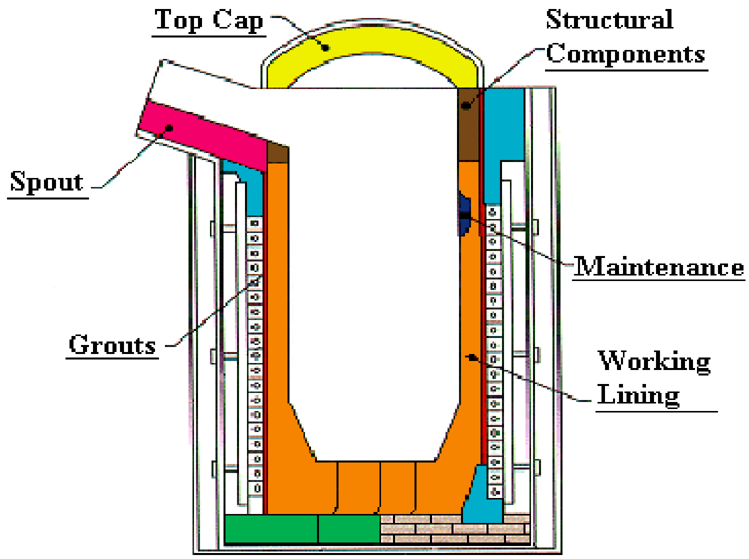

Figure1. Line diagram of a coreless induction furnace.

Figure2. The furnace kept outside in dismantled condition.

Figure3. Hollow Copper pipes bent outward.

Figure4. Hollow Copper pipes sheared off and bent outward at the position of blast.

Figure5. Molten iron (after solidification) sticking around hollow copper pipes.

Figure6. Inlet and outlet of water through hollow copper pipes.

Figure7. The damaged refractory lining on the crucible part.