Steel Making

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Module No. # 01

Lecture No. # 18

Modern Steelmaking II, Electric Arc Furnace

So, in the last lecture, I have told you something about the alternative charge material in the electric arc furnace. There I have said three different types of charge materials are there in the practice. One is the hot metal, another is the directly reduced iron or sponge iron or h b i, and third, I have said about the iron carbide. I have also mentioned, that proportion of hot metal is not unlimited. Because, electric arc furnace traditionally, was developed for melting unit. If we charge hot metal, since hot metal contains varying amount of impurities, starting from carbon, silicon, manganese, phosphorus.

So, depending on the proportion of hot metal in the mix, one has to carry out refining; that is, one has to carry out oxidation, one has to supply oxygen and hence the refining time may increase with the proportion of increase in the hot metal and hence tap-to-tap time may increase with the more proportion of hot metal in the feed. So, taking in to all these aspects under consideration, a 30 percent hot metal is considered to be an optimum amount for maintaining the reasonable tap to tap time, comparable with the 100 percent describe practice.

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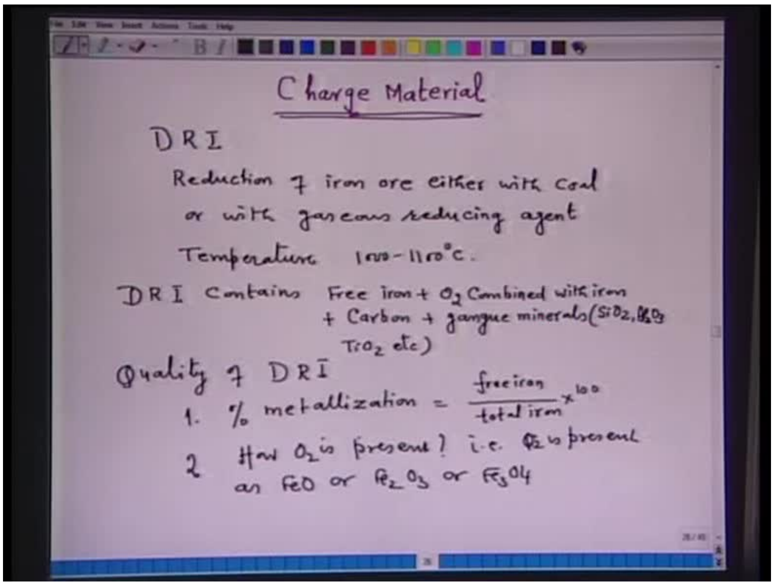

Charge Material

DRI

Reduction of iron ore either with coal or with gaseous reducing agent

Temperature 1000 - 1100 °C.

DRI Contains Free iron + O_2 Combined with iron + Carbon + gangue minerals (SiO_2, Al_2O_3, TiO_2 etc)

Quality of DRI

1. % metallization = $\frac{\text{free iron}}{\text{total iron}} \times 100$
2. How O_2 is present? i.e. O_2 is present as FeO or Fe_2O_3 or Fe_3O_4

Increasing amount of hot metal, though it can be used, but it will increase tap to tap time and increase in tap to tap time will be associated with all disadvantages, like increased refractory wear, increased electrode consumption, then increase electrical power consumption and so on and so forth. Now, the, another charge material is the directly reduced iron and that is what I will be telling you something about directly reduce iron today. In fact, this directly reduced iron is produced by reduction of iron ore, either with coal or with gaseous reducing agent or with gaseous reducing agent. So, the temperature in the production of DRI rarely exceeds 1000 to 1100 degree Celsius. That means, we are not melting any component of the iron ore, simply the oxygen content of iron oxide is getting removed. So, whatever impurities will be in the iron ore, the same will be transferred into the DRI.

So, essentially DRI or h b i, both are the same thing, DRI it contains, it contains free iron plus oxygen combined with iron, plus carbon which is left, plus gangue minerals and these gangue minerals could be S i O 2, could be A l 2 O 3, could be T i O 2 etcetera. That means, whatever present in the iron ore is transferred into the DRI , because, no melting is being done. The reduction is carried out in solid state. Therefore, it is important to characterize DRI. Characterize means - what is the quality of DRI that is being used in the electric arc furnace as a substitute for scrap?

So, the quality of DRI, quality of DRI, first important parameter is percent metallization, percent metallization and this percent metallization, that is equal to free iron, free iron upon total iron into 100. That is the one important characteristic of DRI before it is considered to be used as a substitute of a scrap in electric arc furnace. The important thing to know for an operator or for the person who will be using DRI is - what is the percentage metallization? Because any amount of oxygen that is left with iron in DRI, it will be removed in the electric arc furnace. For example, if we have say 90 percent metallization, then 90 percent is the free iron and 10 percent iron is in the form of FeO or Fe 2 O 3 or Fe 3 O 4, whatever the form may be. So, it is in that reference, the percentage metallization is an important component of DRI.

Second important thing is that, how oxygen is present. That is, either oxygen is present as FeO or Fe 2 O 3 or Fe 3 O 4. Now, this is also important, that is, in which form oxygen is present in combining with the iron, FeO, Fe 2 O 3 or Fe 3 O 4. Because, any oxygen which is with the gangue mineral, it cannot be removed and it is not removed. That point should be clear. What removal of oxygen we are talking about is a removal of oxygen from Fe 2 O 3. So, if we say 90 percent metallization, that means, 90 percent is the free iron and rest iron is either in the form of Fe O or in the form of Fe 2 O 3 or in the form of Fe 3 O 4. Now, it is important to know in which form iron is, one and because, ultimately when this DRI will be charged in the electric arc furnace, we will like to reduce oxygen and get iron back as a yield. So, if the iron is present in Fe 2 O 3 or Fe 3 O 4, then higher amount of energy is required, but if it is present in the form of Fe O again, higher heat load is required because Fe O plus C is an endothermic reaction.

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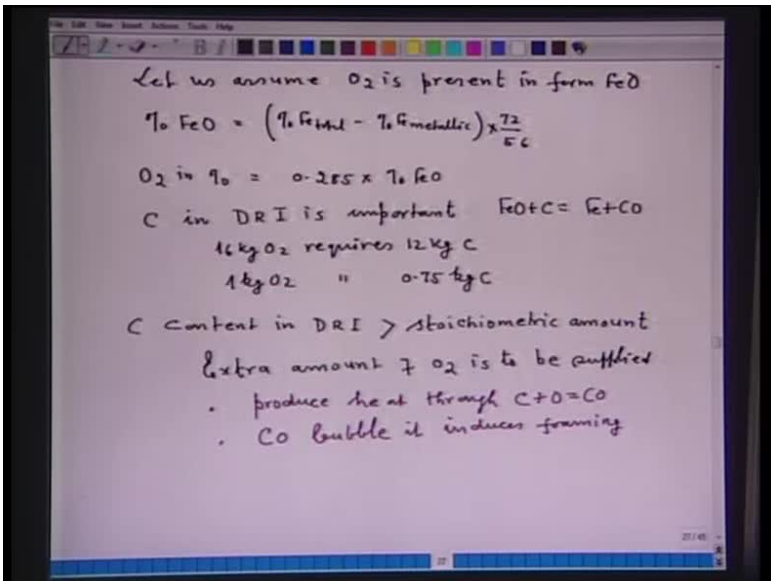

Let us assume O_2 is present in form FeO

$\% FeO = (\% Fe_{total} - \% Fe_{metallic}) \times \frac{72}{56}$

O_2 in % = $0.285 \times \% FeO$

C in DRI is important $FeO + C = Fe + CO$

16 kg O_2 requires 12 kg C

1 kg O_2 " 0.75 kg C

C content in DRI > stoichiometric amount

Extra amount of O_2 is to be supplied

- produce heat through $C + O = CO$
- CO bubble it induces foaming

Now, let us calculate, say, what is the amount of oxygen that is present in DRI. So, let us assume that, oxygen is present in the form of FeO, oxygen in DRI is present in form of FeO. So, we can calculate now, a percentage FeO that will be equal to percent iron total minus percent iron metallic into 72 by 56. Therefore, oxygen in percent, that will be equal to 0.285 into percent FeO, because 16 kg oxygen is present in 72 kg of FeO, from that we can get oxygen present is equal to this. Now, this is the oxygen present in the form of FeO. Now, this oxygen removal also requires carbon. So, therefore, carbon in DRI is important, because ultimately, this FeO will react with carbon and we will get Fe plus CO and this reaction requires carbon.

So, if we look at this reaction, then what you see is that, 16 kg oxygen it requires 12 kg carbon. So, 1 kg oxygen requires 0.75 kg carbon. So, what I wanted to say from here is that, if carbon content in DRI is maintained at 0.75 ratio to the oxygen of FeO, then carbon will react stoichiometrically with FeO during electric arc furnace operation. That means what? If it reacts stoichiometrically, good, it will reduce FeO and you will get the iron. It is a endothermic reaction, no heat will be produced - that is one case. Now, if carbon content in DRI is more than the stoichiometric amount, that means, if carbon content in DRI is greater than stoichiometric amount, amount, what does that mean? There will be extra carbon left in DRI.

So, to remove extra carbon, I have to inject oxygen, and C plus O is equal to C O. So, it will generate a large amount of heat; so, that is what is important. So, what is important is that carbon, content in DRI that can be taken care of during the production of DRI, it should be greater than the stoichiometric amount of carbon required to reduce FeO to iron. So, if the carbon content in DRI is greater than the stoichiometric amount, then extra oxygen has to be injected and on account of extra oxygen injection, the reaction between carbon and oxygen will be producing carbon monoxide. So, here two advantages: one this is slightly exothermic reaction, it will produce the amount of heat, and second, the carbon monoxide bubble which has been formed, they will also help in foaming of the slag.

So, this particular carbon content in DRI is greater than the stoichiometric amount, will need extra amount of oxygen to be supplied and that helps in two ways, one way is you produce heat through C plus O is equal to C O reaction, second the C O bubble, it induces foaming in the slag. So, these are the advantages of having carbon content in DRI greater than stoichiometric amount. So, what this discussion leads to, that quality of DRI, there are certain important thing. First important is that metallization and second important thing is the carbon content in DRI. Now, remember at this point of time, when I am talking of the oxygen content of DRI, then I only mean, that oxygen which is present with iron. Because, no oxygen which is present in the gangue mineral is removed in the process of manufacture of DRI, though this should be very clear.

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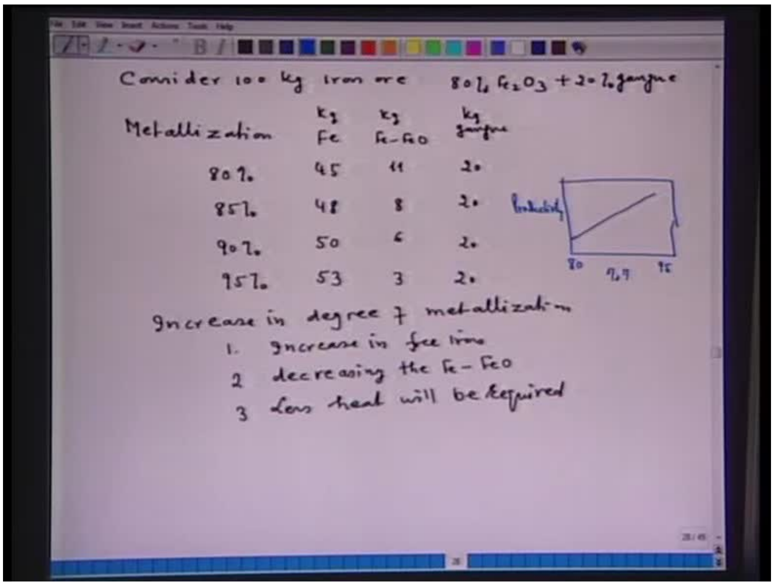

Consider 100 kg iron ore 80% Fe_2O_3 + 20% gangue

Metallization	kg Fe	kg Fe-FeO	kg gangue
80%	45	11	20
85%	48	8	20
90%	50	6	20
95%	53	3	20

Increase in degree of metallization

1. Increase in free iron
2. decreasing the Fe - FeO
3. Less heat will be Required

So, now, let us see the effect of metallization. So, take a case for example, consider 100 kg iron ore, say 56 percent iron. So, it has around 80 percent Fe 2 O 3 and 20 percent gangue. 80 kg Fe 2 O 3 and 20 kg gangue. So, I carry out now, metallization. I produce now, DRI from this particular iron ore. Then I calculate some kg iron. Then kg iron which is combined with FeO and kg gangue. So, if the metallization, for example, is 80 percent, then 45 kg is the iron, 11 kg iron is present as FeO and gangue will of course, will be 20 kg.

If I go for 85 percent metallization, then I have 48 kg iron, 8 kg Fe to FeO and well of course, gangue will remain the same. Similarly, 90 percent metallization and 95 percent metallization, here kg free iron will be 50 and kg free iron will be 53 kg, here it is 6, here it is 3, here it is 20, here it is 20. Because, whatever amount of gangue is there, it will transfer to DRI. So, in the amount of gangue nothing will change. So, what is important to see from here? If I increase degree of metallization, what it is doing? It is increasing the free iron that is being charged with the DRI. That is, first it will do increase in free iron. It is good, because, it will contribute to the productivity directly.

Second, it is decreasing the iron which is combined as FeO. That is also good, because, less amount of energy would be required to reduce FeO by carbon to Feplus C O. As a result, what will happen, less heat will be required during processing, less heat will be required, productivity will be more. So, if I want to illustrate schematically, if I take here productivity and plot it against percentage metallization, I go from 80 percent to some where as 95 percent, then productivity will increase as the degree of metallization increases, 80 percent to 95 percent. In order to produce a high percent metallization, the investment cost is also important, because, it takes sufficient time and sufficient thermal energy to produce highly metalize Wproduct, that is a very high quality product. when you, besides that point, from our argument side, if we increase the metallization in our DRI, then our productivity is increased.

Now, let us see, the another effect, for example, for a constant degree of metallization, if we increase the proportion of a sponge iron, that is I take 90 percent scrap, 10 percent sponge iron, 70 percent scrap, 30 percent sponge iron, 60 percent scrap, 40 percent sponge iron, in that, I vary the proportion, then let me see what effects it does on the various constituents.

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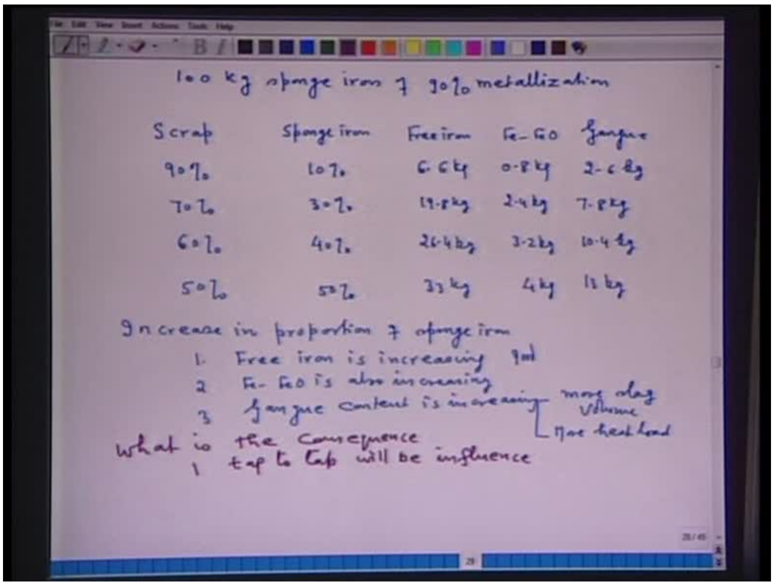

100 kg sponge iron of 90% metallization

Scrap	Sponge iron	Free iron	Fe-FeO	Gangue
90%	10%	6.6 kg	0.8 kg	2.6 kg
70%	30%	19.8 kg	2.4 kg	7.8 kg
60%	40%	26.4 kg	3.2 kg	10.4 kg
50%	50%	33 kg	4 kg	13 kg

Increase in proportion of sponge iron

1. Free iron is increasing good
2. Fe-FeO is also increasing
3. Gangue content is increasing
   - more slag volume
   - more heat load

What is the consequence

1. tap to tap will be influence

So, what I am doing now, I am taking now, 100 kg sponge iron or DRI of 90 percent metallization. Now, just a background calculation, you require around 132 kg of iron ore of 80 percent Fe 2 O 3 and 20 percent gangue. So, if you want to calculate again, what is the effect of changing the proportion of DRI in the feed, on free iron Fe to FeO and the gangue, then you have to perform the calculation by considering how much amount of iron ore is required, how much amount of iron it has and how much amount of gangue it has. I have done this calculation I am presenting here.

So, I am taking a case, say scrap, then I take sponge iron, then I take free iron, then I take iron which is present as FeO and the gangue content. So, if I take now, 90 percent scrap, 10 percent sponge iron, 10 kg, free iron will be 6.6 kg, 0.8 kg and 2.6 kg. If I take now, 70 percent scrap, 30 percent sponge iron, I have 19.8 kg free iron, 2.4 kg as iron is FeO and 7.8 kg in the gangue. Now, if I take 60 percent scrap, then 40 percent sponge iron, 26.4 kg is the free iron, 3.2 kg as the iron as FeO and 10.4 kg gangue. If I take now, 50 percent scrap and 50 percent sponge iron, 33 kg will be free iron, 4 kg will be Fe FeO and 13 kg present as a gangue.

What this calculation indicates? Increase in proportion of sponge iron, talking of the same productivity, I have taken the same productivity. So, increasing proportion of a sponge iron, what is doing, first free iron is increasing. This is good. No problem. Second effect, iron which is present as FeO is also increasing. It is not good. Why it is not good, because FeO plus C is an endothermic reaction. So, more amount of heat you require, to reduce FeO to iron, because you do not want to lose FeO in the slag. You have an option, you can lose FeO also in the slag, but you do not want to do it, because it contains iron.

So, Fe as FeO is also increasing as you see. Fe FeO, from 0.8 kg it goes to 4 kg. So, third thing is that, gangue content is also increasing. Gangue content is increasing in the mix that you have prepared; that means, if you take 50 percent scrap and 50 percent sponge iron, 13 kg is the gangue. If you take 90 percent scrap, 10 percent sponge iron where 2.6 kg is the gangue material. Gangue content is increasing means what? More slag volume. More slag volume means what? More heat load, because you have to supply extra amount of energy.

So, what is the consequence of it? The consequence of it, one, increase in the proportion of a sponge iron in the feed, it is increasing Fe which is combined with FeO as well as the gangue, so, therefore, the tap to tap time will be influenced. For a small proportion of sponge iron, say 10 percent or let us say between 20 and 30 percent, the tap to tap time may decrease, because, that extra load is not that much. But beyond that, the load will be too much and tap to tap time will also begin to increase, instead of decreasing. It appears, as if there is an optimum percentage of sponge iron there, tap to tap time should also be decreasing. Increasing tap to tap time, by increasing the proportion of sponge iron is not very good, because if the tap to tap time increases, electrode consumption will also increase, refractory wear will also increase and productive will also be affected. So, these are the, some of the calculation that I thought I will illustrate.

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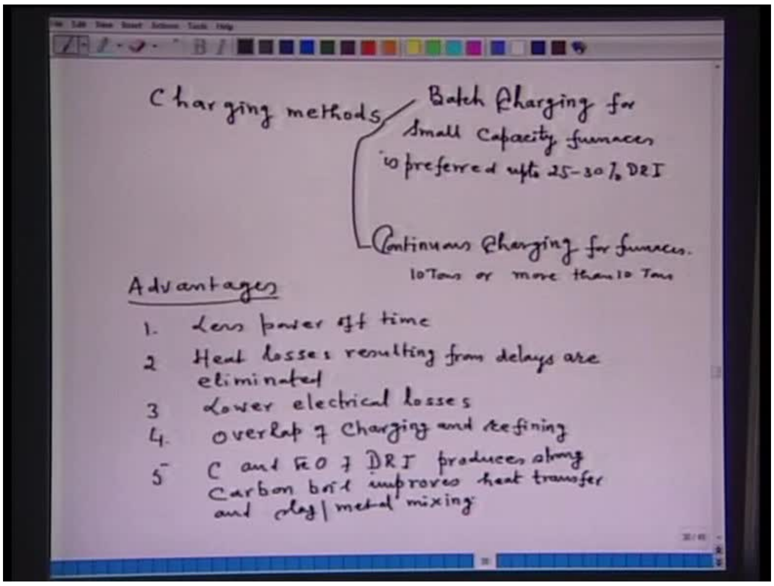

Charging methods

Batch Charging for Small Capacity furnaces is preferred upto 25-30% DRI

Continuous Charging for furnaces. 10 Tons or more than 10 Tons

Advantages

1. Less power off time
2 Heat losses resulting from delays are eliminated
3 Lower electrical losses
4. overlap of Charging and refining
5 C and FeO of DRI produces along Carbon boil improves heat transfer and slag/metal mixing

Now, the next thing is that, the charging methods. So, let us see now, the charging methods. Say one can have batch charging; that means, the DRI is charged in batches. So, batch charging is rather good for small capacity furnaces, for small capacity furnaces, say less than 5 tons capacity and this batch charging is also preferred up to 25 to 30 percent DRI. Any increasing amount, one has to see another method. So, another method is continuous charging. Continuous charging is done for furnaces of 10 tons capacity or more than 10 tons, or more than 10 tons capacity and this continuous charging has certain advantages. So, the advantages of continuous charging, you can think of, we have the roof of the electric arc furnace, where three electrodes are inserted.

Still there is space on the roof and that space can be used for charging sponge iron continuously as and when it is required in the electric arc furnace. So, you can think of the advantages, because now, you do not need to open the roof for charging, as you, yes, you have to do for batch process of charging. So, the first advantage is less power off time, because now, you do not need to switch off the power while charging, as in case of batch charging. Advantages are there, less power off time. Second, heat losses resulting from delays are eliminated. It is obvious, also is it not? Because, what you are doing? You are not removing the roof as you did for batch charging. So, whatever the heat losses, which are there during charging, it is not there. The delay is also not there, because the process is going on and charging is also going on. So, that way heat losses resulting from delays are eliminated.

Third, the consequence of this is to lower electrical losses. Fourth, overlap of charging and refining. What does it mean; that means, both charging and refining can be carried out simultaneously. Because, the process is on, charging is continuous. So, charging and refining are overlapping in each other, that is good. Fifth, say, reaction between carbon and FeO of DRI is taking place during the charging of sponge iron. So, as a result this reaction produces heat. This reaction produces strong carbon boil during charging. Now, remember, this reaction between C and FeO, it takes place during charging and the C O which results, it creates a strong bath agitation in the bath.

So, this carbon boil, it improves heat transfer and slag metal mixing. These are the certain advantages associated with continuous charging. And now, it is obvious also, now anything which is continuous, all the delays which are associated with the batch, they are eliminated and hence the advantages are obvious. Now, say little bit about the Indian condition. So, under Indian condition, the power consumption is around 600 kilo watt hour per ton with heavy melting scrap. So, if 40 to 50 percent of scrap is substituted by sponge iron, then power consumption will go up. Say, I have roughly a figure of 10 percent. Now, this is mainly because, you have introduced extra gangue content, you require to remove oxygen of FeO and because of this, the power consumption also increases.

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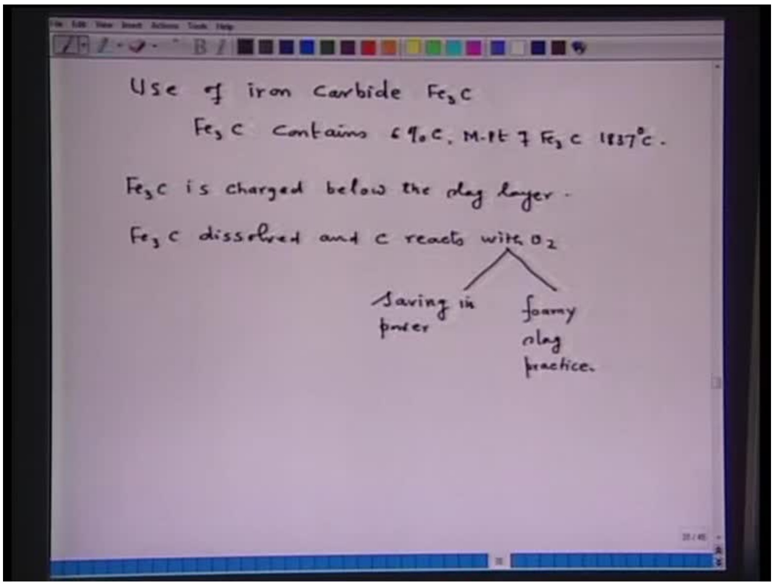

Use of iron carbide Fe_3C

Fe_3C contains 6 % C. M.Pt of Fe_3C 1837°C.

Fe_3C is charged below the slag layer.

Fe_3C dissolved and C reacts with O_2

Saving in power

foamy slag practice.

Now, in fact, electric furnace can be charged with 100 percent sponge iron also. Now, this is only possible for ultra-high power furnaces. So, this is about the assessment of DRI as a feed for electric arc furnace. Now, third is use of Iron Carbide, which is Fe 3 C. Now, this Fe 3 C, it contains 6 percent carbon. The melting point of Fe 3 C is 1837 degree Celsius. It is a very high melting point. So, it can also be used as a alternative charge material, but certain precautions are to be exercised during charging. First of all, say Fe 3 C, is charged below the slag layer. Why, because then, it can dissolve.

So, with this Fe 3 C, it dissolves in slag, it dissolves and carbon reacts with oxygen. It will give two benefits, one saving in power and another benefit is because carbon monoxide is evolving through the charging of Fe 3 C. So, it will also contribute to foamy slag practice. So, this is about the alternative charge materials. In the future, the proportion of sponge iron, hot metal or Fe 3 C will increase and its increase would depend upon what is the quality of scrap available and what is the quality of steel that is desired. So, that is all about the alternative charge material.

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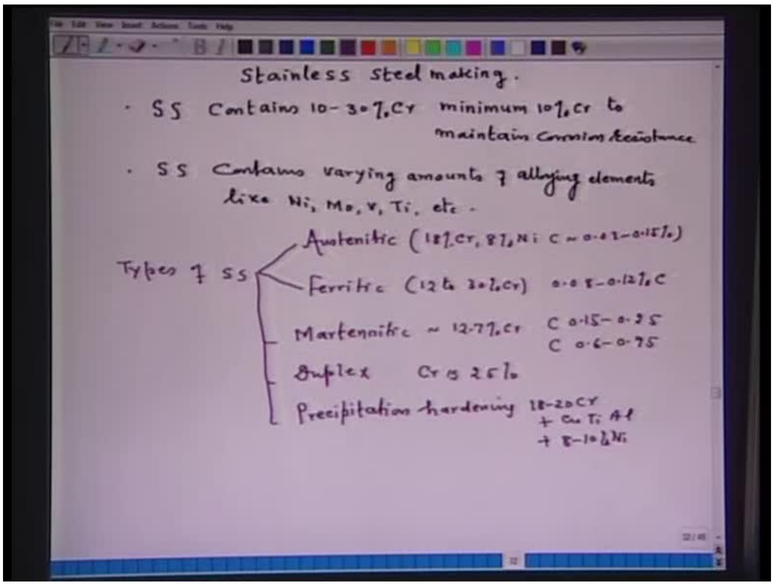

Stainless steel making.

- SS Contains 10-30% Cr minimum 10% Cr to maintain Corrosion Resistance
- SS Contains varying amounts of alloying elements like Ni, Mo, V, Ti, etc.

Types of SS
- Austenitic (18% Cr, 8% Ni C ~ 0.03-0.15%)
- Ferritic (12 to 30% Cr) 0.08-0.12% C
- Martensitic ~ 12-17% Cr C 0.15-0.25 C 0.6-0.75
- Duplex Cr is 25%
- Precipitation hardening 18-20 Cr + Cu Ti Al + 8-10% Ni

Now, the next topic that I want to tell you, is about stainless steel making. Now, some of the manifestation of a stainless steel is that, the stainless steel denoted by S S. It contains 10 to 30 percent Chromium. Minimum 10 percent chromium to maintain corrosion resistance. Second, stainless steel also contains varying amounts of alloying elements like nickel, molybdenum, vanadium, titanium etcetera. Now, these alloying elements are added in order to get some special property. Now, certain types of stainless steel, one, austenitic and this austenitic steel composition, a rough idea I am giving of composition, 18 percent chromium, 8 percent nickel, carbon may vary from 0.03 to 0.15 percent.

So, remember, the austenitic steel is characterized by low carbon and high chromium. That is important for the lecture which is coming now. Another grade is ferritic. Now, ferritic grade has 12 to 30 percent chromium, 0.08 to 0.12 percent carbon. Again low carbon, high chromium. Third grade is Martencitic. They have approximately 12.7 percent chromium. The carbon content, it may go from 0.15 to 0.25, but certain grades have carbon in between 0.6 to 0.95. Another variation is duplex steels. Now, in the duplex, ((when)) chromium is around 25 percent. Then we have a still another variety - the precipitation hardening steels, and they have say 18 to 20 chromium, plus copper, titanium, aluminium, plus 8 to 10 percent nickel. They are highly specialized steel and used for certain specific purposes.

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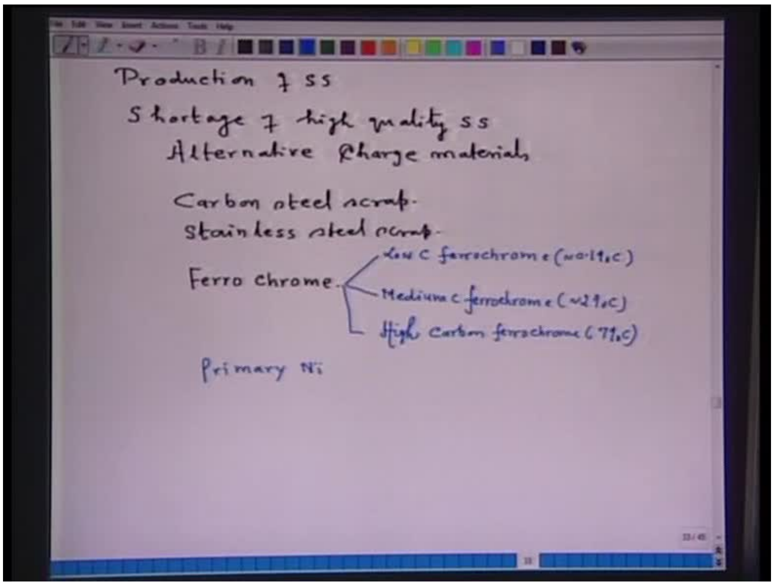

Production of SS

Shortage of high quality SS

Alternative charge materials

Carbon steel scrap.

Stainless steel scrap.

Ferro chrome.
- Low C ferrochrome (~0.1%C)
- Medium C ferrochrome (~2%C)
- High carbon ferrochrome (7%C)

Primary Ni

Now, say, about the production of stainless steel, electric arc furnace is used for production of stainless steel through melting stainless steel scrap. Hardly refining was required, because stainless steel scrap was available of the composition which is required for the product, so, melted and stainless steel of that particular rate is there. But again, over the years, what was happened, shortage of high quality stainless steel scrap has required to find out alternative charge material, so that, the quality of the steel remains as it is required. So, again the problem of having the shortage of high quality stainless steel scrap. So, this require alternative charge material. Now, what are these alternative charge material for production of a stainless steel? One, carbon steel scrap. Then, of course, you have a stainless steel scrap, then, in order to meet the chromium content, you have to charge Ferrochrome.

Now, there are, three grades of ferrochrome are available. One grade is low carbon ferrochrome and this low carbon ferrochrome contains approximately 0.1 percent carbon. Then we have medium carbon ferrochrome and this grade contains around 2 percent carbon. Then, third grade, we have high carbon ferrochrome and this may have approximately 7 percent carbon. What is the problem in this? The problem is very simple. You are charging carbon steel scrap, stainless scrap, you mix and calculate the amount of chromium is far less. Then you have to add the charge material which contains the chromium; that means, ferrochrome is to be produced. You can argue, sir, let us use low carbon ferrochrome, fine.

The production of low carbon ferrochrome is very expensive as compared to production of high carbon ferrochrome. If you rate the ferrolite, production of ferrolite, you will recall from there, that production of low carbon ferrochrome is very expensive as compared to production of high carbon ferrochrome. As a technologist, as a producer of a stainless steel from electric arc furnace, you will love or you will like to use medium or high carbon ferrochrome if the technology exists. Otherwise, you have no choice except, except to use low carbon ferrochrome and to see what is the cost of the stainless steel, that is coming out of the furnace, because the cost of production of ferrochrome will also be added up in the cost of the stainless steel.

So, this is the main issue, whether we go for low carbon or high carbon or whatever type of ferrochrome. The another alloying element is a primary nickel, you also required to it, because certain grades which require nickel, you have to add nickel. So, what is become important now, for production of stainless steel is that, refining became essential to produce stainless steel in electric arc furnace. As you have noted, the different grades of stainless steel require carbon very low. So, if you use high carbon or if you use carbon steel scrap, then carbon content of the bath is very high.

So, you have to decrease the carbon; that means, you have to refine. So, the refining became essential and the refining of a stainless steel essentially consists of carbon and chromium and to obtain the, both carbon and chromium up to the specification. What is the sign says? The sign says if you have a melt which contains iron, carbon and chromium and if you supply oxygen, for removal of carbon, if you see the Ellingham diagram, you will note that, the oxidation of carbon begins only at high temperature.

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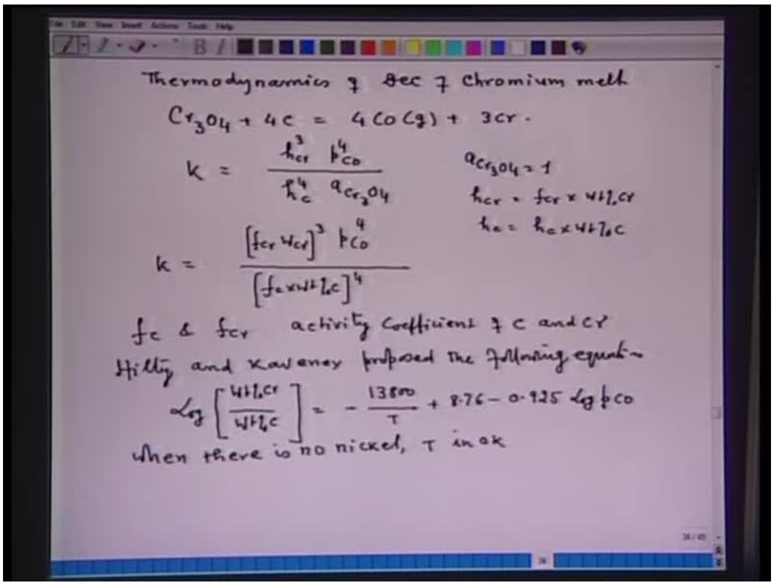

Thermodynamics of dec of Chromium melt

$Cr_3O_4 + 4C = 4CO(g) + 3Cr.$

$$k = \frac{h_{cr}^3 \, p_{CO}^4}{h_c^4 \, a_{Cr_3O_4}}$$

$a_{Cr_3O_4} = 1$

$h_{cr} = f_{cr} \times wt\%Cr$

$h_c = h_c \times wt\%C$

$$k = \frac{[f_{cr} W_{cr}]^3 \, p_{CO}^4}{[f_c \times wt\%C]^4}$$

f_c & f_{cr} activity coefficient of C and Cr

Hilty and Kaveney proposed the following equation

$$\log\left[\frac{wt\%Cr}{wt\%C}\right] = -\frac{13800}{T} + 8.76 - 0.925 \log p_{CO}$$

when there is no nickel, T in oK

So, unless you have a very high temperature, the carbon oxidation will not proceed. So, let us see, now, what is the underlying thermodynamics of decarburization of chromium melt. So, thermodynamics of decarburization of chromium melt. What we are doing now, we are trying to arrive the conditions, under which carbon oxidation will proceed or chromium oxidation will proceed. So, chromium oxidizes to Cr 2 O 3or Cr 3 O 4. Now, let us take it, it oxidizes to Cr 3 O 4 and we write down the reaction, say Cr 3 O 4 plus 4 C that is equal to 4 C O, the gaseous phase plus 3 chromium.

Now, if you write down the equilibrium constant k, that will be equal to h 3 C O h c and activity of Cr 3 O 4. Remember, again the liquid steel we have, Henry’s, follows Henry’s law. So, accordingly we put, for example, certain assumption, let us take activity of Cr 3 O 4 is equal to 1, h chromium that is equal to f Cr into weight percent chromium and h C that is equal to h C into weight percent carbon. So, if we replace h 3 C r h c r, an activity of C r 3 O 4 by 1, then we get k that is equal to f Cr W chromium 3 p C O to the power 4 and f C into weight percent carbon to the power 4. Here also f C to the power 4 and activity h Cr 3 O 4 is equal to 1. Now, say f C and f Cr, they are activity coefficient of carbon and chromium in the melt.

Now, this is a very complicated relationship. Now, say Hilty and Kaveney have proposed the following equation. Log weight percent chromium in the metal upon weight percent carbon in the metal, that is equal to minus 1 3 8 double 0 upon T plus 8.76 minus 0.925 log of p C O.

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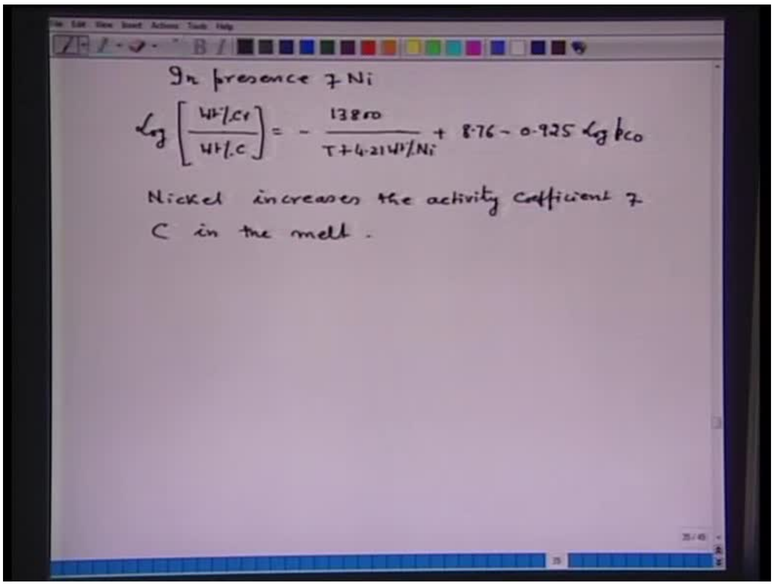

In presence of Ni

$$\log\left[\frac{wt\%Cr}{wt\%C}\right] = -\frac{13800}{T+4.21wt\%Ni} + 8.76 - 0.925\log p_{CO}$$

Nickel increases the activity coefficient of C in the melt.

Now, this equation is valid, when there is no nickel. T is to be substituted in degree Kelvin. Now, in presence of nickel, the following equation is to be used. Log weight percent chromium melt upon weight percent carbon in melt, that is equal to minus 13800 T plus 4.21 weight percent nickel plus 8.76 minus 0.925 log of p C O.

Now, why it is though? So, nickel increases the activity coefficient of carbon in the melt. Now, what we can do now, we utilize these two equations and we can calculate the ratio of percentage chromium upon percentage carbon in the bath as a function of temperature, as well as, as a function of C O. To illustrate what will happen if we increase the temperature or we decrease partial pressure of carbon monoxide and this we will be taking in the next lecture.