UNIT 3

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QUALITY STEEL MAKING

- Inclusions in steel:

- The term cleanliness is used to refer relative freedom from the entrapped non-metallic particles of solid ingot.

- In some steels this is the most important criteria in judging their quality. The fact that it is non-metallic and therefore, incongruent with the metal lattice, has been considered as *prima facie evidence* of its undesirability.

- Inclusions are of two types:
  - Indegenious: Those arising in the course of steelmaking.
  - Exogenous: Those arising from mechanical erosion of contacting refractory lining.
- Indegenous inclusions comprise of deoxidation products like oxides, oxy-sulphides or precipitates like sulphides, carbides, nitrides etc.
- Almost all sulphur is precipitated in form of iron sulphide or manganese sulphide, the best way is to keep sulphur as low as possible to avoid formation of inclusions.

- Oxide inclusions can be kept at a minimum by suitable deoxidation practice. Enough time is allowed for them to rise to the surface in the ladle.

- Alternatively, if economically permissible, vaccum treatment may be adopted to decrease the oxygen content of steel.

- Nitrides form only if dissolved nitrogen level is high. Addition of Zr, Ti and V form stable nitrides.

- Titanium carbide may act as an inclusion

- In general proper care during refining and more particularly during deoxidation can minimize the indigeneous inclusions.

- The exogenous inclusions arise from the mechanical erosion of refractory lining with which metal comes in contact during its processing.

- In particular the erosion of ladle and more so of the refractories used in the assembly of the mould contributed most to the formation of exogenous inclusions.

- The best way to keep them down is to use minimum of such refractory channels through which metal has to flow before solidification.

- Use of strong refractory for such places is definitely beneficial.

- Inclusions are not always undesirable.

- These are purposefully introduced to gain certain desirable effects.

- For example sulphur inclusions when form mangenese sulphides improves machinability.

- Exogenous inclusions are used for dispersion strengthening of steels.

- Stable nitrides are useful since the ill effects of dissolved excess nitrogen is thereby eliminated.

Sulphur in Steels

o S is an element which is always present in steel in small quantities. S in steel is introduced through iron ore and fuel (coal and coke).

o The removal of S during steel making is a tedious and difficult process.

o S is normally regarded as an impurity in steel and is required to be reduced to the limits of practicality.

- However steels which are to be machined need a certain minimum S content for proper chip formation.

- Where machining constitutes a major fraction of the end products cost, many types of steel (carbon, alloy, and less often stainless) are intentionally resulphurized just for this reason.

- Except in those cases where it is added for machinability, or where residual S content of around 0.040 % maximum is tolerable, the usual aim during iron and steel making is to reduce S to low levels, consistent with mechanical property requirements.

- For high strength (HS) steel plates and for some special bar quality (SBQ) steel products, this may mean removing the S to a level of 0.005 % maximum.

- There are several methods which are widely used for achieving this level of S.

- Further, efficient removal of S from liquid steel or iron depends on specific metallurgical and thermodynamic conditions.

- Though these conditions may vary with the type of S removal system, most of them require reducing conditions (low FeO level).

- Also, it is important that slag, and therefore refractory conditions be basic (having high basicity ratio).

- Also the temperature preferably be high since the process of S removal is normally endothermic.

- While S can be removed anywhere between the blast furnace and the steel teeming ladle, it is now generally established that larger cost benefits are obtained when desulfurization is performed at the hot metal stage.

DESULPHURISATION

- Removal of sulphur from hot metal is called desulphurization of hot metal. Sulphur is a desirable element in steel when good machinability is required from the steel product.
- However it is an unwanted element in most of the applications of steel due to the following reasons.

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- Sulphur affects both internal and surface quality of steel
- Sulphur contributes to the steel brittleness and when it exists in sulphide phase it acts as a stress raiser in steel products.
- It forms undesirable sulphides which promotes granular weakness and cracks in steel during solidification.
- It has adverse effect on the mechanical properties.
- It lowers the melting point and intergranular strength and cohesion of steel.

- Unlike other impurities which are removed from the hot metal by oxidation in the oxygen converter, the most economic method of removing sulphur from the hot metal is by reduction either in the transfer ladle or in the charging ladle, before it is charged in the converter.

- A number of technologies have been developed for the external desulphurization of hot metal but all of them have the basic requirement of a reagent and a method of mixing.

- The difference between the technologies used is the properties of the reagents, the effectiveness of the reagent to remove sulphur and the effectiveness of the mixing method to get the reagent into solution. .

- Also the effectiveness of hot metal desulphurization is inversely proportional to the desulphurization reagent injection rate.

- The most popular desulphurizing process today is deep injection of desulphurizing agent in the hot metal.

DESULPHURIZATION PROCESS

- Dip lance process is the most economical, effective and reliable method of desulphurization hot metal.

- It consists of pneumatic injection of fine grained desulphurization reagent into the hot metal with high dosing precision via a dispensing vessel and a refractory lined lance.

- For each reagent, one separate dispensing vessel is used.

- All the vessels are identical.

- Nitrogen gas is normally used as a carrier gas for the desulphurization reagent.

- The reagent transfer in the injection line is under dense flow conditions.

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- The dense flow conditions maximize reagent delivery as well as reduce abrasion wear of injection lines.

- The injection of desulphurization reagents through deeply submerged lance causes an intimate mixing of the desulphurization reagent with the hot metal.

- The process allows the use of several desulphurization reagents, such as lime, calcium carbide and magnesium, which remove the sulphur in the hot metal by chemical reaction and convert it to the slag.

- Sulphur rich slag generated during the process is removed immediately after completion of the reagent reaction.
- The most common method is to tilt the ladle and rake the slag off with the help of a slag raking machine.

- Hot metal sulphur content is reduced in charging ladle or transfer ladle worldwide by this method.
- For controlling the operating cost, a combination of dip lance method with mathematical process control and flexible control of the desulphurization plant is adopted.
- This combination provides a range of possible process technological variations.

- One of these possibilities is to vary the injection rate (kg/min.) to suit the production requirements.

- Another possibility is to inject different desulphurization reagents during the process of desulphurization.

- The desulphurization reagents can be injected singly, simultaneously or with a time lag.

- Accordingly the process variations are known as mono injection, co injection or multi injection.

- Dip lance method can reliably reduce the sulphur content of hot metal to figures as low as 0.001 %.

DESULPHURIZING REAGENTS

- The most commonly used desulphurizing reagents are lime (CaO), calcium carbide (CaC2) or magnesium (Mg).

- There are some important issues with respect to the desulphurizing reagents. All desulphurizing reagents are not equal in their ability to remove sulphur. Magnesium although more expensive, has approximately 20 times the capacity of removing sulphur as lime.

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- Calcium carbide has eight times more potential to remove sulphur than lime.
- However, if injected into hot metal on its own, it must be blended with volatiles in order to increase the agitation of the bath.
- Pre blending of different desulphurizing reagents such as magnesium-lime or magnesium- calcium carbide is not useful since blended reagents are prone to segregation during transport and storage besides individual injection rates of desulphurizing reagents gets sacrificed

PHOSPOROUS IN STEEL

- P is normally considered an undesirable impurity in steels. It is present in varying concentrations in iron ore, is retained in hot metal, but is eliminated early in the steelmaking process.

- P oxidizes readily and is removed from steel as P_2O_5, which is taken up by the oxidizing slag, before the oxidation of carbon takes place. Carryover of any P_2O_5 containing oxidizing slag can result in P reversion to the steel in subsequent steelmaking operations.

- In normal commercial steels, residual P content is usually at a level of 0.05 % max, but concentrations as low as 0.005 % are not unusual. P is readily removed only in basic steelmaking processes.

- Detrimental effects of P in steel include various forms of embrittlement which reduce the toughness and ductility.

- The most familiar example in this category is the classic phenomenon of temper embrittlement in heat treated low alloy steels resulting from segregation of phosphorus and other impurities at prior austenite grain boundaries.

GASES IN STEEL (NITROGEN)

- Except a small proportion of steel wherein the hardening influence of extra nitrogen content is made use of in developing

GASES IN STEEL (OXYGEN)

- Oxygen is supplied for refining iron and hence, a certain fraction is inevitably left over as dissolved oxygen in liquid steel at the end of refining.

- Several useful deoxidisers have been found to effectively deoxidise liquid steel is to obtain sound ingots on solidification.

- The use of deoxidisers, unless it forms gaseous product of deoxidation reaction, tends to decrease cleanliness of the steel.

- Where cleanliness is of prime importance and where oxygen is to be reduces to a lower level than that attainable by normal deoxidation practice, liquid steel has to be treated under vaccum prior to solidification.

DEOXIDATION: INTRODUCTION

- Refining of hot metal to steel is done under oxidizing atmosphere.

- During refining oxygen dissolves in steel.

- Solubility of oxygen in steel is negligibly small.

- During solidification of molten steel, excess oxygen is rejected by the solidifying steel.

- This excess oxygen produces defects like blow holes and non- metallic oxide inclusion in solidified casting.

- Defects have considerable effect on mechanical properties of steel.

- Therefore, it is necessary to remove oxygen from steel; removal of oxygen is called Deoxidation.

- **Sources of oxygen in steel**
  - Rust on steel
  - Oxygen blowing
  - Steelmaking slag
  - Atmospheric oxygen dissolved in steel during teeming
  - Oxidizing refractories

- At 1600°C solubility of oxygen in liquid steel is 0.23% which deceases to 0.003% in solid steel during solidification. According to the degree of deoxidation, carbon steels may be subdivided into three groups:

i. Killed steel: Oxygen is removed completely. Solidification of such steels does not give gas porosity (blow holes).

ii. Semi –killed steel: Incompletely deoxidized steels containing some amount of oxygen which froms CO during solidification.

iii. Rimming steel: Partially deoxidized or non-deoxidized low carbon steels evolving sufficient CO during solidification. These steels have good surface finish.

DEOXIDATION OF STEEL

- Deoxidation can be carried out either by single element such as Si,Al,Mn etc or by mixture of elements such as Si+Mn,Ca−Si−Al etc.

- De oxidation by single element is known as simple deoxidation, whereas deoxidation by a mixture of elements is known as complex deoxidation.

- In both simple and complex deoxidation, oxide is formed; hence it is also termed precipitation deoxidation.

- Deoxidation is also carried out by carbon under vacuum; which is called vacuum deoxidation.

- Elements are added in the form of Ferro-alloys Fe− Si,Fe−Mn or Fe Si + Fe Mn etc.

- Simple deoxidation can be represented by
$$a[M]+b[O]=(M_a O_b) \text{ ------(1)}$$

- If deoxidation product is pure then activity of $(M_a O_b=1)$ and if elements are in dilute solution
$$[W_M]^a[W_O]^b=K_m \text{ --------(2)}$$

- Where K_M is deoxidation constant and equals to $1/KM_1$ where KM_1 is equilibrium constant.
$$\log K_M = -X/T + Y \text{ ---------(3)}$$

- Where X and Y are constants and T is temperature. Increase in T increases K_M.

- Using equations 2 and 3 one can calculate the variation of W_O with W_M when W_M is in small quantity.

- In complex deoxidation where a mixture of Si+Mn,Ca+Si,Ca+Si+Al is used, the following advantages are reported as compared with simple one:

  - The dissolved oxygen is lower.

  - Due to formation of liquid deoxidation product agglomeration of the product into large size can be obtained easily and can be floated easily.

- According to equation 2

$$[W_O]^b = K_M[W_M]^a \text{ ----------(4)}$$

- Equation 4 indicates that weight percent oxygen in steel depends on value of K_M for small concentration of deoxidizers. At 1600°C the value of Km is 2.4×10^{-5} for the reaction

- $Si + O_2 = SiO_2$ and for the reaction

- 2 Al+3O=Al$_2$O$_3$ the value of K$_M$=3.32×10^{-14}.

- Similarly for the reaction Ca+O=CaO, K$_M$=9.84×10^{-11}.

- The value of K$_M$ indicates the deoxidizing ability of an element.

- For the above reaction, calcium is the most efficient deoxidizer and Si is not so efficient as compared to calcium. Aluminum is also a strong deoxidizing element when compared with silicon.

- Though calcium and aluminum are very efficient deoxidizers, but they oxidize very fast and moreover, their density is much lower than steel.
- Also Ca has a boiling point 1485℃ which means calcium is gaseous phase at the steelmaking temperature. Suitable injection methods or addition methods are to be developed.

KINETICS OF DEOXIDATION

- Total oxygen in steel equals to dissolved oxygen + oxygen present in deoxidation products (SiO_2, Al_2O_3, MnO etc). Even if the dissolved oxygen is low, deoxidation products (also called inclusions) have to be removed, otherwise steel is not clean (clean steel refers to number and size of inclusions in steel). Kinetics of inclusion is concerned with deoxidation reaction and separation of deoxidation products as well.

THE DEOXIDATION PROCESS CONSISTS OF THE FOLLOWING STEPS

- Dissolution and homogenization of de oxidizer. Mechanism of dissolution depends on melting point. Ferro alloys melt at around 1500°C. Aluminium is expected to melt faster due to its much lower point. Intensity of agitation will govern the homogenization of deoxidizer in steel melt for faster kinetics of reaction between oxygen and deoxidizer.

- Nucleation of solid product becomes easier if interface is present. Deoxidation by Al produces solid Al2O3 and as such Al2O3/steel interface is useful for nucleation.

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- Growth of the de oxidation product: It depends on the state of the product. A liquid product can coalesce easily as compared with the solid product. Deoxidation with single elements like Al,Si etc. produce solid deoxidation product at the steelmaking temperature. Deoxidation with ferro silicon+ ferro manganese produces liquid deoxidation product. Boron, titanium zirconium are also quite effective deoxidizers. Manganese and silicon are used in the ratio 7:1 to 4:1 in order to obtain a thin liquid slag.

- Removal of deoxidation product: Removal of de oxidation product is equally important. It is achieved by floatation and absorption into a slag. Following steps are important for removal of de oxidation products from steel:

  i. Growth of de oxidation product

  ii. Movement through molten steel to surface

  iii. Absorption of inclusion by a suitable designed synthetic slag.

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- Floatation of an oxide product depends among physical properties of steel, on the size of the product. The rate of rise of a spherical particle in a quiet fluid or in a fluid of laminar flow (i.e. at very low Reynold's number) can be described at steady state by Stoke's law :

$$V_t = \frac{gd^2 \Delta \rho}{18 \, \eta}$$

- Where,

- Vt= terminal velocity (m/s)of the inclusion,
- g is acceleration due to gravity (m/s^2),
- $\Delta\rho$= differnce in density of steel and deoxidation product and
- η is viscosity of steel (kg/m.s).

- Deoxidation products are lighter than steel; hence they move up.

- According to Stokes equation the rising velocity is proportional to square of the size of the deoxidation product.

- Larger sizes move faster. Moreover different sizes of de oxidation product will move with different velocities.

- During their movement, they may collide with one another. Stirring of melt may help floating of de oxidation products.

- Degree of stirring in the melt is important. Vigorous stirring may not be of much help since deoxidation product may be circulated in the liquid.

- For the removal of deoxidation product, equally important is the design of synthetic slag to absorb the deoxidation product

DEOXIDATION PRACTICE

- Deoxidation can be carried out during tapping, in ladles runners and even in moulds. Bath stirring is important.

- During tapping, bath is stirred due to potential energy but this subsides towards the end. When deoxidation is carried out in ladle, it is called ladle deoxidation in industrial practice.

- Depending on the extent of deoxidation, killed, semi killed and rimming steels are produced. For carbon content less than 0.15% and enough oxygen in steel, rimming steel can be produced.

- Alloy steels are fully killed to obtain maximum recovery of alloying additions.

Degassing processes

- There are 3 methods of degassing which are in practice:
  - Ladle degassing
  - Stream degassing
  - Circulation degassing

- All these processes are carried out in ladles.

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- i) Ladle degassing : Liquid steel is held in a ladle which is put inside a vacuum chamber. steel may be stirred by bubbling an inert gas or by an electro-magnetic stirrer while being exposed to vacuum.

- ii) Stream degassing : Liquid steel flows down in the form of a stream from the furnace or ladle to another ladle or mould during its exposure vacuum.

- iii) Circulation degassing : Liquid steel is either continuously or intermittently circulated during its exposure to vacuum.

LADLE DEGASSING

Ladle degassing unit (VD)

Addition hopper

To vacuum pump

Vacuum chamber

Argon
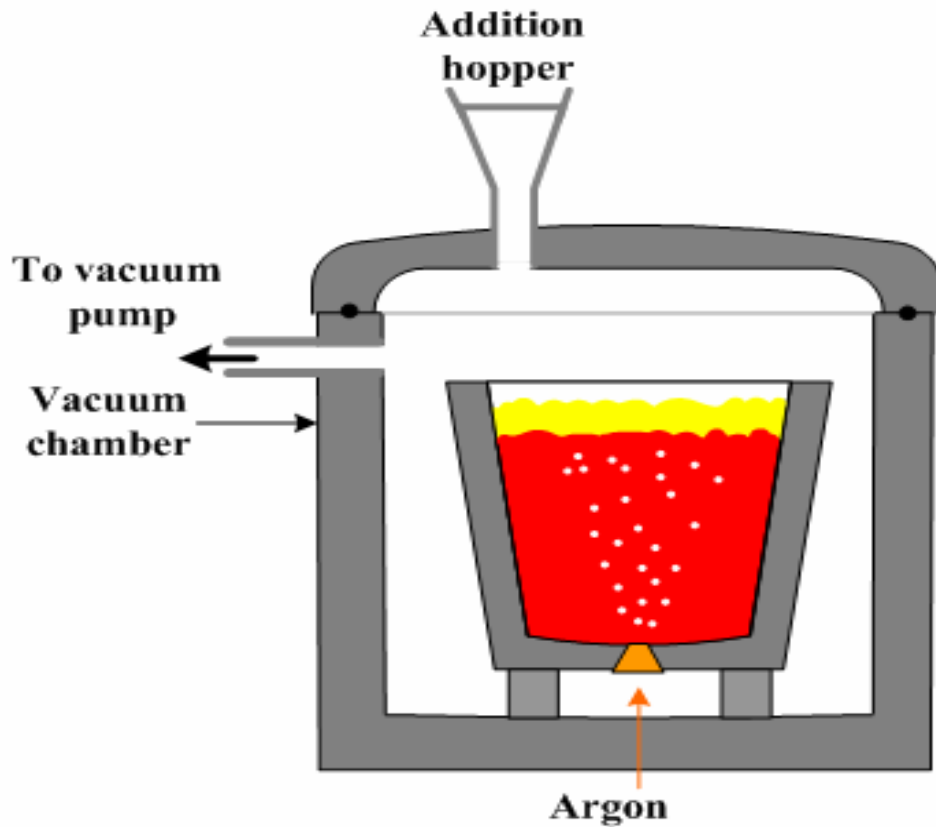
- Ladle containing molten steel is placed in a chamber which is then evacuated. After a determined time ladle is removed from the chamber and is teemed for casting. Fig. shows ladle degassing unit.

- Ladle is provided with a porous plug at its bottom to purge argon gas as shown in the figure. In a vacuum chamber the ladle is placed.
- The vacuum chamber is equipped with a hopper so as to make additions of elements as and when it is needed.
- For effective degassing of fully killed steel, it is necessary to purge argon through the bottom of the ladle. Stirring the bath enhances rate of gas removal.

- Vigorous removal of gases causes metal splashing too. Therefore ladle is not filled completely and about 25% of its height is kept as freeboard to accommodate the splashed metal droplets.

- Pressure is maintained in between 1mmHg to 10mm Hg for effective degassing. During degassing additions are made for deoxidation and alloying.

- In certain cases ladle is heated to compensate for the loss of heat during degassing.

- For the effectiveness of degassing , it is necessary that carry-over slag either from BOF or EAF should be as low as possible.

- Carry-over slag contains FeO and since oxygen content of steel is in equilibrium with FeO content of slag, oxygen content of steel increases.
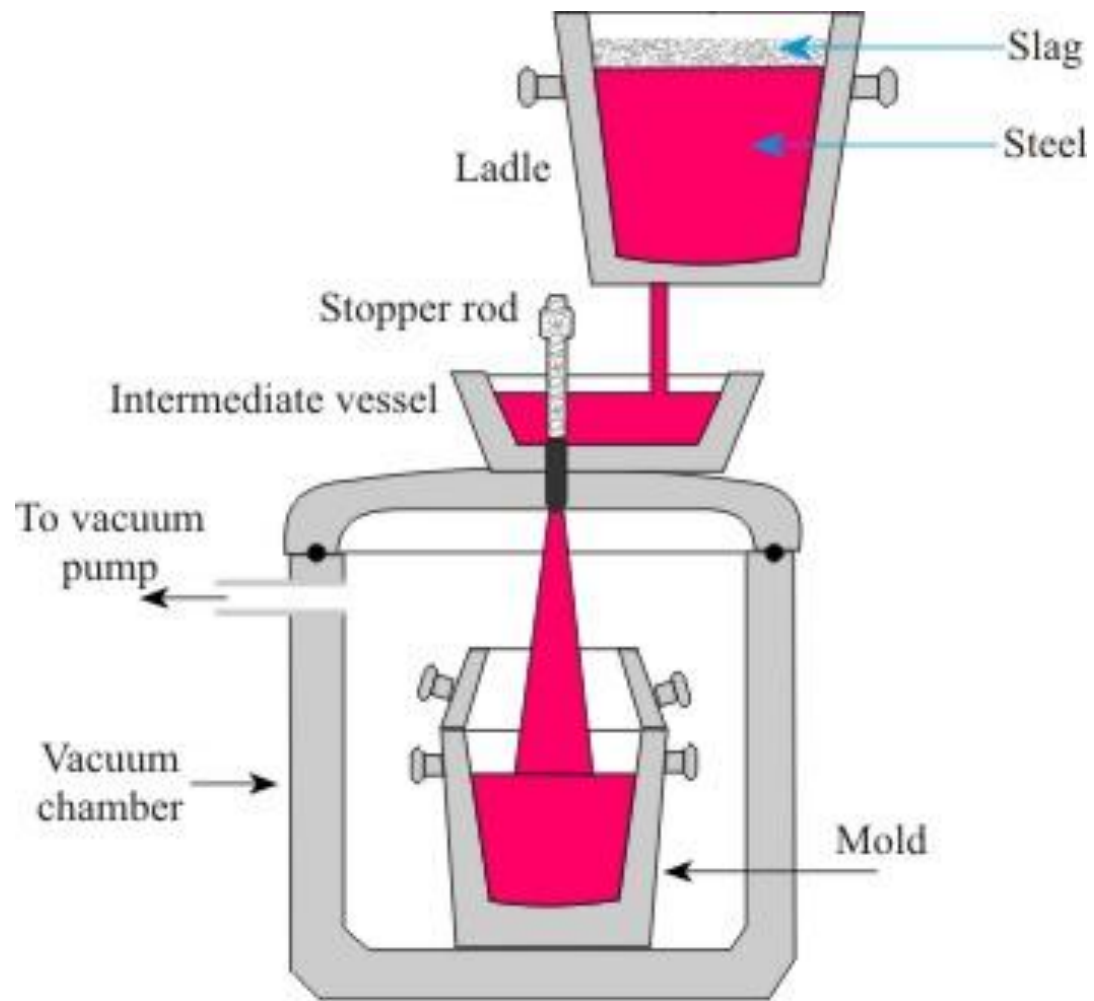
- Stirring gas is introduced either from top through the roof by a submerged refractory tube or through the porous plug fitted at the bottom of the ladle.

- Electromagnetic stirring is employed for degassing. For this purpose ladle has to be made of non magnetic austenitic stainless steel or stainless window could be provided.

- For certain grades of alloy steels, both induction stirring and arc heating are employed for degassing.

- The final content of gas in steel depends on degree of vacuum and time of treatment. Hydrogen is generally reduced to below 2ppm from 4 to 6ppm, nitrogen content of steel is also reduced. The pick-up of nitrogen from the atmospheric air may occur during open pouring of steel, which must be controlled.

- Ladles are generally lined with high alumina bricks at upper part of the ladle while the lower portion is lined with fireclay.

STREAM DEGASSING

- In stream degassing technology, molten steel is teemed into another vessel which is under vacuum.

- Sudden exposure of molten stream in vacuum leads to very rapid degassing due to increased surface area created by breakup of stream into droplets.

- The major amount of degassing occurs during the fall of molten stream. Height of the pouring stream is an important design parameter.

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Slag

Steel

Ladle

Stopper rod

Intermediate vessel

To vacuum pump

Vacuum chamber

Mold

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STREAM DEGASSING TECHNOLOGY HAS FOLLOWING VARIANTS IN THE PRACTICE

i. Ladle to mould degassing

- Preheated mold with hot top is placed in vacuum chamber.

- Above the chamber a tundish is placed. Steel tapped in the ladle at superheat equivalent to 30°C is placed above the tundish.

- Steel is bottom poured in the tundish. One ingot could weigh around as high as 400tons and several heats from different furnaces are used for casting.

II. Ladle to ladle degassing

- In ladle to ladle degassing, a ladle with the stopper rod is placed in a vacuum chamber.
- Ladle containing molten steel from BOF or EAF is placed on top of the vacuum chamber and the gap is vacuum sealed.
- Alloy additions are made under vacuum. Stream is allowed to fall in the ladle where molten steel is degassed.
- Alloy additions are made under vacuum.

- In some plants degassing is done during tapping. In this arrangement molten steel from EAF is tapped into tundish or pony ladle.

- From the pony ladle molten stream is allowed to fall into a ladle which is evacuated.

- Ladle is closed from top with a special cover which contains exhaust opening. Steel with 25°C to 30°C superheat is tapped into ladle.

RECIRCULATION DEGASSING

- In the recirculation degassing technology, molten steel is allowed to circulate in the vacuum chamber continuously by special arrangement.

- In RH degassing technology a cylindrical refractory lined shell with two legs (also called snorkel) is designed such that steel is raised in one leg and falls back into the ladle after degassing through the second leg.

- Top side of the cylindrical shell is provided with exhaust, alloy additions, observation and control window.

- Cylindrical shell is lined with fire bricks in the upper portion, and alumina bricks in the lower portion in order to sustain high temperature.
- The legs are lined with alumina refractory.
- A lifter gas argon is injected at the inlet snorkel in order to increase the molten steel velocity entering into inlet snorkel.
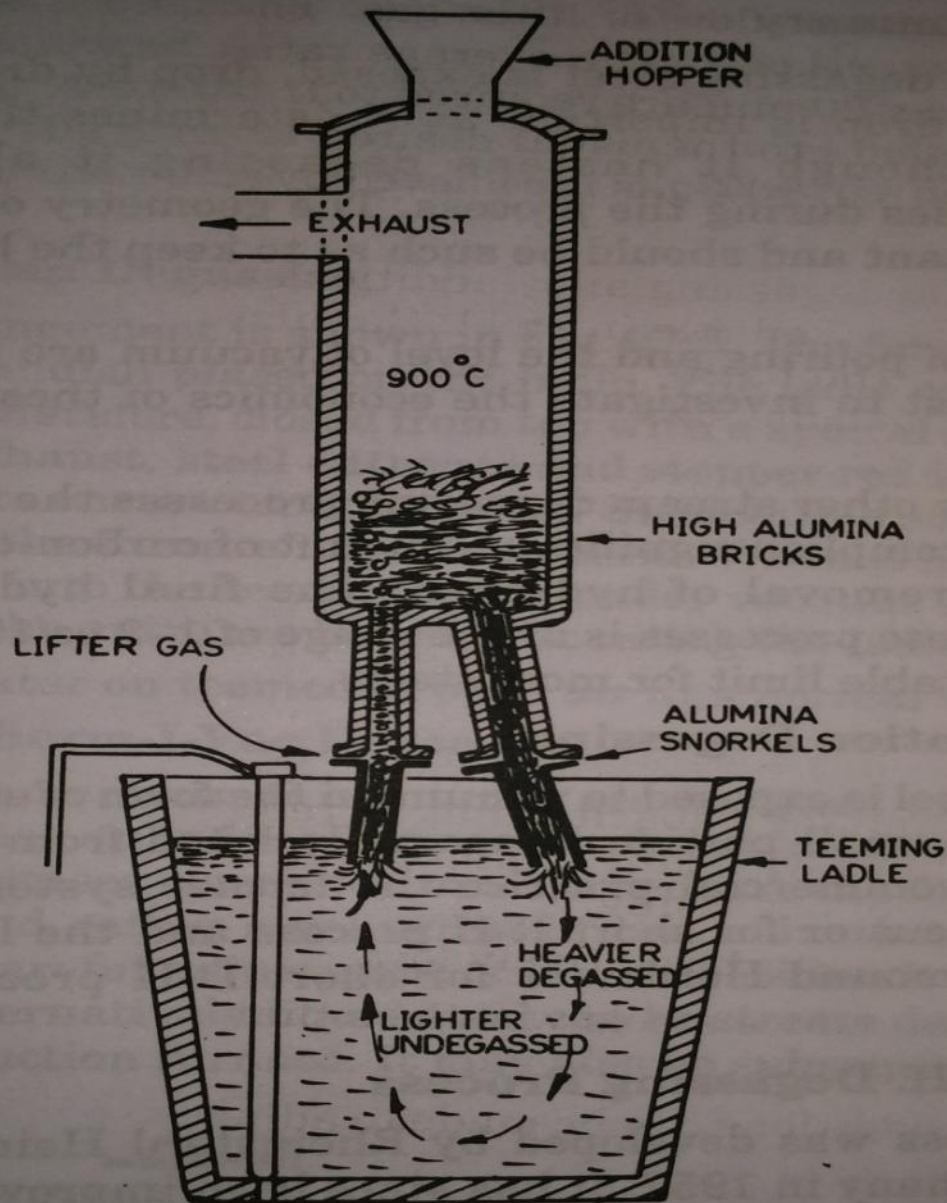- Figure shows a schematic sketch of a RH degassing unit.

Fig. 27·7. R.H. process of degassing.

The operation of RH degasser is as follows

i) Cylindrical chamber is heated to the desired temperature (varies in between 900℃ to 1500℃ in different plants).

ii) The chamber is lowered into molten steel up to a desired level.

iii) The chamber is evacuated so that molten steel begins to rise in the chamber. Lifter gas is introduced. This gas expands and creates a buoyant force to increase the speed of molten steel rising into the inlet snorkel.

iv) Molten steel in the chamber is degassed and flows back through the other snorkel into the ladle. This degassed steel is slightly cooler than steel in the ladle. Buoyancy force created by density difference (density of cooler liquid steel is > hot steel) stirs the bath

v) Rate of circulation of molten steel in cylindrical chamber controls the degassing. Circulation rate depends upon amount of lifter gas and the degree of vacuum. A 110 T steel can be degassed in 20 minutes by circulating molten steel at 12 tons/min., amount of argon is around 0.075 0.075 m3/ton.

vi) Alloy additions can be made at the end of degassing depending on the superheat.

vii) Process has several advantages like

- Heat losses are relatively low.
- Alloy additions can be adjusted more closely
- Small vacuum pumping capacity is adequate since smaller volume is to be evacuated as compared with ladle to ladle or stream degassing.

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DH Degassing

- In DH degassing, a small amount 10-15% of the total mass of steel is degassed at a time. The process is repeated until required level of degassing is achieved. The arrangement of a vessel and the ladle is somewhat similar to figure except the following:
  - In DH unit, the cylindrical vessel has one snorkel .
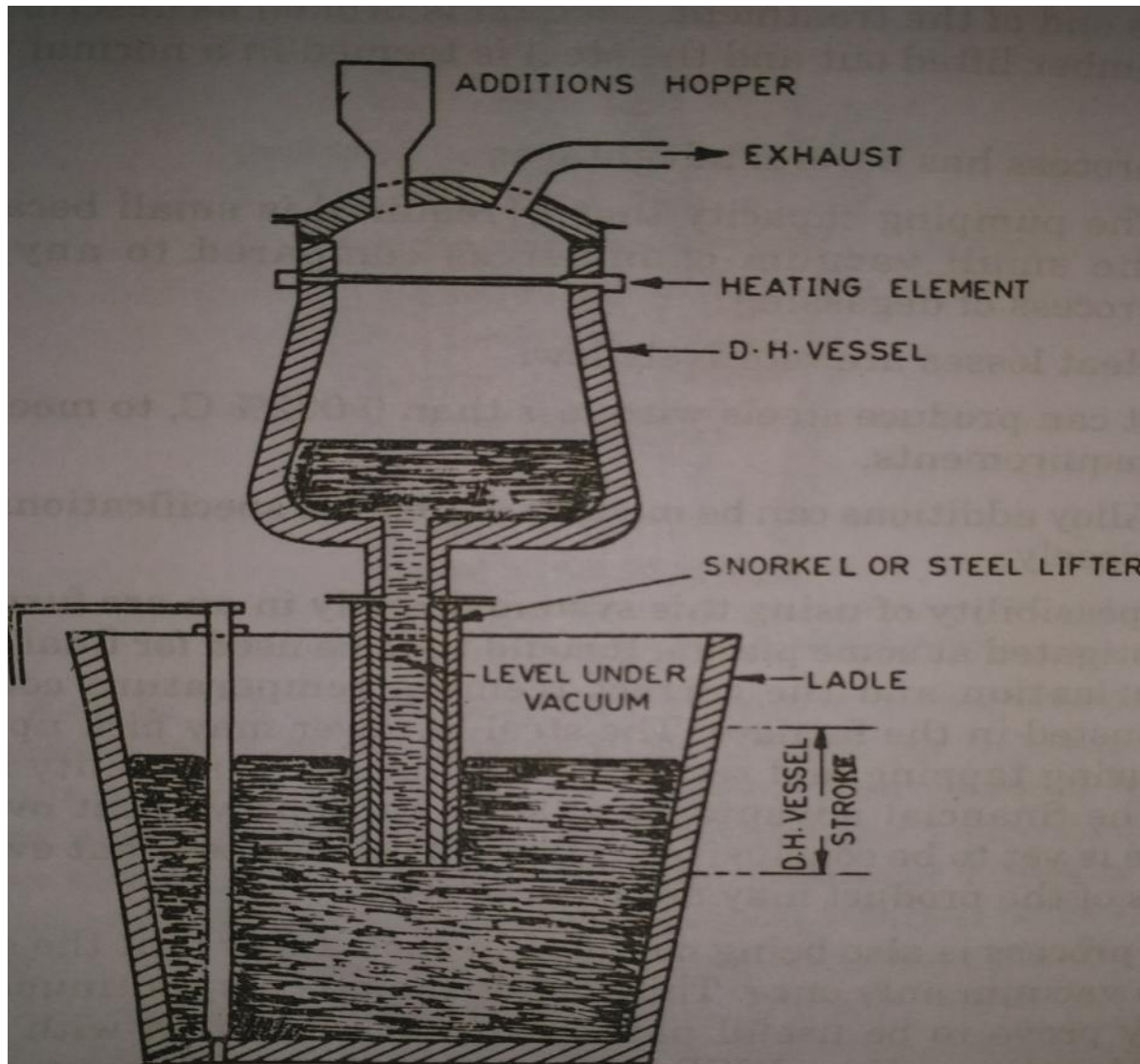 - Cylindrical vessel has heating facility.

Fig. 27·8. D-H process of degassing.

- The DH chamber is equipped with heating facility, alloying addition arrangement and exhaust systems.

- Bottom of the cylindrical vessel is provided with a snorkel which can be dipped into molten steel.

- The upper portion of the DH vessel is lined with the fireclay and the lower portion with the alumina bricks, snorkel is lined with high quality alumina brick.

- The length of the snorkel is sufficiently large to realize the effect of atmospheric pressure on rise of steel in the snorkel.

The following steps may be noted for operation

i) DH vessel is preheated and lowered in the ladle so that snorkel tip dips below the molten steel surface

ii) The evacuated chamber is moved up and down so that steel enters the chamber

iii) The chamber is moved for 50-60 times with a cycle time of 20 seconds.

iv) Adequate degassing is possible in 20 -30 cycles.

v) A layer of slag is kept in the ladle to minimize heat losses.

vi) The DH degassing unit can operate with lower superheats compared with RH since DH unit has heating facility
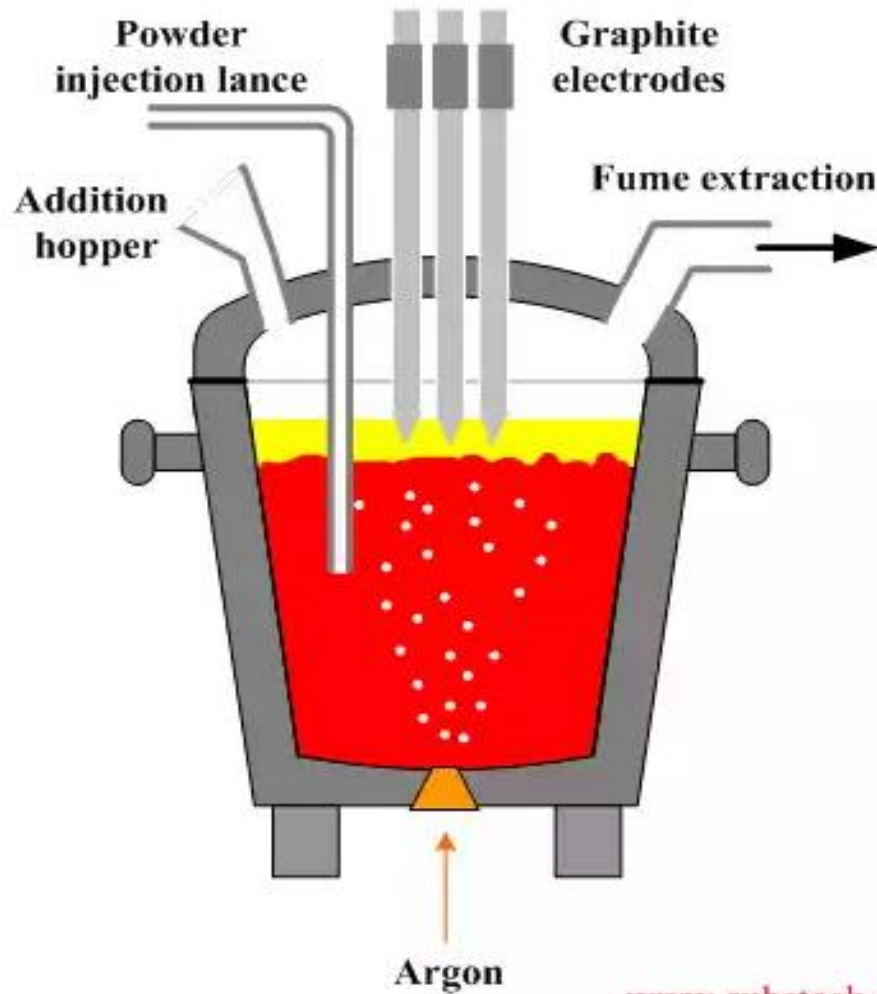
SECONDARY STEEL MAKING

- Secondary steel making is resorted to achieve one or more of the following requirements:

1. Improvement in quality.

2. Improvement in production rate

3. Decrease in energy consumption

4. Use of relatively cheaper grade or alternatively raw materials.

5. Use of alternate sources of energy

6. Higher recovery of alloying elements.

LADLE FURNACE

- Non-metallic inclusions are naturally occurring and typically undesired products that are formed into various types depending on their favourable thermodynamic conditions in almost all treatment practices involving molten steels.

- The equipment and processes are equally varied. Secondary Refining processes are performed at atmospheric pressure or under a vacuum, with or without heating, solids and/or gas injection, and stirring.

- The purposes of secondary refining are many: temperature homogenization or adjustment; chemical adjustments for carbon, sulphur, phosphorus, oxygen and precise alloying; inclusion control; degassing, and others.

- After tapping from electrical arc furnace, the ladle furnace is put on LF refining position.
- LF refining is conducted through arc heating and argon blowing.
- During this process, the steel deoxidization, desulfurization, the adjustment of steel temperature and chemical composition are completed.
- In primary slag, there is no vacuum function in LF, but room of vacuum device may be obligated in LF zone for future development.

Ladle Furnace (LF)

Powder injection lance
Graphite electrodes
Fume extraction
Addition hopper
Argon
www.substech.com

❑ A Ladle Furnace is used to relieve the primary melter of most secondary refining operations, and its primary functions are:

- Reheating of liquid steel through electric power conducted by graphite electrodes

- Homogenization of steel temperature and chemistry through inert gas stirring

- Formation of a slag layer that protects refractory from arc damage, concentrates and transfers heat to the liquid steel, trap inclusions and metal oxides, and provide the means for desulphurization
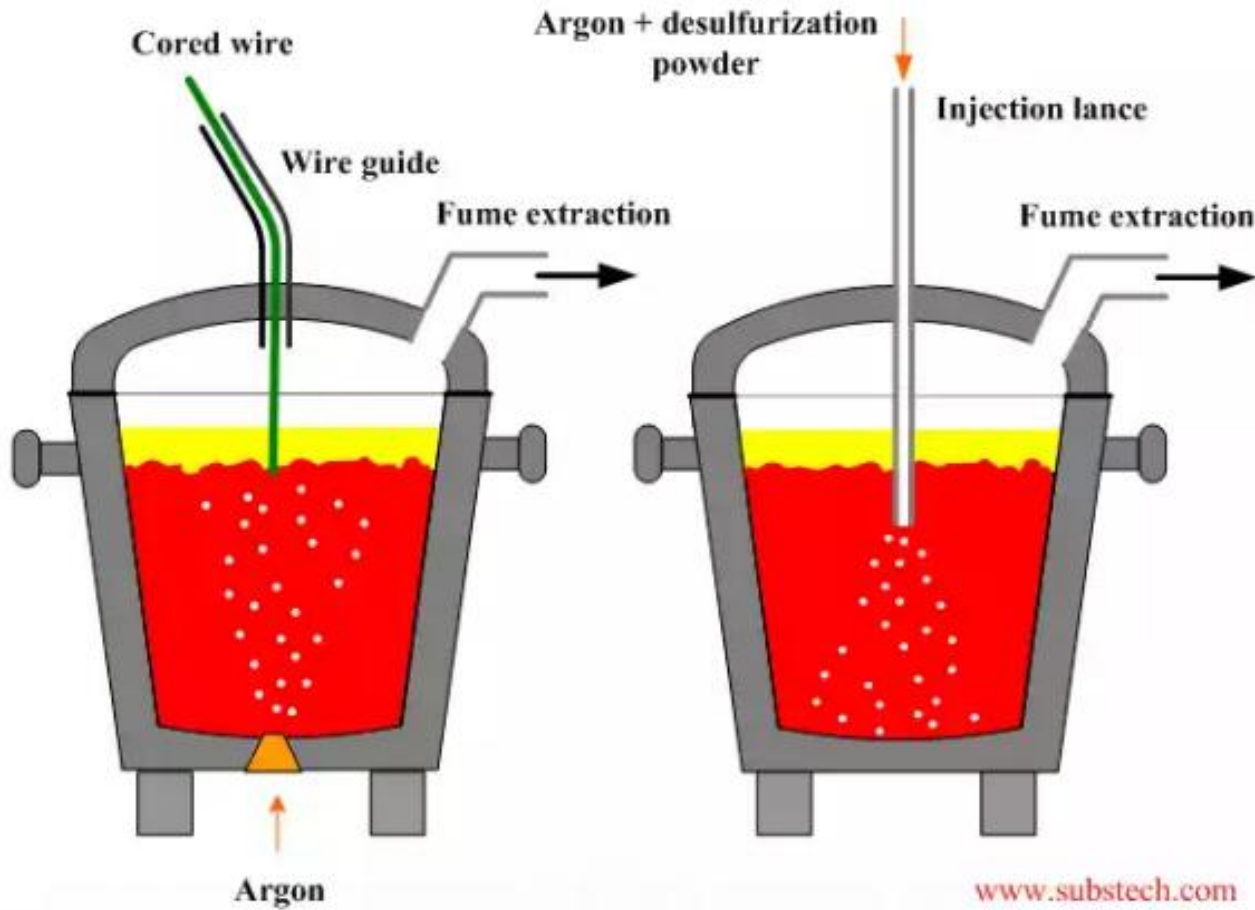
Secondary functions

- Alloy additions to provide bulk or trim chemical control
- Cored wire addition for trimming or morphology control
- Provide a means for deep desulphurization
- Provide a means for dephosphorization
- Act as a buffer for down stream steelmaking equipment

Ladle desulfurization

Cored wire injection desulfurization unit

Cored wire

Wire guide

Fume extraction

Argon

Powder injection desulfurization unit

Argon + desulfurization powder

Injection lance

Fume extraction

www.substech.com

SPECIFICATION OF THE LF

- LRF of liquid metal is a proven technology to produce high quality steel. Also used to raise the temperature and adjust the chemical composition of molten metal.

- LRF are used to desulphurise steel, remove other impurities and hold the molten steel for casting operations.

- Costs of extended furnace time, refractory wear and power/fuel consumption can all be reduced using LRFs to perform holding and refining.

- Reduced scrap melting capacity in BOF is another disadvantage of higher tap temperatures. LRFs also acts as a buffer between BOF and EAF and the Continuous Caster, reducing casting costs and allowing greater flexibility in steel making operations.

WORKING OF LRF

- The function stirring of molten metal is to promote homogenization. Normal stirring operations are performed by percolating argon gas through a purge arrangement in the bottom of the ladle.

- A top lance mechanism serves as a back up means for bath stirring in the event the plug circuit in the ladle is temporarily inoperable.

- The gas supply connection to the ladle is automatically when made the ladle is placed on the transfer car.

- Fumes and particulates generated during heating and alloying operations at the LF will exit the water-cooled ladle roof through the various openings in the roof.

- The ladle roof is typically a water-cooled design with a refractory center or delta section and is configured to coordinate with existing ladles such that roof will completely cover the top portion of the ladle when in operating position.

LRFs ARE USED FOR THE FOLLOWING REFINING PROCESS:

- Homogenization
- Inclusion Flotation
- Desulphurization
- Vacuum degassing

ESR (ELECTRO SLAG REFINING)

○ ESR has been known since the 1930s, but it took approx 30 years before it became an acknowledged process for mass production of high-quality ingots. The ESR technology is of interest not only for the production of smaller weight ingots of tool steels and super alloys, but also of heavy forging ingots up to raw ingot weights of 165 tons.

- It is a process of remelting and refining steel and other alloys for mission-critical applications in aircraft, thermal power stations, nuclear power plants, military technology.
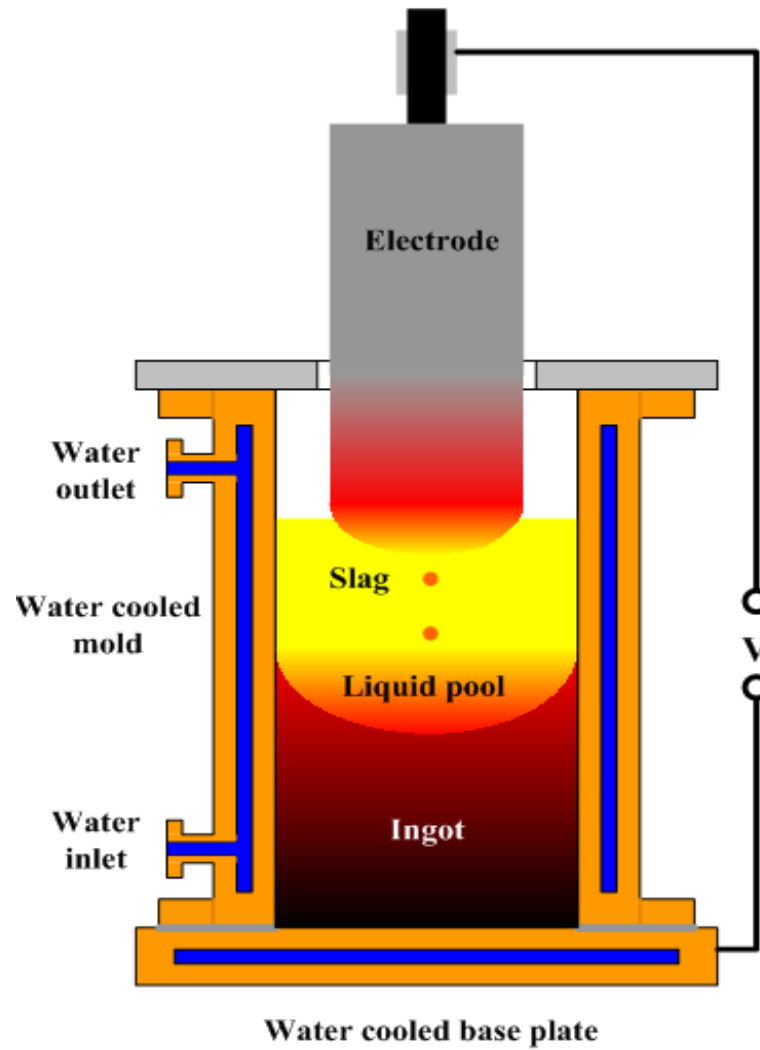
- The consumable electrods are as cast or forged cylindrical parts made of an alloy to be remelt.

- An electroslag remelting process (ESR) starts when the lower tip of a consumable electrode is immersed into a pool of molten slag.

- The premelted slag possessing electrical conductivity is located on the water-cooled mold base connected to a power supply.

- The electric current (commonly AC) passing through the the slag keeps it at high temperature, which is about ($200ºC$) higher than the melting point of the remelted metal.

- The electrode tip is heated by the hot slag and starts to melt forming droplets of liquid metal, which disconnect from the electrode and sink through the slag layer.

- The slag composition is based on calcium fluoride (CaF_2), lime (CaO) and alumina (A

- The molten steel in form of both liquid film on the electrode tip and descending droplets contacts with the slag and get refined due to desulfurization and removal of non-metallic inclusions (Sulfides and Oxides). l_2O_3).

- The droplets enters the molten steel pool, bottom of which is progressively solidifying. The water-cooled copper mold provides relatively high gradient of temperature resulting in high solidification rate. Solidification front is moving upwards (unidirectional solidification) forming sound homogeneous metal structure.
- The ingot has a good surface quality due to a thin slag film covering it.

Electroslag remelting

Electrode

Water outlet

Water cooled mold

Water inlet

Slag

Liquid pool

Ingot

V

Water cooled base plate

The slag composition provides the following properties:

- Melting point lower than that of the remelted alloy.
- Required level of viscosity.
- Required level of electrical conductivity.
- High solubility of sulfur.
- Capability to adsorb non-metallic inclusions.

Metallurgy of the ESR

Slags for ESR are usually based on calcium fluoride (CaF_2),

lime (CaO) and alumina (Al_2O_3). Magnesia (MgO), titania

(TiO_2) and silica (SiO_2) may also be added, depending on the alloy

to be remelted. To perform its intended functions, the slag must

have some well-defined properties, such as:

- Its melting point must be lower than that of the metal to be remelted;

- It must be electrically efficient;

- Its composition should be selected to ensure the desired chemical reactions;

- It must have suitable viscosity at remelting temperature.

Inert Gas Melting

A new trend is emerging in ESR melting that involves melting of Oxygen and Nitrogen sensitive alloys under an inert gas enclosure. The major benefits of the inert gas melting system, besides very low oxygen and nitrogen levels, are as follows:

- The system is fully enclosed preventing the possibility of contamination from the melt shop during melting.
- Different slags can be used because the oxidation of the slag is no longer a concern
- No deoxidant is required. Deoxidant has been shown to be a principal source of inclusions in ESR ingots.

ADVANTAGES

- Deep desulfurization.
- Refining non-metallic inclusions.
- Homogeneous distribution of non-metallic inclusions.
- Fine Grain structure.
- No Shrinkage defects.
- Low macrosegregation.
- Good surface quality.
- Controllable process.

APPLICATIONS

- Tool steels for milling cutters, mining, etc.
- Die steels for the glass, plastics and automotive industries.
- Ball-bearing steels.
- Steels for turbine and generator shafts.
- Superalloys for aerospace and power turbines.
- Nickel-base alloys for the chemical industry.
- Cold rolls.