MODERN PRACTICES OF POST TAPHOLE OPERATION IN FERRO CHROME PRODUCTION AND ITS ADVANTAGES

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ABSTRACT

Improvement of post tap hole practices is achievable by mechanized handling of melt during the production of Ferro Chrome, resulting in higher recovery of chromium.

The paper deals with modern practices adopted in the production of ferro-chrome since past two decades. The methods and practices deal with various areas :

a) Improved method of operating the tap hole by selection of right quality of refractory to maintain the life of tap hole.

b) Collection of melt in different types of receptacles like refractory brick lined mild steel ladles, cast steel ladles, cast iron pans being chosen for cost effective and efficient handling.

c) Separation of slag and metal, casting of metal, crushing, sizing and stock piling etc.

d) Slag disposal and recovery of entrapped metal.

The drive behind the above development is continuous improvement, which results in higher chromium recovery and reduces loss of metal in slag by completely mechanized method so as to be at the same level with producers of ferro-chrome in other advanced countries , in the emerging global economy.

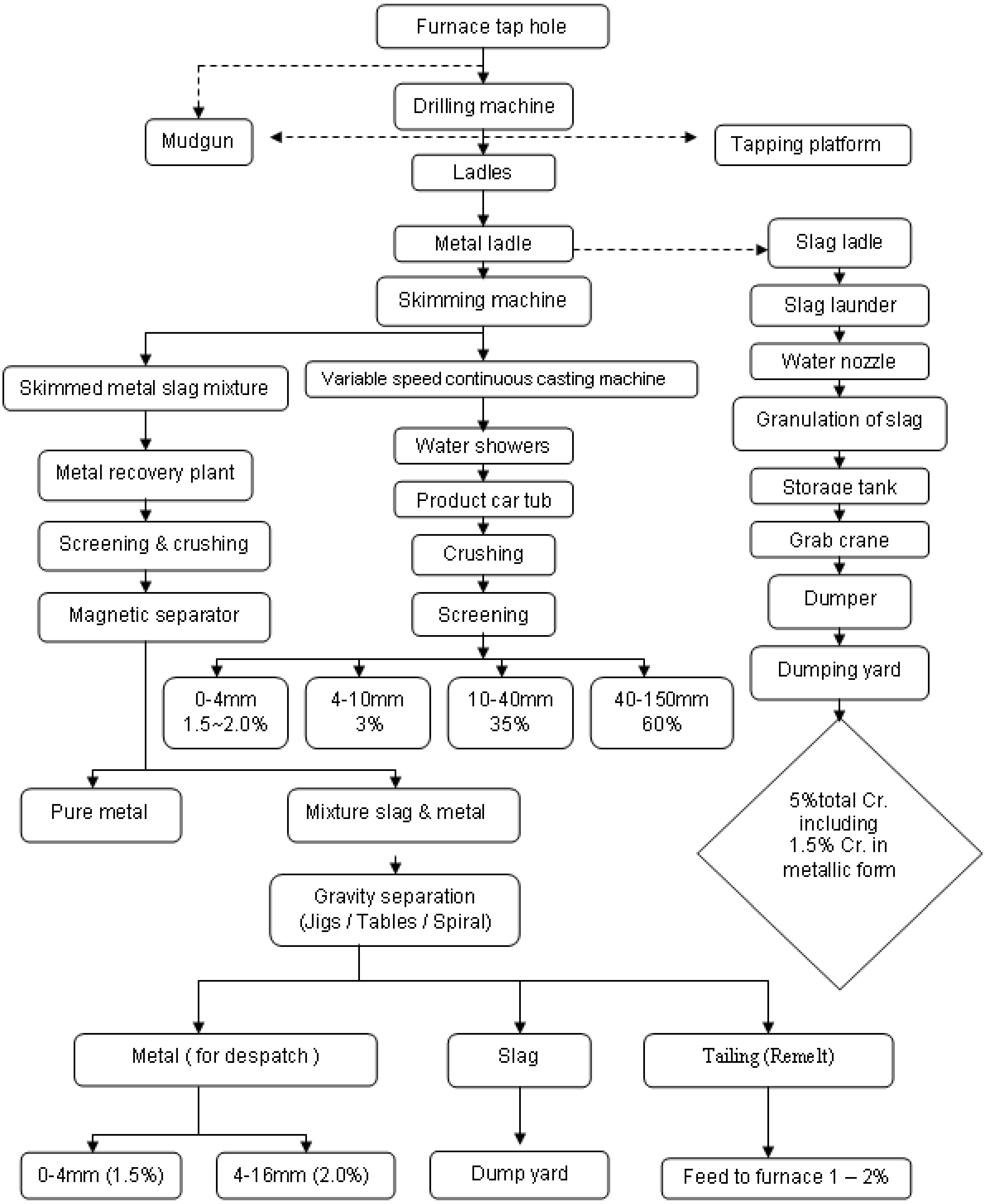
1. INTRODUCTION

The true economics of any production plant are not calculated on the basis of hot metal tapped out but on the basis of the sized slag free metal sold ! Hence it is the endeavor of every operator to try to achieve the ratio of sized metal sent out, to hot metal produced, as close to unit as possible.

This paper presents the first hand experience gained in utilizing the concept and design of post tap hole operations in a 45 MVA submerged arc furnace. During the early 1980's work under taken for initial installation of the submerged arc furnace and auxiliary equipments from Japan. The subsequent additions have driven to exhibit a history of break through in over all operational efficiency, ultimately bringing down the cost of production.

The flow sheet for handling of metal and slag in mechanized way is presented below in details.

2. MECHANIZED FLOW SHEET FOR HANDLING HIGH CARBON FERRO CHROME METAL 62000 T/Y AND CORRESPONDING SLAG



3. POST TAPHOLE CONCEPT

Post tap hole treatment plays the role once the melt in the furnace is ready for tapping. Smelting process efficiency is determined in two parts.

First part efficiency depends on -

- Furnace design parameters.
- Appropriate raw material.
- Accurate weighing, batching and feeding system
- Proper process control to achieve desired slag and metal composition.

Second part efficiency depends on post tap hole processes comprising of -

- Tap hole installation. (location and refractory lining around tap holes)
- Repair of tap hole.
- Suitable tapping platform.
- Drilling machine for drilling the tap hole prior to oxygen lancing.
- Mud gun for proper closing of the tap hole.
- Receptacles for collection of liquid metal and slag.
- Skimming of floating slag on hot metal prior to casting.
- Casting of alloy in safe, economical and environmentally acceptable manner achieving compact structure of metal.
- Method for slag disposal and/or utilization
- Crushing, sizing and handling of finished product.

4. TAPHOLE INSTALLATION

4.1 Conventional And Freeze Lining Concept

Based on trouble free operation in past two decades, it was opined to retain the conventional lining configuration having three tap holes at 120 degrees arrangement with considerable modification specially in tap holes area, as maximum damage was seen in these areas due to high wear by the fluid melt , oxygen lancing done for opening of the tap holes and very high thermal stresses on furnace shell around tap holes. How ever intensive study and survey was carried out on "freeze lining" concept prior to taking the decision in favour of conventional lining configuration. The major reason being much higher cost of freeze lining.

The theoretical consideration in "freeze lining" is to achieve the low temperature on the inner surface of lining during operation such that freezing takes place of fluid metal and slag and it forms protective accretion (skull) on the hot face of the lining. This is achieved by water cooling on the furnace shell's outer surface, high thermal conductivity lining to get the hot face temperature of the lining material sufficiently below the solidus temperature of the metal and slag being produced. If the frozen accretion is stable, it will become the working lining of the furnace, protecting the refractory and providing insulating layer to keep the heat losses low.

But in the present Indian scenario with process parameters not stable due to frequent changes in composition of input raw materials, variations in power input of furnace, non-availability of experienced personnel to interpret the extensive thermocouple readings, it is difficult to maintain the conditions inside the furnace desirable for a true freeze lining. Hence it may not give the expected life time of over 25 yrs.

The above reasons along with much higher capital costs involved have gone against the proposal of a true freeze lining, though many ferro alloys producers claim the benefits of freeze lining in terms of longer life and faster installation.

4.2 Taphole Configuration

Selection of location and positioning of the tap hole is made on the basis of the past experience, keeping in view the availability for installing the moveable tapping trolley, drilling machine and safe method for collection of the melt such that there is an easy approach to take out the melt to the crane bay for further handling of the melt, in the shortest possible time to avoid skulling in the ladle.

Taphole Lining

Tap hole is lined with micro pore carbon block having 75mm ∅ hole right up to the hot face. Infront of it another 580mm long replaceable micro pore carbon block having 75mm diameter hole upto the cold face of the shell. Due to oxygen lancing for opening of the tap holes, in due course the block gets oxidized and from time to time it must be replaced to keep the tap hole area lining in tact.

- Reinforcement of the side wall refractory lining at the tap hole area with additional carbon ramming by about 500mm extra in the cross sectional area was done keeping in view higher wear by fluid metal and slag and practice of oxygen lancing for opening of the tap holes.
- To keep the hot face temperatures relatively low by providing high thermal conductivity silicon carbide refractory bricks at the tap hole region nearest to the shell which is water cooled.
- We have not provided water cooled copper tube bellows around the tap hole in the carbon block to cool and reduce its wear as any water leakage internally may go undetected and cause more serious damage.

5. TAPHOLE OPERATION

5.1 Temperature Monitor and Control

Monitor – Thermo couples are provided in the refractory during the installation at various places for continuous monitoring of lining condition by recording the temperatures. These temperatures are basis for control of the operations and process.

Control – Increase in the furnace shell bottom temperatures is co-related with penetration of the electrodes, composition of slag and that of the metal. Corrective action consists of controlled slipping and changes in the mix to attain desired composition of the metal and slag, to keep the temperatures under control.

Figure 1: Furnace bottom cooling air outlet

Outer shell of the furnace is cooled with continuous water film all around the shell. The grillage provided at the bottom provides high velocity air flow in which the heat transfer is effective. The heat at the bottom of the shell is dispersed by radial air flow with a velocity of about 10 meters per second.

Additional steel ribs are provided all around the furnace shell to take care of any distortion due to unforeseen thermal stresses.

5.2 Important Aspect for Effective Taphole Operation

Refractory failure occurs mostly at tap hole region due to wear by fluid metal and slag flow and practice of oxygen lancing, So it deserves special attention in installation, operation, repair and maintenance.

Tap hole spout is the most important integral part of tap hole. The spout must with stand the abrasion of flow of the melt during tapings. In the early 80's we used to use only SK 32 alumina refractory bricks along with a layer of Alumina refractory castable. This used to cost more without giving much life as the spouts used to get damaged after about twenty tappings and needed to be repaired with castable frequently. Subsequently we tried using tamping paste/carbon blocks with refractory sand as topping. As some times we used water spray this resulted in damage to carbon block in a short duration. Further trials were made to improve the condition of the tap hole spouts and we started using process slag on top of the refractory lining. This not only increased the life of the spout but also resulted in lower maintenance cost of the spout. In the early 80's the tap holes were opened invariably by oxygen lancing. The tap hole was dug about 100mm manually and then the lancing carried out. The consumption of oxygen was to the tune of about 4 Nm^3 per ton of metal. Drilling deeper prior to lancing has brought down the oxygen lancing requirement. The taphole is drilled about 100cm and then lancing is carried out. Oxygen consumption for taphole opening is brought down to 1Nm^3 per ton of metal by drilling to the maximum length of tap hole. The installation of drilling machines has resulted in reduction of oxygen consumption by about 70% with increased life of the refractory around the tap holes. After draining out the melt the tap hole must be closed using refractory clay. The clay must have certain properties to withstand high temperatures and must not be attacked by the process melt. Usage of inferior quality tap hole clay will result in self tapping leading to the damage to the equipment and also will result in refractory failure at the tap holes. Tap holes are closed manually by making plugs with broken paste pieces and refractory clay by many producers in older and smaller furnaces. In this type of closures the plug do not go deep inside the tap hole leaving the melt close to the mouth of the tap hole. Melt remaining close to the shell tends to cause pressure on the refractory and would result in ultimate failure. In order to over come this electrically driven mud guns put into operation. With the mud gun, the tap hole can be closed deep inside. With this arrangement the pressure of the melt on the tap hole refractory, could be over come. Mud gun clay properties were enhanced by using process slag along with refractory clay , carbon paste and binder.

6. MOVABLE TAPPING PLATFORM

It is equally important to select right type of arrangement for carrying out the taping. One can go for –

1. Rigid type stationary tapping platform
2. Movable type tapping platform.

Generally the selection of the types of tapping platform depends on need base. Most of ferro alloys producers with lower capacity furnaces tend to go for rigid platforms as they are economical and simple.

But for large furnaces they have different methods of collection of melt and they go for the movable type platforms.

The movable tapping platforms have many advantages.

We can mount pneumatic drilling machine on the same platform which reaches closer to the tap hole for carrying out drilling and oxygen lancing. As the platform is movable we can reach closer to the tap hole. This will result in minimum usage of lancing pipe. Once the tap hole is opened the platform is moved away from

Figure 2: Movable tapping platform close to taphole

Figure 3: Movable tapping platform away from taphole

the tap hole zone. Combined application of mudgun, drilling machine and movable tapping platform in post taphole practice gives excellent performance advantages ensuring :

- Longer life of taphole block, spout block as well as longer lining life in the tap hole region.
- Lower cost of consumable materials and tapping tools.
- Shorter tapping duration.
- Easy regulation of flow of liquid slag and metal.
- Emergency closing is possible in case of operational demand to avoid over flow which other wise will have disastrous effect on other equipments in the area.
- Safe working conditions.

7. RECEPTACLES

Selection of proper receptacles for the collection of melt in the production of ferro chrome is need- based and one has to select what is most economical.

The basic idea being collection of metal and slag during tapping and handling of the same so as to recover maximum metal as fast as possible. Various combinations with circular cast iron pans, refractory lined mild steel ladle, refractory lined mild steel ladle with carbon paste inner lining and cast steel ladles were tried.

The mild steel ladles lined with refractory bricks and carbon paste used for metal receptacles resulted in higher recurring expenses on refractory bricks and carbon paste. It did not give the desired economical benefit to the, though the usage of same resulted less skulling of the metal in the ladle.

While going for bulk production it is found to be worth going for cast steel ladles. Cast steel ladles are used by providing coating with the process slag and hence there is no recurring expenditure on lining. The quality of the metal recovered from the ladle skulls is relatively clean so there is less generation of the remelts.

Figure 4: Skimming of floating slag

Figure 5: Casting of metal

8. SKIMMING SYSTEM

It was found that inspite of pouring out some metal with the top slag in the first ladle ,the metal cast in the casting machine had traces of slag. Hence a hydraulic skimming machine was installed to skim away the floating slag from the surface of the metal before casting in the casting machine.

So this is now treated as an integrated part of post tap hole practice. It ensures pure metal for casting and avoids any further handling process for removal of slag from metal except crushing and size wise separation of alloy after crushing.

9. CASTING, CRUSHING, SCREENING & HANDLING OF FINISHED PRODUCT

It is of no use to have a successful smelting operation unless there is proper casting, crushing, screening & handling of finished product to make it salable as per customer's specification. Hence one has to ensure the

Figure 6: Metal solidification with water showers

Figure 7: Cast metal in product tubs

quality of final product for size and chemistry, to achieve closest to unity ratio between hot metal produced and salable product , to minimize proportion of fines while handling the product since they fetch lower price or need to be fed back to the furnace as remelts. Having variable traveling speed of casting machine gives the flexibility to vary thickness in the moulds and supply different sizes of the cast metal as per the requirement of the customers. The mechanized casting machine gives economic advantage and product quality.

The metal after skimming is taken for casting in the casting machine. This consists of setting ladle in pouring stand , hydraulically lifting up of the ladle to pour out the metal at desired rate through the runner into the cast iron moulds. The melt in the moulds is immediately solidified with water jets and falls as pigs at the elevated end of the casting machine.

This results in instantaneous solidification of the metal giving it the desired compact structure. The moulds travel about 28 meters giving required cooling time and when discharged into the product tubs, the solidified metal breaks into 150-200mm size lumps.

The product tubs are taken on trolleys into crane bay and by electric overhead traveling crane into an overhead hopper for feeding in the mechanized system consisting of jaw crusher and vibrating screens to get different sizes which are conveyed by over head conveyors to get stock piles of each size as shown in the picture.

Figure 8: Jaw crusher for metal crushing

Figure 9: Size wise stock piling of meta

The crushing and screening system is equipped with flexibility to cater to the needs of various customers with respect to the size.

Having the facilities like cast steel ladles, skimming machine, casting machine and crusher, enables us to supply the material as per requirement of the customer within two hours after the tap hole is closed.

10. LIQUID SLAG HANDLING AND DISPOSAL

Slag is the by product in ferro chrome production which needs to be treated and disposed off in the most economical manner. Many practices are used world wide for slag handling and disposal. Some producers have succeeded in its use in refractory bricks or as aggregate in cement concrete, in road making etc. But mostly it is used as filler for land reclaiming or leveling. Up till now the ground water percolating through disposed slag in pits is found to be free of hexavalent chromium but as a precaution at some places the authorities are insisting on lining the pits with lime before filling slag in them.

The simplest way of slag handling is to pour the molten slag into slag pit on the ground or sand bed. After solidification and cooling removal by mechanical means like – crane or earth moving equipment like front end loaders preferably crawler mounted. As per experience, this process is found to be expensive. Hence slag granulation process, supersedes this process and is presently in practice in most of the large size modern plants.

If a proper system is not followed for quick disposal of slag, the whole smelting operation can get delayed, resulting in production interruption.

Slag granulation practice ensures –

- Adequate savings in expenses compared to any other means of slag handling and disposal.
- Granulated slag is easy to handle and dispose off compared to solidified lump slag.
- Easy to recover the entrapped metal if any in slag at metal recovery plant since it does not require crushing and jigging . The metal can be obtained by shaking tables.

10.1 Granulation Process

In slag granulation molten slag is poured into a runner, water stream jets from a suitably designed nozzle hits the stream of molten slag breaking it into small particles which flow with water into the granulated slag tank. Make up water addition is done to compensate the evaporation loss maintaining the desired level and temperature of water in the tank. The granulated slag settles down to stock pile in the tank. The excess water over flows by gravity from granulation tank into a cooling reservoir. The slag is removed periodically with the help of grab crane and disposed off at slag yard by dumpers.

Figure 10: Granulating of liquid slag

Figure 11: Granulated slag disposal

All the process parameters are to be designed properly to achieve trouble free operation. Excessive quantity of water in the system takes care of metal that may flow with slag and the system is fairly safe avoiding any explosions if metal flows with slag in the runner.

11. RECOVERY OF ENTRAPPED METAL FROM THE SLAG

Entrapment of metal is most common in ladle skull which is an unavoidable generation in ferro chrome production. If the entrapped metal is not recovered properly, it contributes metal loss lowering chromium recovery. Depending on ladle practices, temperature drop before metal is poured and cast, the skull formation is about 5% of total production.

By primary crushing of ladle skulls clean lumpy alloy is segregated. Further, metalics are with about 3 – 4% slag contamination which are re-cycled in the furnace and 2 – 3% of total production is slag and metal mixture which is more problematic to process by any other economical means except jigging in the Metal Recovery Plant.

Hence, Metal Recovery Plant in post tap hole practice has proved to be ideal option in order to recover metal from the slag metal mixture by further sizing in a closed loop system followed by jigging equipped with minimum mechanical handling devices.

Metal Recovery Plant gives advantages like –

- Almost 100% recovery of metal from slag metal mixture including finer particles (0-4 mm).
- Low recovery cost because of very low operational and maintenance cost in Metal Recovery Plant.

Figure 12: Metal Recovery Plant

12. CONCLUSION

In summary, significant benefits can be derived by using mechanical equipments in post taphole practice in the production of high carbon ferro chrome in large quantity say above 50,000 MT per annum.

- Prime quality and quantity of metal can be obtained faster compared to manual handling
- Reduction in formation of mixture (slag and metal) during handling of finished product.
- Metal recovery plant will have minimum feed quantity for recovering entrapped or mixed metal.
- The metal can be crushed and sized if required even tap wise.
- Bulk handling becomes easy by mechanized method and reduces manpower requirement to the minimum.

All the above attribute to the highest percentage of recovery from the tapped hot metal from the furnace in the shortest time and in most economical way. The percentage of saleable sized metal achieved from tapped hot metal after following the mechanized procedure is about 98.5 percent.