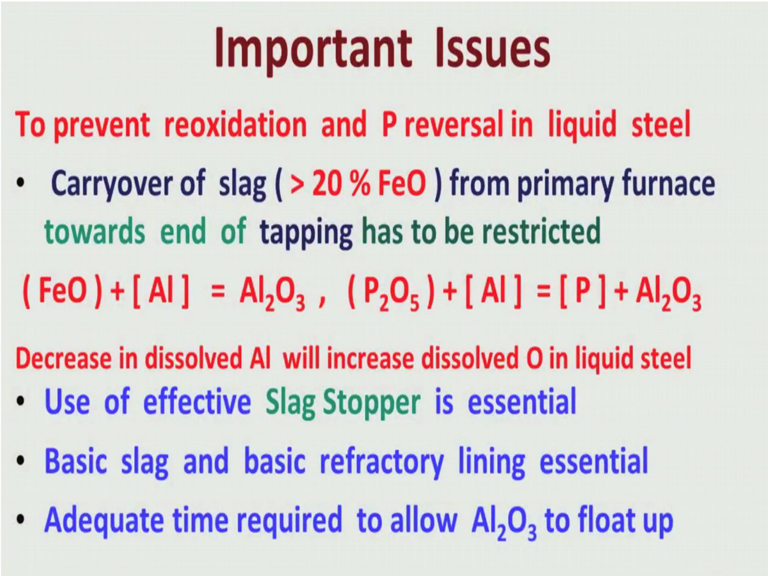
Steel Quality Role of Secondary Refining and Continuous Casting
Dr. Santanu Kr Ray
Department of Mechanical Engineering
Indian Institute of Technology, Madras

Module - 02
Lecture - 08
Prevention of Slag carryover

(Refer Slide Time: 00:16)



Let us go in to the steps now. Now I have told you the deoxidation is basically the reaction of dissolved oxygen with deoxidant is of which is dissolved and finally, creation of alumina in steel which we want to remove slowly at that and finally, go in to the slag. But here is one problem, when we are you know tapping liquid steel from BOF or EAF or induction furnace at the top of the liquid steel there is slag so that means, towards the end of tapping, there is a possibility of the slag getting carried over from the primary furnace; that means, BOF or EAF for us to the level because when we are draining out the liquid steel there is a you know funnel formation. That means, liquid steel which is coming to an end coming towards the end of the tapping that a portion of liquid steel is less on top of it there is slag. So, when this there is a funnel formation and along with the liquid steel some amount of liquid slag might be carried over from the furnace that is from BOF or EAF to the ladle.

So, this carryover of slag from the primary furnace towards end of tapping has to be restricted why because as I have told you this slag has very high amount of iron oxide it is more than 20 percent, it can be 25 percent, it can be almost 30 percent, total oxygen FEO defined types of oxides are there. So, assuming it is FEO the amount is more than say 20 or 25 percent. So, if some of it comes to the ladle; that means, it will react with the aluminum which is present in the dissolved aluminum or dissolve deoxidant which is present in the liquid steel this iron oxide in slag will react with aluminum liquid steel to form alumina. Moreover I had told you that we have reduced phosphorus in primary steelmaking stage phosphorus most of it has gone from the elemental stage in liquid steel to the slag, but the slag has about 3 percent P 2 O 5 I am talking of the slag from the primary furnace. Which has more than 20 percent FEO it has some amount of (Refer Time: 03:05) may be around 4 5 percent and also about 3 percent phosphorus oxide.

Now this phosphorus oxide if this slag comes in to the ladle during use you know during secondary refining this may react with aluminum; that means, after deoxidation whatever aluminum is there the soluble aluminum is there a liquid steel phosphorus oxide in the slag would may react and you see the phosphorus will come back we call it re-phosphorization. So, it is called phosphorus reversal from slag to linguistic.

So, re-oxidation of liquid steel and phosphorus reversal in liquid steel these 2 will be possible if there is a carryover of slag from the primary furnace is this clear, try to think over it what is happening here. I have told that at the final stage of that means, towards the end of tapping from the pan primary furnace we are when we are tapping liquid steel from primary furnace to the ladle that is a possibility of some slag getting carried over from the primary furnace to the ladle. Now the primary furnace slag is reaching FEO more than 20 percent maybe 25 percent maybe slightly more it has some amount of amino also, it has also about 3 percent or slightly more phosphorous oxide. So, this FEO can react with dissolved aluminum phosphorous oxide in slag which comes to the ladle from the primary furnace it can react with aluminum in liquid steel amino like a few amino also can react with aluminum and you know give rise to amino.

In this process what is happening this dissolved aluminum in liquid steel is coming down. So, it is the steel is getting re-oxidized and what is the most potential element which will re-oxidized first of course, it is aluminum. So, whatever you know FEO an amino are they are in liquid steel they will react with aluminum in liquid steel and finally, give rise to alumina. So, the problem is dissolved aluminum is coming down phosphorus is getting reversed; that means, phosphorus is increasing in liquid steel alumina is forming in liquid steel. So, whatever alumina has formed because of deoxidation more amount of alumina is forming more amount of aluminum which was present as dissolved aluminum is coming down. So, what is the you know implications if dissolved aluminum is coming down because aluminum and dissolved aluminum in and dissolve oxygen multiplication is constant. So, dissolved aluminum coming down means dissolve oxygen will increase in liquid steel; that means, again re-oxidation we call it phosphorus is also increasing alumina is also increasing.

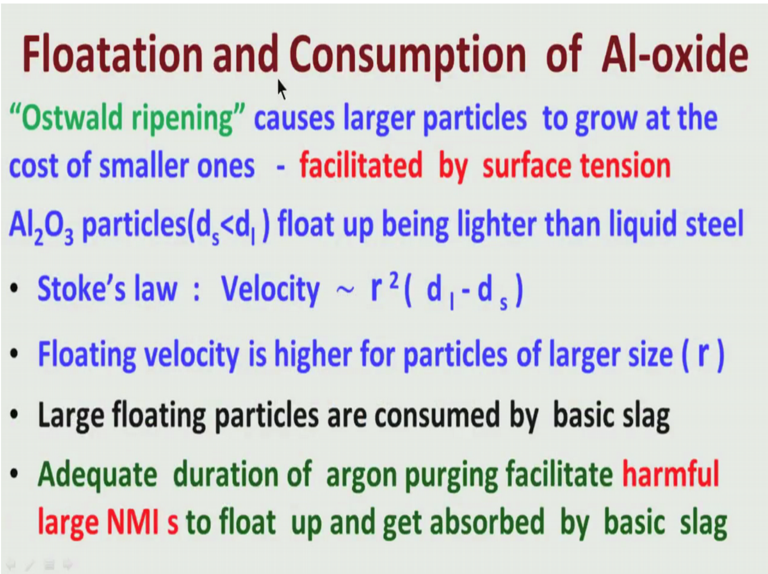
So, again there is a possibility up to certain extent affection of cleanliness the cleanliness is getting enhanced in this process you have to be very careful about how this slag from the primary furnace can be stopped I have mentioned here the decrease in dissolved aluminum will increase in dissolved oxygen in a liquid steel because the multiplication of aluminum and oxygen is constant as I have told you earlier. So, what is important is use of effective slag stopper is essential; that means, slag from the primary furnace v O f or EAF should not be allowed to be carried over in the ladle it should not be allowed to come from the primary furnace to the ladle.

So, what is slag stopper some of you possibly know it can be 2 ways you can stop slag one is you can put a refractory some balls or something like that we call it a dart you know and the density of this is in between that of slag and liquid steel you know the slag has lower density that is why it is at top of the liquid steel. So, if the density of the refractory ball or the dart is in between slag and liquid steel. So, whenever it will whatever if it is floating it will float at the interface of liquid steel and slag? So, at that time of liquid steel is getting tapped it will come whenever slag tries to come near the tapped hole it will stop the slag from coming through the tapped hole because the dart will come to the slag hole or the tap hole rather the tap hole.

So, this is a way it can be talk stopped or to some extent control another way is and you know technique that whenever slag tries to come the signal will be generated and the BOF will be tilted; that means, you can control the slag coming in you can you can detect the point where slag is coming near the tap hole and the BOF will be tilted back. So, these are technique for slag stopping these helps in subsequent stages of secondary refining because if you have slag primary slag the you can know the power of the attempt to enhance the quality is restricted to some extent. So, another requirements are basic slag and basic refractory in the ladle because if you have a acid slag; that means, if I have SiO2 then this SiO2 will again react with aluminum in liquid steel or dissolve oxygen in liquid steel create SiO2 and generate some problems.

Moreover the slag also should be basic. So, that alumina when it is floating up it gets absorbed by the basic slag. So, I have mentioned that we have to give adequate time to these alumina particles to float up. So, during deoxidation we are generating alumina. So, I have told you generation of alumina takes place very fast, but this floating up of this alumina this takes time. So, we should allow some time maybe about 20-25 minutes for these alumina inclusions to float up during the secondary refining processes. So, that whatever alumina is getting generated during deoxidation or during re-oxidation they should be able to float up this also we will tell you in some details the basic mechanism how does it happen.

(Refer Slide Time: 10:26)



So, let us talk about the flotation and consumption of this aluminum oxide consumption at the level of slag basic slag. Now I have told you this alumina inclusions are generating or forming fast now they are trying to you know combine with each other why it is called Ostwald ripening. These causes larger particles to grow at the cost of smaller ones because you know smaller ones means their surface area is more compared to the bigger ones. So, if the smaller ones combine to become a larger one the surface area decreases.

So, it is called Ostwald ripening; that means, from the energy point of view this is favored. So, smaller particles will combine and bigger particles will form now this alumina particles their density is less than d s; that means, density of the solid is less than the density of the liquid steel that is why they will float up because they are lighter than liquid steel now we know of stokes law is basically talks about what will be the velocity of the solid particles in liquid.

It talks about this velocity of the particles they are dependent on the square of the you know size of the particles r is the size of the particles they are square and also they will depend on the density difference between the liquid and the solid; that means, the lighter the particles the velocity will be more and the bigger the particles because it depends on r square the velocity will be increasing very much it depends on the size. That means, the particles which are larger they will have more velocity that means they will float faster. So, we know that larger particles they will rise faster they will go to the top and finally, if you give adequate duration during argon purging or other you know secondary refining processes these harmful large n m is now we have to recall what I have told at the beginning this large size n m is are really harmful.

So, these large particles fortunately they will if they are in liquid steel they will float up faster from this we can get this idea from the stokes law because the velocity is directly proportional to the square of the size of the particle the larger the size higher will be the velocity faster the particles will move at the top and of this and why this you know particles are floating because they have they are lighter the density d s is less than the d l; that means, the density of the liquid. So, this particles whatever smaller particles are formed nucleated they will generate they will coagulate; that means, they will come together the larger particles will form and it is known as Ostwald ripening and these larger particles will move faster relatively faster compared to the smaller ones go to the top and if you have a basic slag alumina will be consumed by the basic slag. So, this way we can reduce the quantity of alumina which has been formed by deoxidation reaction. So, I have told you; what are the stages of deoxidation reaction.

What is the criteria of knowing which element is a strong deoxidizer this depends on the deoxidation constant I have told you k and since the weight percent of the deoxidant soluble in metal in liquid steel that particular metal aluminum calcium or silicon or whatever it is are manganese and the weight percent of oxygen the multiplication of this is constant at a particular temperature which comes from the free energy values. So, we have told why this k values being very small relatively small compared to k values of silicon or manganese the small amount of aluminum will be useful to reduce oxygen to a very low level.

So, whatever is forming now say aluminum we are using mostly for getting very low soluble aluminum for good killing of steel whatever alumina particles will be fall forming they will try to combine together and they try to float because confessing they are lighter than liquid steel they try to float and whenever their particles are combining with each other larger particles will float faster the velocity of floating will be more compared to the smaller particles. So, larger particles will float come to the slag will get absorbed by the slag if we have a basic slag. So, you know this deleterious large deoxidants alumina particles whichever formed because of deoxidation they will be consumed by the liquid slag. So, there by the inclusion level is coming down because by deoxidation we have taken care of the soluble oxygen.

Now, whenever these alumina inclusions are forming if they are also taken care of from liquid steel to the slag; that means, the liquid steel now becomes low in soluble aluminum low in alumina or other oxide inclusions; that means, oxygen present in liquid steel as soluble element as well as oxides or inclusions is combined also is coming low; that means, the total oxygen is coming low. So, that way we ensure that the cleanliness oxide cleanliness of the steel is also enhanced. So, I have tried to mention to you what are the secondary refining processes what are the expectations of secondary refining I have told the first and foremost requirement is deoxidation.

So, this is required and this is ensured by all types of secondary refining whether it is l f whether it is b d whether it is VAD whether it is VOD whether it is argon gas purging whether it is in to injection metallurgy whatever you are doing whatever process you resort 2 deoxidation is the first step because the soluble oxygen has to be brought down in liquid steel and in this process you are bringing now soluble oxygen and also the deoxidation product. If it is alumina you are trying to allow these inclusions to float up giving sufficient time you know putting argon putting argon gas as a purging gas from the bottom of the ladle and trying to facilitate the inclusions alumina inclusions to float up and get absorbed by the basic slag.

So, in the process dissolved oxygen as well as oxygen as oxides in liquid steel are coming down the total oxygen is coming down. So, the cleanliness level is enhanced in this process next in subsequent you know presentations I will talk about the other requirements how they are fulfilling secondary refining like desulphurization degassing you know shape control of oxygen control of the melting point of the oxides and related issues.

Thank you very much.