ARC FURNACE - A NEW DIMENSION FOR MAKING SPECIAL STEELS

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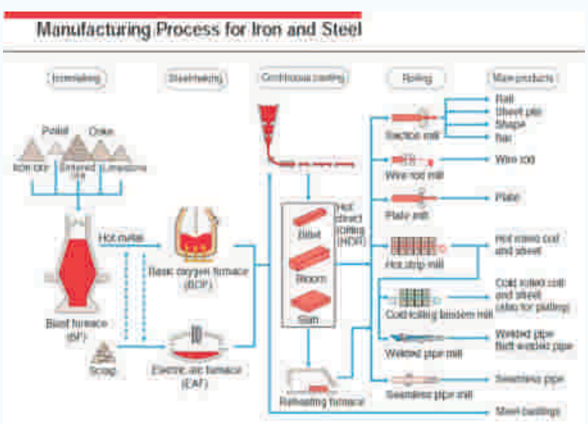
Blast furnace-open hearth-ingot casting was the popular route in olden days. After introduction of oxygen converters, continuous casting the present practice followed is - Blast furnace-converter-secondary refining-concast. Electric arc furnace-ingot casting was the general route in earlier days. It was general practice to complete the steel making in arc furnace itself as secondary refining like use of ladle furnace, VADR, VOD became popular in sixties only. Generally special steels were made only through the arc furnace route because of flexibility in selecting different charge mixes for making different grades of steel and capability for producing small batch orders.

The introduction of secondary refining revolutionized the steel making process. Arc furnaces became only melting pots and refining and finishing of steel was carried out in LF/VAD/VD. After continuous casting became popular and well established many special steel grades were also made through concast route. By continuous improvement in concast technology initial resistance of customers for using concast materials was overcome.

Typical line diagram showing BF-BOF route and arc furnace route is shown below-



The diagram does not indicate secondary refining facilities, but they are situated after steel melting in BOF or Arc furnace. Traditional charge mix for arc furnace consists of cold return scrap, market scrap, fluxes, ferro alloys etc. and the entire materials are charged either in two buckets or three buckets into the furnace after raising and swinging the roof out. The scrap is melted by the energy generated by the arc between the electrodes and the conducting charge materials. The arc may flicker and may go off if it encounters non metallics like slag etc.

The transformer rating expressed in KVA/t can vary from 300 to 500 KVA/t for high power furnaces and from 500 KVA/t upwards for ultra high power furnaces. Arc furnaces which were traditionally making tool and high alloy steels, today thanks to ultra high power operation and secondary refining facilities have been converted to mass production units.

The steps involved for making quality alloy steel products starts right from the charge preparation stage. Modern charge for arc furnace can be anything from liquid hot metal, sponge iron, HBI, revert scrap, market scrap etc. Because of the heterogeneity of the scrap, charge preparation is extremely important to aim for target chemistry after all melt. Scraps of different categories have to be stored separately to recover costly alloying elements like nickel, chromium, molybdenum etc. While the composition of hot metal, sponge iron, HBI can be easily predicted after analysis, market scrap can contain undesirable tramp elements, non metallics etc.

Steps involved in arc furnace can be summarized as follows:

1. Charging—anything between single bucket to three buckets.
2. Melting
3. Refining
4. De-slagging
5. Tapping
6. Furnace preparation

1. Charging

The charge is prepared according to the grades proposed to be made to aim for target chemistry after all melt. Care is also required to alternate heavy and light scrap so that volume does not exceed the two/three bucket volumes. If the charge is not prepared correctly sometimes the roof may not sit after swinging in. The buckets used are normally of the clam shell type. Operation described is only for batch charging and not for continuous charging.

In quite a few plants processed skull is charged and if the skull is not processed to the right size and non metallics kept to the minimum, this may lead to electrode breakages and costly down time.

2 Melting

Melting is accomplished by injecting energy to the charge materials. This can be in the form of electrical energy or chemical energy. Modern furnaces have replaced a large part of electrical energy by chemical energy supplied by oxy fuel burners, oxygen lances injecting pure oxygen which oxidizes silicon, manganese, carbon and iron, all of these reactions being exothermic.

Carbon injected inside the furnace reacts with oxygen producing CO, which bubbles through the bath creating foamy slag. The excess CO reacts with oxygen converting to CO2 again generating heat.

Initially after creating a metal pool tap voltage can be increased without danger of damaging the roof or side walls. Oxygen lances help in cutting down large scrap in `cold areas. Once sufficient scrap has been melted and enough space has been created, second charge can be taken and the process is repeated. Once the final charge has been melted and all melt stage is reached, temperature measurement is taken and sample is drawn for analysis.

3 Refining

Refining operation starts after all melt. This may not apply to melting practice with hot heel where melting and refining may proceed simultaneously. Refining means reduction of undesirable elements in steel like sulphur, phosphorous, manganese and bringing down the carbon to required levels. Phosphorous removal is favourable in the early stage of refining. Phosphorous retention in slag is dependent on bath temperature, slag basicity and FeO levels in slag. At higher temperature and low levels of FeO content Phosphorous will revert back. High slag passivity also helps in P removal but a high passivity may make the slag viscous and fluorspar may have to be added to fluidize the slag. Sulphur is removed as sulphides in slag Sulphur removal in arc furnace when oxidation levels are high, is difficult, and is better achieved during reducing stage, during tapping. Aluminium silicon and manganese react with oxygen earlier than carbon to form oxides which go into slag.

The reaction of carbon with oxygen produces CO and produces free energy. With carbon and oxygen injection in modern furnaces up to 30 to 35% energy input can be obtained. CO gas thus produced bubble through the bath causing the slag to foam and has many beneficial effects. The arc can be immersed and furnace can be operated with higher voltage tapping. The foaming also helps in bringing down Nitrogen and hydrogen levels in steel.

At the end of refining temperature measurement is done and sample drawn for analysis.

4. De-slagging

The furnace is tilted towards the slag door for removal of slag .It is preferable to remove slag as early as possible to prevent Phosphorous reversal to metal. Carbon injection into the slag results in reaction with Feo in slag, reducing it to metallic iron and evolving CO. During foaming operation slag may overflow through the slag door.

5. Tapping

After reaching the temperature and analysis aimed for, the ttap hole is opened and metal is tapped into well heated ladle for further processing in LF/VAD/VD as the case may be. De oxidants in the form of Aluminium or ferro silicon are added in the ladle during tapping. Ferro alloy additions are also made as per requirement. Slag forming elements are added in the ladle so that a new slag cover can be made for LF operations.

6. Furnace preparation

After the furnace is tapped the inside of the furnace is inspected for any weak spots in refractory lining, water leakage etc. Lining weak spots are repaired by gunning with a special refractory mass. In today's practice furnace preparation should not take more than 5 to 7 minutes. The furnace is ready for next charging.

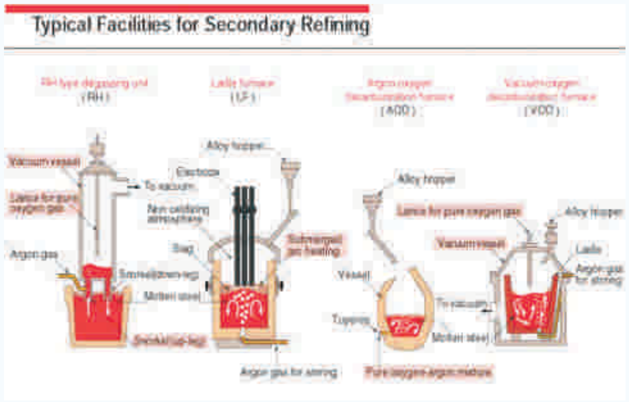
Secondary refining

Various elements in steel have to be controlled within a narrow range as per customer requirement. These elements in steel and dissolved gases determine the characteristics of steel like strength, toughness, formability, hardening-ability, corrosion properties. Alloy steel requirements are getting more stringent and to meet these requirement strict discipline and quality control is required in all stages of operation right from raw material stage. With ladle furnace operation chemistry can be obtained within a narrow range compared to earlier days when steel was finished in arc furnace itself. This is possible because of accurate chemical analysis during treatment, precise additions, very good temperature control and above all good homogenization of the heat because of argon stirring.

Slag free tapping into ladle is essential to achieve good metallurgical characteristics. Argon stirring starts as soon as metal is tapped into ladle. Care has to be taken to see that violent stirring is not done and the metal top cover is not broken exposing the metal to atmosphere. Argon stirring is continued during transfer of ladle to LF station.

The ladle is lifted and placed in ladle car for positioning in LF station. Ladle furnace operation starts after the ladle is positioned and roof is lowered.

The bath is heated for a few minutes and then temperature measurement and sampling is done. Corrective ferro alloy additions are done and if required further heating and final temperature measurement and sampling are done before removing the ladle to concast machine or vacuum degassing as



per grade requirement.

De-oxidation is carried out by manganese, silicon or aluminium. After the deoxidation process the oxides formed have to be removed to avoid detrimental effects on steel as they will form non-metallic inclusions.

Argon stirring and CaSi injecion will help in homogeneous steel composition and temperature, flotation of oxides to the top and desulphurisation of Al killed grades.

Degassing

In RH degassing, steel is sucked through one leg and returns to the ladle through other leg. Steel is fully and thoroughly exposed to the vacuum. In tank degassing ladle is placed in a chamber and vacuum is created. Bath is vigorously stirred to expose the steel to vacuum.

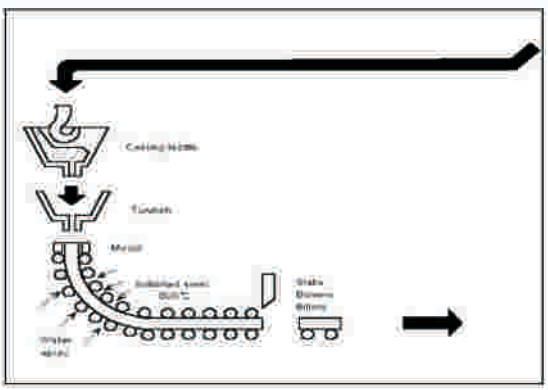
Proper degassing ensures H2 levels below 2 ppm, good cleanliness of steel and homogenization. Minimum of one meter free board in ladle is essential to prevent overflow. As temperature drop of 40 to 50 centigrdes will be there during degassing ladle has to be heated higher in LF before degassing

Continuous casting

Liquid steel can be processed either through the ingot route or the concast route. After the stabilization of concast route nearly 80 to 90 % of steel is processed through concast route only. Ingot is preferred for heavy forgings, heavy rounds and sections and steels that cannot be processed through concast route. After the desired temperature is reached the ladle is lifted to the casting platform .A good practice followed in continuous casting will eliminate many subsequent defects which will be observed in semis or finished products.

Requirements that have to be normally taken care are

1. A good homogeneous bath properly deoxidized.
2. Superheat above liquidus to be controlled.
3. Easy opening of ladle slidegate nozzle.
4. Covering of ladle with ladle cover.
5. Shrouding from ladle to tundish
6. Hot tundish practice is preferred for alloy steels.
7. Submerged casting.
8. Automatic mould level control.



Continous casting

9. EMS-mould
10. Proper quality of casting powder.
11. Regular check on quality of water used for primary and secondary cooling.
12. Close control of delta T of mould cooling water.
13. A good saw cutting machine to check the macro of cast billet/bloom.

The above are only general points but each grade of steel or group of steels will have different requirements and difficulty factors which will have to be taken care of.

Inspection of cut to length billets provides a lot of information about the cast quality. If no visual defects are found and the shape of the billet is normal then it can be assumed that the billet is of satisfactory quality. Examination of the macro sample will provide more information about the quality of the billet. The general trend of end users particularly automobile industry is to demand the best quality at competitive prices. With the entry of many international players in Indian market, demand for quality has to be addressed seriously by the steel producers. Many of the producers have risen to meet the challenges and have installed modern equipment and stringent quality control systems to ensure quality products to the consumers.

The real efficiency of the manufacturers can be judged only when the market goes down to realistic levels and then the fittest and strongest only will survive.

Some of the areas which will require the attention of the manufacturers are:

1. Energy consumption
2. Yield improvement
3. Improvement in product identification
4. Online inspection of finished materials, including ultrasonic inspection, surface inspection.

Some of the well known producers who follow the arc funace route for producing alloy steels are:

1. ASP,Durgapur
2. MUSCO
3. MUKAND
4. FACOR
5. Kalyani Carpenter
6. Usha Martin (Hot metal input in arc furnace)
7. Jindal Steel and Power (HM input in arc furnace)
8. Sunflag Iron and Steel
9. ISMT
10. Aarti Steel
11. Vardhman Steel
12. Marmagoa steels
13. Adhunik Metals.

Two of the earliest manufacturers of Alloy Steels in India are ASP, Durgapur MUSCO followed by Bihar Alloys. The entire range of alloy steel grades conforming to various international specifications can be made by this route. The flexibility of charge mix, right from hot metal to total solid scrap makes this technology an attractive proposition.

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