Steel Quality Role of Secondary Refining and Continuous Casting

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Module – 02
Lecture – 09
Desulphurisation

Good morning, last session I have been talking about importance of secondary refining. I have just started taking up the topic the whole idea is to refine whatever elements are present to whatever extent possible control the inclusions and increase the cleanliness level.

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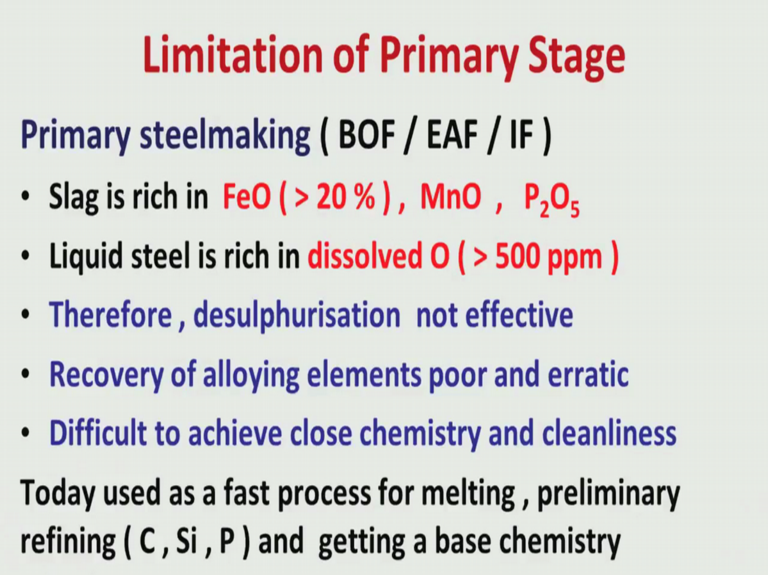

Limitation of Primary Stage

Primary steelmaking (BOF / EAF / IF)

- Slag is rich in FeO (> 20 %) , MnO , P_2O_5
- Liquid steel is rich in dissolved O (> 500 ppm)
- Therefore , desulphurisation not effective
- Recovery of alloying elements poor and erratic
- Difficult to achieve close chemistry and cleanliness

Today used as a fast process for melting , preliminary refining (C , Si , P) and getting a base chemistry

I have talked about what is the limitation of primary stage why it is not possible to enhance cleanliness in this primary stage because the slag here is very rich, iron oxide in the slag is more than 20 percent that is some amount of MnO, some amount of P2O5 which will create problem during the subsequent stages if this slag is not you know restricted. Even in the secondary refining stage if this slag goes there will be a problem. So, because the slag is rich in FeO liquid steel in primary stage; that means, that has dissolved oxygen more than 500 ppm which is very very high and this causes total oxygen to be more; that means, it is dissolved as well as the dissolve oxygen is more there will be more chances of formation of you know oxide inclusions and so as a whole cleanliness is poor. And since dissolved oxygen is more desulphurization is not effective at this stage recovery of alloying elements are poor because of this high dissolve oxygen alloying elements they will be forming oxides they are you know yield is less this is erratic you do not know how much you will finally, get. So, it is difficult to achieve close chemistry as well as cleanliness.

Now I have told that this primary stage these days is basically used as a fast and efficient process for melting and preliminary refining; that means, basically to control carbon silicon and phosphorus and getting a best chemistry on which you can fine tune during the subsequent secondary refining stages.

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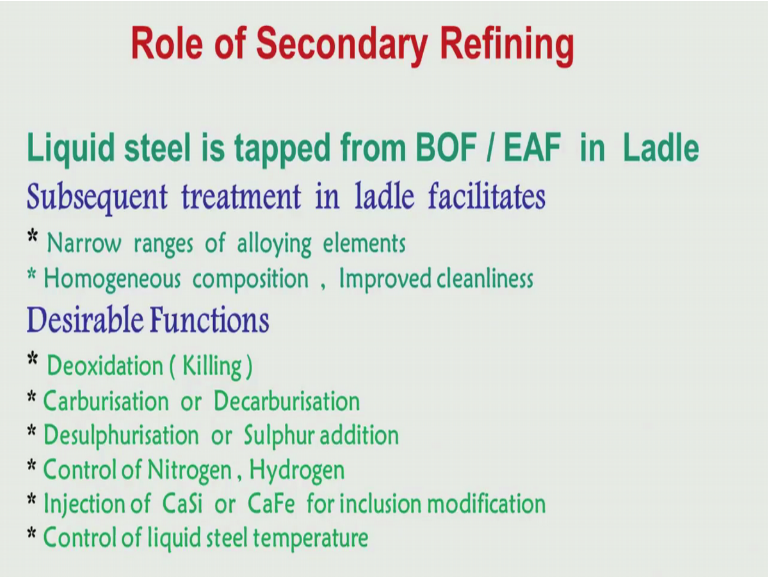

Role of Secondary Refining

Liquid steel is tapped from BOF / EAF in Ladle

Subsequent treatment in ladle facilitates

* Narrow ranges of alloying elements
* Homogeneous composition , Improved cleanliness

Desirable Functions

* Deoxidation (Killing)
* Carburisation or Decarburisation
* Desulphurisation or Sulphur addition
* Control of Nitrogen , Hydrogen
* Injection of CaSi or CaFe for inclusion modification
* Control of liquid steel temperature

Now, I have also covered what is the role what is expected in the secondary refining stages first liquid steel is stacked from basic oxygen furnace or electric arc furnace in ladle. So, subsequent treatment in ladle what are expected we should get narrow ranges of alloying elements.

We should get a homogeneous composition as well as homogeneous temperature throughout the you know liquid steel, but we must get improved cleanliness that is that is the principle you know requirement for secondary refining. So, what are the desirable functions I have talked about first is deoxidation which is known as killing this is a first requirement for any secondary refining process and it is of primary requirement for getting a clean steel next is decarburization or in 1 or 2 cases even carburization; that means, control of carbon in the bath then desulphurization or sulphur addition in may be one case only when you need more sulphur for good machinability otherwise in most of the applications we require less sulphur.

So, desulphurization is one important requirement then control of gaseous elements like nitrogen and hydrogen in liquid steel this is done to degassing I will come to these in details later on. Then may be injection of CaSi or CaFe basically injection of calcium helps in inclusion modification making the inclusion liquid at steel making temperature and it is easier to float them up and get absorbed in the slag basic slag and finally, control of liquid steel temperature this is essential if you want to do a good casting.

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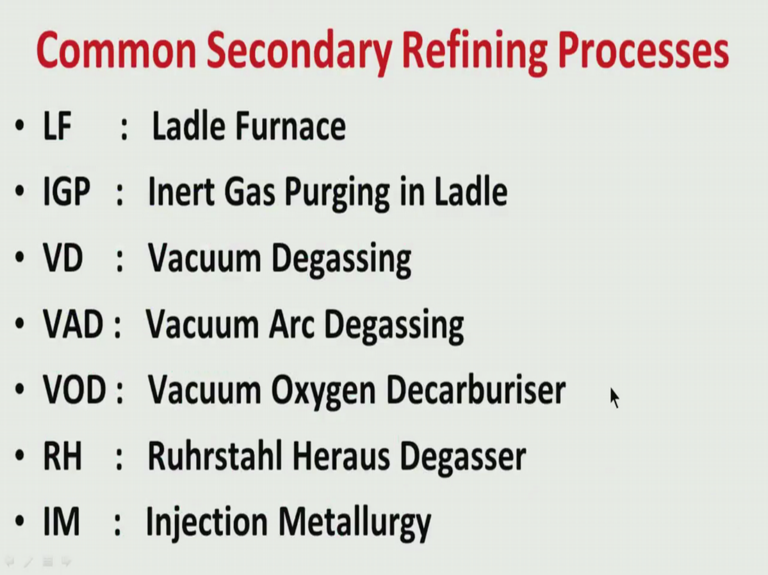

Common Secondary Refining Processes

- LF : Ladle Furnace
- IGP : Inert Gas Purging in Ladle
- VD : Vacuum Degassing
- VAD : Vacuum Arc Degassing
- VOD : Vacuum Oxygen Decarburiser
- RH : Ruhrstahl Heraus Degasser
- IM : Injection Metallurgy

Now, I have talked about what are the common secondary refining processes, I have talked about ladle furnace which is a very common process most of the steel produces today have ladle furnace. I will come to what ladle furnace can do what are the capabilities then in to inert gas purging in ladle this is very simple at the bottom of the ladle; through the bottom of the ladle; there is a you know get through which you can pass inert gas say argon. So, it is possible to make a good circulation in the bath; the bath becomes homogeneous this helps in some reactions like you know deoxidation reaction putting all of deoxidants and related advantages are there. When I am talking or I have talked about the vacuum processes it may be vacuum degassing where degassing is possible you create vacuum; vacuum we will discuss today how it helps in degassing then we can have VAD that is vacuum arc degassing; that means, on top of vacuum it there is a facility of arcing; that means, you can control the temperature you can increase the temperature in the liquid bath in the liquid steel.

So, even if there is a temperature decrease during the process it is possible to get back to the desired temperature using arcing then we can have vacuum oxygen decarburiser; VOD what does it do that is vacuum as well as you are passing oxygen. So, that this helps in decarburization; that means, oxygen will react with carbon will generate carbon monoxide which is a gas and if you have a vacuum this carbon monoxide removal becomes easier. So, it is an efficient process for decarburizing. So, VOD is basically vacuum oxygen decarburization then I have talked about RH, today I will discuss; what are the specialties of RH why it is beneficial how it is different from other degassing and related issues. So, RH basically stands for Ruhrstahl Heraus process degas, it is basically degassing in this process you can bring down oxygen and nitrogen and steel it was invented in Germany.

So, it is known as Ruhrstahl Heraus degasser RH degasser then there is a possibility of you know injection metallurgy; that means, you are injecting either some powder or somewhere of calcium. So, injection metallurgy is possible in the ladle in by that process you can get you know better control of the inclusions I will come to that later on.

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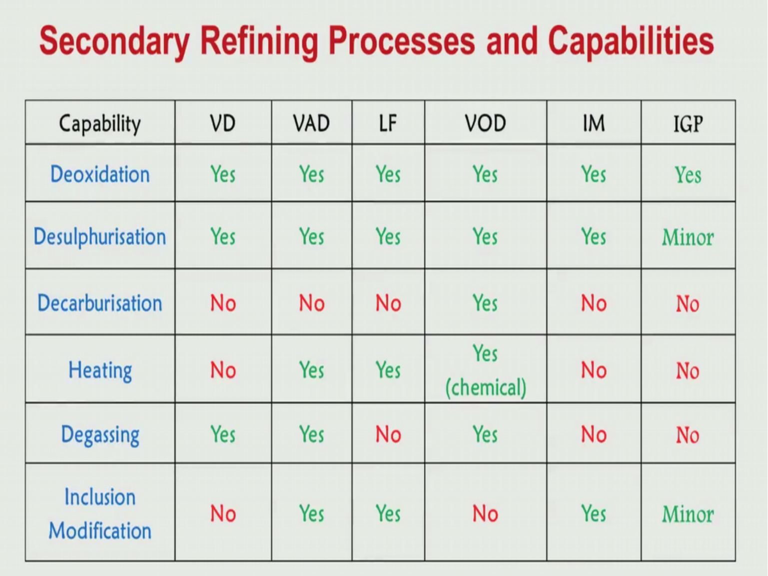

Secondary Refining Processes and Capabilities

Capability	VD	VAD	LF	VOD	IM	IGP
Deoxidation	Yes	Yes	Yes	Yes	Yes	Yes
Desulphurisation	Yes	Yes	Yes	Yes	Yes	Minor
Decarburisation	No	No	No	Yes	No	No
Heating	No	Yes	Yes	Yes (chemical)	No	No
Degassing	Yes	Yes	No	Yes	No	No
Inclusion Modification	No	Yes	Yes	No	Yes	Minor

Then I had discussed this what how these capabilities are actually taken care off or taken benefit off in the different processes, I have told deoxidation which is a primary requirement of a secondary refining process it is possible in all the known secondary refining processes whether it is VD vacuum degassing or vacuum arc degassing ladle furnace vacuum oxygen decarburization injection metallurgy inert gas purging in you. Name any secondary refining process deoxidation is possible then desulphurization it is possible in most of the you know secondary refining processes whether it is VD VAD LF VOD injection metallurgy inert gas purging everywhere it is possible only thing is inert gas purging it is relatively less, but if you can add some calcium oxide; that means, you can create a basic slag then you can get some amount of desulphurization in inert gas purging also then decarburization I have told you it is possible only in VOD when along with vacuum you have some oxygen in rest in the facility.

So, oxygen reacting with carbon can give rise to decarburization. So, this is possible in VOD then heating I have told you whenever there is an arcing facility you can do heating and you can increase the steel temperature liquid steel temperature. So, this is possible in VAD because you have arcing it is possible in ladle furnace because you have arcing it is possible in VOD through addition of aluminum because it is aluminum and oxygen will react and will give some chemical heating. So, it is possible to some extent in VOD it is also possible in RH which I will discuss today in details where it is possible to increase the temperature through some heating.

Then degassing I have told you whenever there is a vacuum in any process whenever we can we can we know increase the vacuum level there is a possibility of degassing; that means, removal of nitrogen gaseous elements like nitrogen hydrogen. So, vacuum degassing it is possible in VD VAD is possible in VOD because there is vacuum it is possible also possible in RH, I will discuss this today then I have talked about inclusion modification; that means, you can change the inclusion by putting some calcium. So, it is possible in VAD, it is possible in LF it is possible in injection metallurgy definitely it is possible it is to a minor extent possible in IGP.

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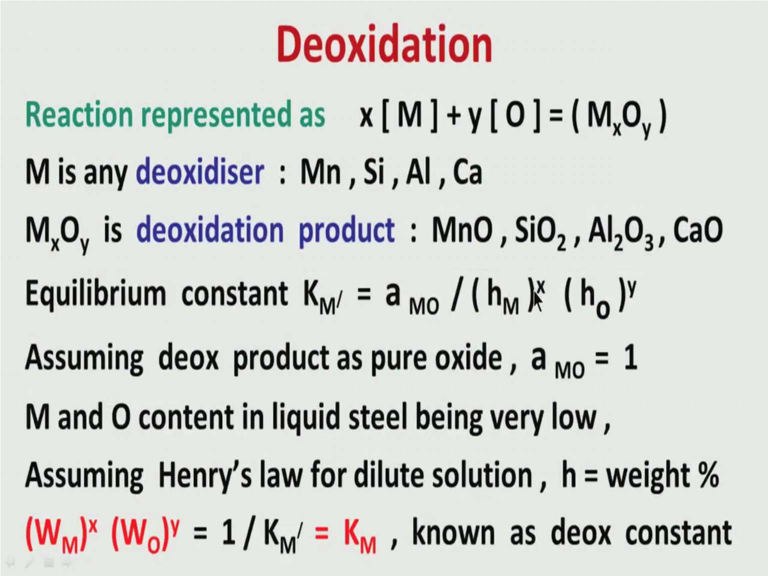

Deoxidation

Reaction represented as $x[M] + y[O] = (M_xO_y)$

M is any deoxidiser : Mn, Si, Al, Ca

M_xO_y is deoxidation product : MnO, SiO_2, Al_2O_3, CaO

Equilibrium constant $K_M' = a_{MO} / (h_M)^x (h_O)^y$

Assuming deox product as pure oxide, $a_{MO} = 1$

M and O content in liquid steel being very low,

Assuming Henry's law for dilute solution, h = weight %

$(W_M)^x (W_O)^y = 1 / K_M' = K_M$, known as deox constant

Now, I have also discussed in the last session that how deoxidation takes place which is the principal requirement of any secondary refining process. So, it is a reaction between the deoxidant M with oxygen which is present as element in liquid steel, so, as a residual element, so, this reaction of formation is M x O y. So, M can be any deoxidizer manganese silicon aluminum calcium anything. So, depending on the element or the deoxidizer the deoxidation product can be manganese oxide can be silicon oxide can be aluminum oxide can be CaO or a combination of this if you have 2 or 3 deoxidizers which can be used for deoxidation which is known as complex deoxidation if you use more than one deoxidizer.

So, from this reaction we know the equilibrium constant is basically related to the activity of the deoxidant divided by the Henry and activity of the metal which is causing deoxidation its multiplied by the Henry an activity of oxygen soluble oxygen in liquid steel now if we assume the deoxidation product as pure oxide we can take the activity of the deoxidant as one and. So, assuming Henry's law for dilute solution where activity can be taken and weight percent because it is much low very very low it is a dilute solution. So, Henry's law is worried. So, the weight fraction of the element deoxidant in liquid steel to the power x in to the weight fraction of oxygen in the liquid steel to the power y it is constant.

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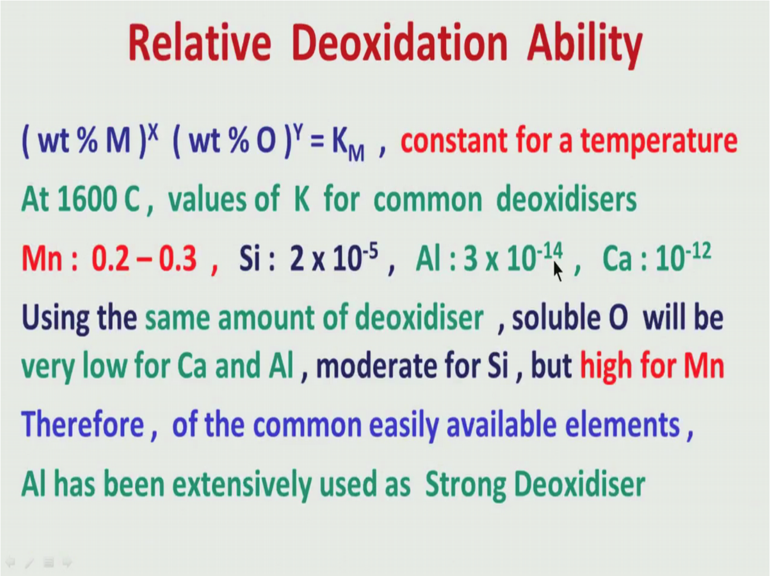

Relative Deoxidation Ability

$(\text{wt \% M})^X\ (\text{wt \% O})^Y = K_M$, constant for a temperature

At 1600 C , values of K for common deoxidisers

Mn : 0.2 – 0.3 , Si : 2×10^{-5} , Al : 3×10^{-14} , Ca : 10^{-12}

Using the same amount of deoxidiser , soluble O will be very low for Ca and Al , moderate for Si , but high for Mn

Therefore , of the common easily available elements ,

Al has been extensively used as Strong Deoxidiser

It is it known as deoxidation constant. So, I have also discussed that from this value of the constant you know the weight percent of the you know deoxidant in to the weight percent of deoxidant is constant at a particular temperature. So, from the value of the constants like at 1600 centigrade which you know is a common liquid steel temperature if at this temperature if you evaluate what is K from the thermo dynamics thermo dynamics you know values. So, we can get that manganese for manganese this K value is 0.2 to 0.3 silicon it is about 2 in to 10 to power minus 5 aluminum it is 3 in to 10 to power minus fourteen means very low calcium tells way around 10 to power minus 12 very low now the lower this value what is the advantage. That means, for a particular amount of M the multiplication is lower means the oxygen also will be low; that means, when you are using the same amount of deoxidant if the value of K is low; that means, for aluminum and calcium the soluble you know level of oxygen dissolved oxygen also will come down for alum when you are using aluminum and calcium.

So, using the same amount of deoxidizer soluble oxygen will be very low for calcium and aluminum moderate for silicon and relatively high for manganese. So, therefore, of the common available elements easily available elements aluminum in aluminum has been extremely extensively used as a strong deoxidizer we have taken up these issues in the last session just to make you understand that from the basic theoretical values we can know which one is a good oxidizer which one is a relatively poor oxidizer to what extent deoxidation is possible.

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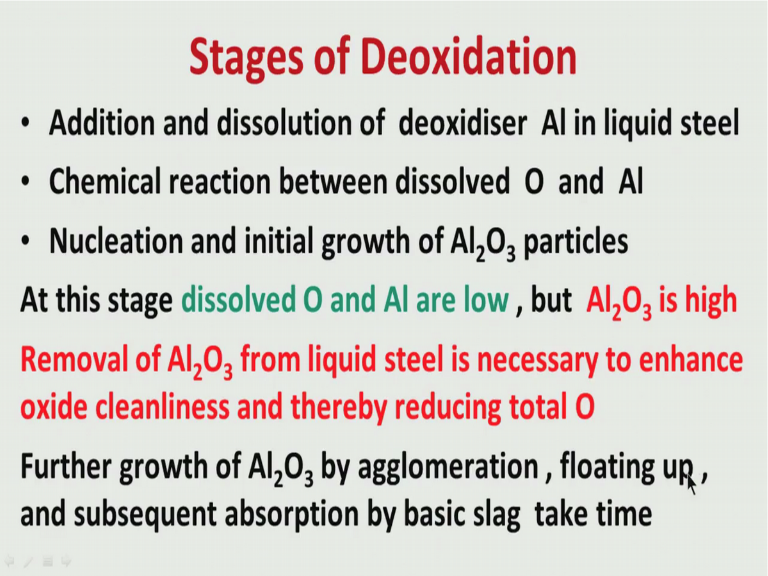

Stages of Deoxidation

- Addition and dissolution of deoxidiser Al in liquid steel
- Chemical reaction between dissolved O and Al
- Nucleation and initial growth of Al_2O_3 particles

At this stage dissolved O and Al are low, but Al_2O_3 is high

Removal of Al_2O_3 from liquid steel is necessary to enhance oxide cleanliness and thereby reducing total O

Further growth of Al_2O_3 by agglomeration, floating up, and subsequent absorption by basic slag take time

Now, I have also discussed what are the stages of deoxidation; that means, when we are adding the deoxidant what are the steps how does it react first we have to add and then this gas gets in to the solution; that means, dissolution of the deoxidizer in liquid steel. So, when we are adding aluminum in liquid steel first it has to get dissolved; that means, the dissolution of aluminum in liquid steel is the next step then there will be a reaction between this dissolved oxygen and dissolved aluminum in liquid steel. So, first we are adding a aluminum which is getting dissolved in liquid steel then this dissolved oxygen and dissolved aluminum in liquid steel they are reacting and nucleation of alumina particles; that means, the deoxidation product alumina is getting nucleated and there is some initial growth and all these 3 steps that take place very fast. So, we get nucleation of alumina and some initial growth of alumina particles.

So, at this stage of deoxidation what is the situation we get dissolve oxygen and dissolve aluminum which are very low because dissolve all aluminum has reacted with dissolve oxygen and since aluminum is a very good deoxidant at a very low amount of aluminum dissolved aluminum we get very low amount of dissolved oxygen, but what is happening what is the deoxidation product this is alumina. So, this alumina particles which are nucleating and there is some initial growth initially at the start these alumina particles are still in liquid steel. So, alumina is relatively high we have very low dissolve oxygen very low aluminum, but good amount of very low aluminum as element, but good amount of alumina the deoxidation product. So, this alumina from liquid steel has to be removed then only we get good cleanliness and thereby the total oxygen which is a combination of dissolved oxygen and oxygen present as alumina. So, if you can remove this alumina from the steel we get good cleanliness low value of total oxygen.

Now, how is it possible this growth of the alumina particles you know they happen by agglomeration; that means, these particles they combine with each other agglomerate with each other they will float up and subsequently they will be absorbed by the basic slag, but the whole this process this was very fast you know formation of alumina, but this growth of the alumina particles they are floating up and getting absorbed by the top liquid slag it takes time. So, we have to give that sufficient time that adequate time for the inclusions to float up and get absorbed.

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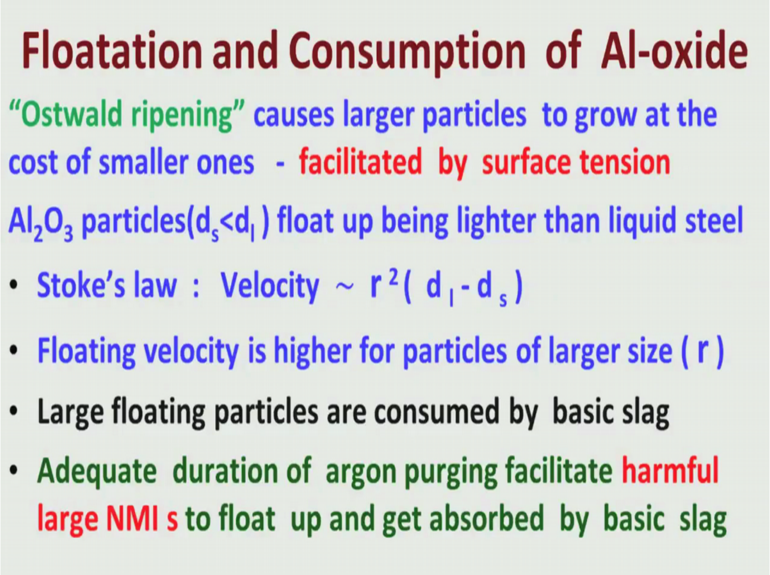

Floatation and Consumption of Al-oxide

"Ostwald ripening" causes larger particles to grow at the cost of smaller ones - facilitated by surface tension

Al_2O_3 particles($d_s<d_l$) float up being lighter than liquid steel

- Stoke's law : Velocity ~ $r^2(d_l - d_s)$
- Floating velocity is higher for particles of larger size (r)
- Large floating particles are consumed by basic slag
- Adequate duration of argon purging facilitate harmful large NMI s to float up and get absorbed by basic slag

Now, I have talked about you that how the floatation and consumption of aluminum oxide takes place I have talked about Ostwald ripening this helps these alumina particles to coagulate and form larger particles, why it happens this why this smaller particles grow the smaller particles combine and you know form larger particles this is basically from the surface point of view surface tension surface energy point of view because you know smaller particles have relatively larger surface area surface to volume ratio is more so that means, if they combine if the smaller particles combine the surface to volume ratio will come down.

So, the surface energy also will come down from this point of view we call it Ostwald ripening you know small particles they will combine and large particles will form now we know that from Stokes law. Stokes law these particles how they will you know what will be the velocity when they flood up it is related to it is proportional to square of the size of the particles and it is directly related to the density difference between the liquid and the solid particles we know the solid particles that is alumina or SiO2 whatever is or the deoxidation products they have relatively less density compared to liquid steel. That is the reason why they will float that is the reason they why the velocity will be dictated that is the reason why that rather another reason for the velocity to go up is the size more is the size and larger is the size of the particles more is the velocity; that means, larger particles will try to float up.

Because of this Stokes law and then they will be consumed by the basic slag basic slag means which has very high amount of calcium oxide which has good basicity. So, they will consume this alumina or SiO2 particles which are which are basically the deoxidation products. So, duration of argon purging this is very important adequate duration of argon purging say about 15-20 minutes is necessary to allow these particles to float up these larger particles are harmful. So, fortunately if you give some good time for design you know adequate time through you know argon purging in the ladle.

So, these harmful large NMIs, they will float up and get absorbed by the basic slag. So, I have told you how these alumina oxides are forming; that means, you varying aluminum as deoxidant it is causing the dissolve oxygen to come down. So, we have dissolve oxygen and dissolve aluminum in steel as well as alumina as particles these alumina particles will try to float up they will try to coagulate and try to become you know bigger and then the bigger particles will float up this process is enhanced by use of argon purging because it helps the larger particles to form faster and larger particles to go up float up and get absorbed by the slag slag which is basic in nature.

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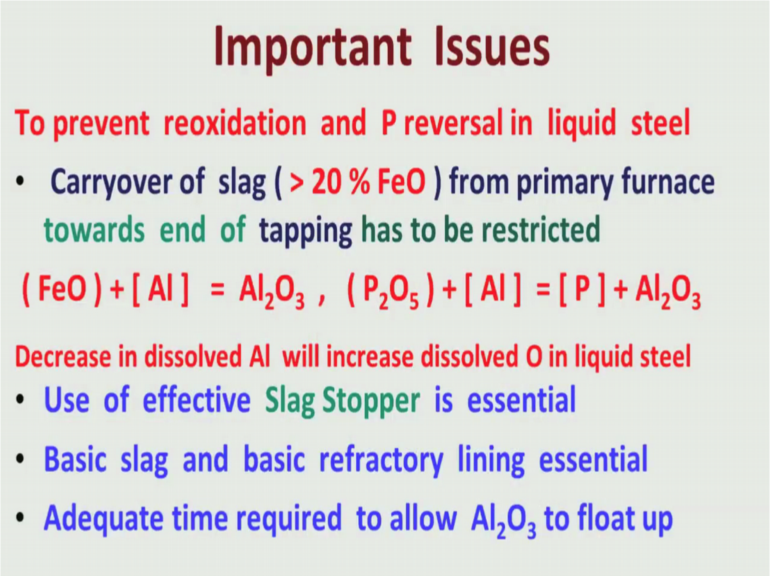

Important Issues

To prevent reoxidation and P reversal in liquid steel

- Carryover of slag (> 20 % FeO) from primary furnace towards end of tapping has to be restricted

$(FeO) + [Al] = Al_2O_3$, $(P_2O_5) + [Al] = [P] + Al_2O_3$

Decrease in dissolved Al will increase dissolved O in liquid steel

- Use of effective Slag Stopper is essential
- Basic slag and basic refractory lining essential
- Adequate time required to allow Al_2O_3 to float up

Then I have also talked about some important issues of deoxidation what are the issues the carry over slag from primary furnace as I have told towards the end of tapping there is a possibility because of this funnel formation. So, this has to be low because this carry over slag; that means, the slag from the primary steel I have told you it is very rich in iron oxide more than 20 percent it maybe 25 percent it may be slightly more then there is about 5 percent MnO then there is about maybe 3 percent phosphorous oxide we just removed phosphorous from liquid steel. So, the slag; so, all these oxides FeO, MnO, P2O5, they can react with the dissolve aluminum in liquid steel where from dissolve aluminum is coming because by the process of deoxidation when you are adding aluminum.

Some amount of aluminum will be retained in liquid steel as dissolved aluminum and the other portion of aluminum will react with dissolved oxygen and form alumina and this alumina we are trying to float up and get rid of it in the process of you know for the removal. But if you have some amount of carryover of slag from the primary furnace then what is happening this iron oxide which is you know present in the carryover of primary oxide you know furnace slag this will react with the dissolved aluminum in liquid steel it will again generates some alumina then phosphorous oxide by removing phosphorus by controlling phosphorus lot of amount of phosphorus has you know got transferred from the liquid steel to the slag. Now if this slag from the primary steel comes to the ladle at the end of the tapping then whatever phosphorus oxide is there in the slag it again might react with aluminum and there will be phosphorus reversal.

So, the possibility of re-oxidation and phosphorus reversal and liquid steel will be there if we cannot control that carryover of slag from the primary furnace. So, this is an essential requirement. Now what happens if that dissolved aluminum because of these reactions with FeO and P2O5 this amount of dissolve oxygen will come down by reaction dissolve aluminum whatever was present due to re-oxidation this will come down and in the process what is going to happen because the weight percent of this dissolved aluminum and weight percent of the dissolve oxygen is constant as I have told you earlier. So, if the dissolved aluminum comes down dissolved oxygen in liquid steel will increase. So, what is going to happen this is going to you know affect the cleanliness of the steel.

So, re-oxidation will take place phosphorus reversal will take place; that means, phosphorus also will increase in steel because you know some soluble aluminum is coming down because of this reactions dissolved soluble oxygen in liquid steel will increase. So, these are creating a cleanliness problem. So, effective slag stopper I have told you is very very important we must stop the slag from the primary steelmaking process. That means, b O a for a f to come to get carried over to the ladle at the time of tapping this is very important then I have told you the basic slag and basic refractory these are essential because why if you do not have basic refractive basic refractive means refractive which is reach in c O if you have some amount of SiO2 in the refractory lining then this SiO2 will again react with aluminum in liquid steel and you know generate SiO2 you know re-oxidation will take place dissolved aluminum will come down dissolve oxygen will go up.

So, this is again a problem. So, basic slag is required to take care of the alumina to take care of the SiO2 deoxidation products. So, basic slag and basic refractory these are also essential requirements and then I have told you that this adequate time say about 15-20 25 minutes is necessary for argon purging to allow the alumina inclusions to float up and get absorbed.

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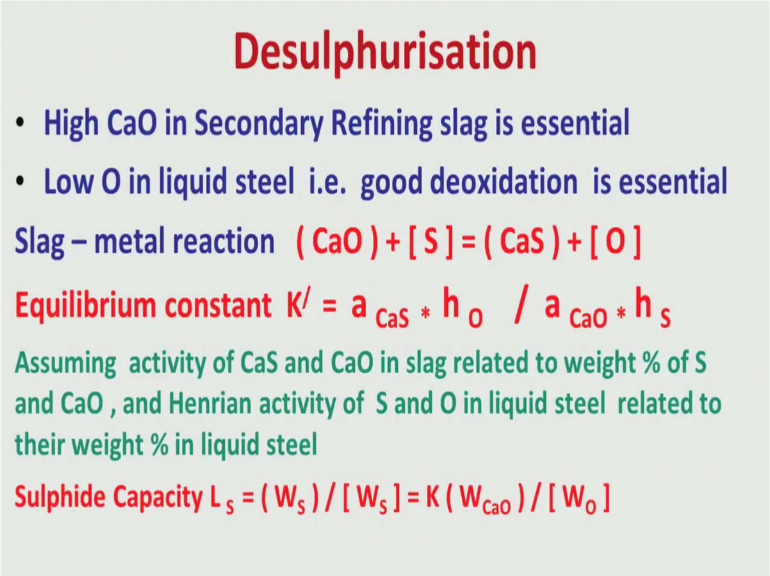

Desulphurisation

- High CaO in Secondary Refining slag is essential
- Low O in liquid steel i.e. good deoxidation is essential

Slag – metal reaction $(CaO) + [S] = (CaS) + [O]$

Equilibrium constant $K^{/} = a_{CaS} * h_{O} \;/\; a_{CaO} * h_{S}$

Assuming activity of CaS and CaO in slag related to weight % of S and CaO , and Henrian activity of S and O in liquid steel related to their weight % in liquid steel

Sulphide Capacity $L_S = (W_S) / [W_S] = K (W_{CaO}) / [W_O]$

Now, today let me talk about another important requirement called desulfurization I have told you the deoxidation is the first requirement for secondary refining you have to first deoxidize the steel; that means, oxygen soluble oxygen level must be brought down then only the subsequent reactions are really effective I will come to that now.

Why it is required the initially there has to be deoxidation then only desulphurization reaction is effective. Now what is desulphurization let me first talk about that desulphurization basically means whatever sulphur is present in liquid steel after you know primary steelmaking as I have told you since there is lot of iron oxide in the primary steelmaking slag. So, the oxygen dissolve oxygen level is also very high and if the dissolve oxygen level is high desulphurization is not very affected which I have already discussed earlier and today I will come to it also in a more elaborate fashion. Now what is the desulphurization reaction the sulphur whatever is present in liquid steel it will react with calcium oxide which is present in the slag.

So, what is the essential requirement is there has to be good amount of calcium oxide in the secondary refining slag; that means, we must add calcium oxide in ladle. So, that the slag contains good amount of calcium oxide what is meant by good amount it has to be say about 50 percent; that means, the necessity of the slag CaO by SiO2 should be very high maybe more than 3. So, the calcium oxide should be at least about 50 percent basicity should be more than 3.

So, this is one important requirement now what is the reaction slag metal reaction first bracket I have told you indicates there is a presence in slag. So, CaO whatever is present in slag will react with sulphur which is present in liquid steel you see it is third we have given third bracket for the sulphur; that means, calcium oxide in slag is reacting with sulphur which is present in liquid slag liquid sorry not in liquid slag liquid steel third bracket is the liquid steel. So, calcium oxide present in slag sulphur is present in liquid steel. So, this is these 2 are reacting for the formation of calcium sulfide which is going to the slag and oxygen is getting generated which is present in liquid steel third bracket; that means, liquid steel.

So, the reaction is between sulphur in liquid steel with calcium oxide which is present in the slag and generating calcium sulfide which goes to the slag and oxygen which grows to the liquid steel. Now the equilibrium constant what is reaction what does it indicate that the activity of the calcium sulfide in slag in to activity of h is basically the Henrian activity of oxygen in liquid steel divided by activity of calcium oxide in the slag in to activity Henrian activity of sulphur in slag in liquid steel sorry. So, the activity of calcium sulfide though sulfur whatever was present in liquid steel is going to slag as calcium sulfide and the oxygen whatever was present in slag as calcium oxide is trying to part of it is trying to come in liquid steel in the form of elemental oxygen so; that means, this reaction is basically a slag metal reaction.

So, the equilibrium constant is basically K dash is basically activity of calcium sulfide; that means, the sulphur in slag in to the activity of oxygen Henrian activity of oxygen in liquid steel divided by activity of calcium oxide in slag in to activity of sulphur in liquid steel. So, what does it indicate how they you know reaction will be faster it can be faster when we have very good amount of calcium oxide in slag we have very low amount of dissolve oxygen in liquid steel because you just see look at the equilibrium constant activity of calcium sulfide in to you know activity of oxygen divided by activity of CaO and activity of sulphur. Now assuming that calcium sulfide and calcium oxide in slag are related to weight percent of sulphur, so calcium sulfide I am trying to convert it to the weight percent of sulphur and calcium oxide if you assume whatever you know weight person is present in slag. So, calcium sulphide and calcium oxide they are present in slag and if you assume their activity to be related to the weight percent of sulphur in slag and the weight percent of CaO; that means, calcium sulfide I am trying to represent with weight percent of sulphur in slag

And this Henrian activity of sulphur and oxygen in liquid steel related to their weight percent in liquid slag because they are very small you know weight percent of sulphide weight percent of oxygen liquid steel is very small. So, we can represent them by weight percent Henrian activity; that means, Henry's law is effective here for dilute solution. So, what is the sulfide capacities is a you know new term sulfide capacity is the weight fraction of sulphur in slag first bracket divided by weight fraction of sulphur in liquid steel third bracket. So, what is happening the sulphur from liquid steel is going to sulphur in slag as calcium sulphide; that means, the weight fraction of sulphur in slag divided by the weight fraction of sulphur in liquid steel.

So, this ratio more is the ratio more is the desulphurization is it clear w s is the weight of sulphur present as calcium sulphide in slag because the reaction is calcium oxide in slag reacting with sulphur in liquid steel to generate calcium sulfide in slag and oxygen in liquid steel. So, whatever sulphur was present in liquid steel the idea is to transfer as much as possible from the liquid steel to slag as calcium sulphide. So, the weight of sulphur in calcium sulphide present in slag divided by the weight of sulphur in the liquid steel. So, that ratio is known as the sulfide capacity higher the, this way higher this ratio; that means, more is the amount of sulphur in slag as calcium sulphide more is the sulphide capacity better is the desulphurization. Now this is equal to what this is equal to one divided by K dash; that means, another constant in to weight of CaO in slag divided by weight of oxygen in liquid steel. So, just look at this ration. So, the sulfide capacity l s which is an indication of how good is the desulfurization is basically proportional to weight of CaO; that means weight of calcium oxide in the slag.

Divided by the weight of oxygen in liquid steel; that means, this is directly proportional to the CaO person type CaO percentage in slag not inversely proportional to oxygen present in liquid steel. So, lower the liquid steel oxygen better will be the sulfide capacity better will be the desulphurization. Now is it clear why every time I have been talking about the deoxidation has to be first done if deoxidation is done oxygen level is in steel comes down these helps not only in creating you know low amount of total oxygen, but also helps subsequently in desulphurization.

So, high CaO in secondary refining is essential also low oxygen in liquid steel that is good deoxidation is also essential. So, there are 2 requirements for having good desulphurization first is good amount of CaO more than fifty percent the basicity has to be basicity means CaO by SiO2 ratio in slag has to be more than 3; 3.5 is better and another important requirement is the oxygen liquid steel has to be low; that means, good deoxidation prior to desulphurization is essential. So, for all secondary refining again I am repeating fast activity is deoxidation once we achieve good deoxidation; that means, the solubility of oxygen in liquid steel is brought down to say less than 5 ppm then desulphurization will be very effective I think it is very clear to you.

Now why first deoxidation is necessary and then desulphurization is good desulphurization is possible and then given you a concept of sulphide capacity of the slag; that means, the slag must have very good amount of CaO then only it can hold on to the sulfur in the slag; that means, the sulfur weight percent of sulfur in the slag in the form of calcium sulfide will be more when you have mole calcium oxide. So, this sulfide capacity of the slag is very important; that means, we must have adequate CaO in the steel which will generate adequate calcium sulfide in the steel then only we have weight percent of sulphur in the steel is more compared to the weight percent of sulphur in you know steel this ratio is important. So, the amount of slag also coming comes to the picture because if the amount of slag is less this ratio there is a restriction on the ratio it cannot go high and you know desulphurization is not very effective. So, good amount of slag having high amount of CaO and viscosity and very low oxygen in liquid steel these are the requirements for effective and very good desulphurization.