Iron Making
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Lecture – 17
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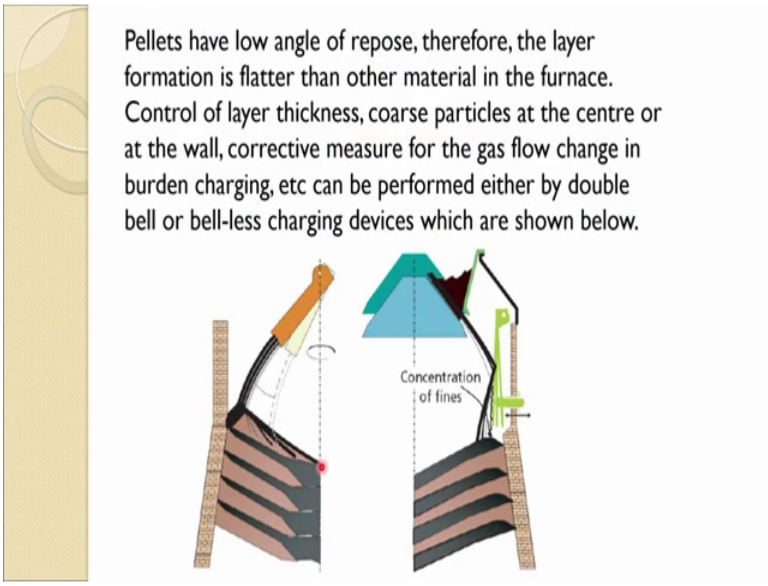

So, pellet us have low angle of repose therefore, the layer formation is flatter than other material in the furnace. Control of layer thickness, coarse particle at the centre or at the wall corrective measure of the gas flow change in burden charging etcetera can be performed either by double bell or bell less charging devices which are shown below.

These few devices in the starting of our introduction I showing you, but now we I will show only these two which are mostly used in the blast furnace plants. So, this is double bell charging and this is bell less.

So, you can see in double bell charging you have a very limited. So, charge is reflected through this armour plate and there is a limited only movement by which you can do that and even some time by pushing a rod here also you do that. So, it keeps a less flexibility in changing the pattern or in distributing the charge. However, when in the bell less one it is through which it which can rotate in all the direction and it has a much more manularity in distribution or feeding charging the material. So, it can come up to here.

So, in most of the modern blast furnaces or the coming up blast furnaces being adopted the bell less charging then this, but most of the furnaces are having this. But the very new furnaces are having now bell less charging because that gives the more flexibility in controlling the burden distribution and now you already aware about it how the burden distribution can control the gas flow. And not only the gas flow in these gas flow interns control the heat transfer and mass transfer which is very important. So, these are the thing which are very important in terms of distribution of the burden charge.

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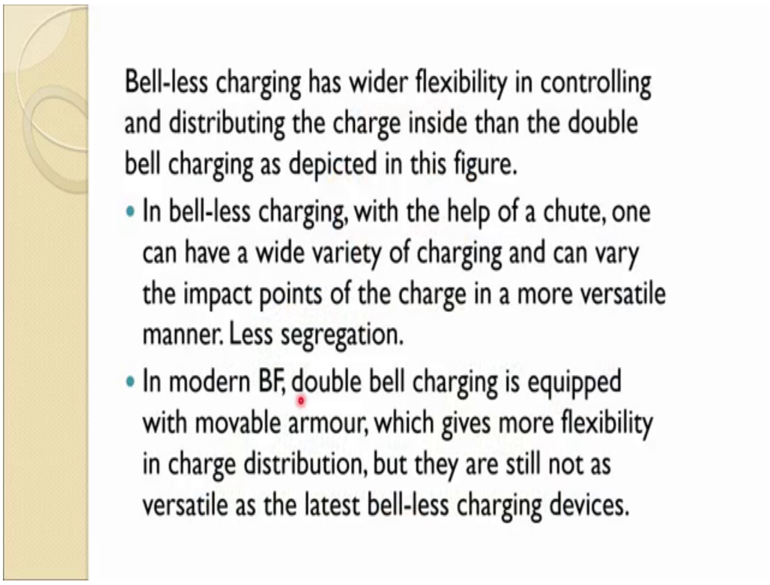

So, bell less charging has wider flexibility in controlling and distributing the charge inside, then the double bell charging as depicted in the previous figure. So, in bell less charging with the help of chute one can have a wide variety of charging and can vary the impact point of the charge in a more versatile manner and less segregations you have.

So, segregation means you are this smaller size, and bigger size particle even density based on the density different segregation can have occur at the point of impact when you are putting the material, then segregation can occur these are. There are many things. In fact, in the charging which one has to consider.

Mostly the impact point you will find the point deposition comes we will show that. So, in modern blast furnace double bell charging is equipped with moveable armour which gives more flexibility in charge distribution, but they are still not as versatile as the latest bell less charging devices.

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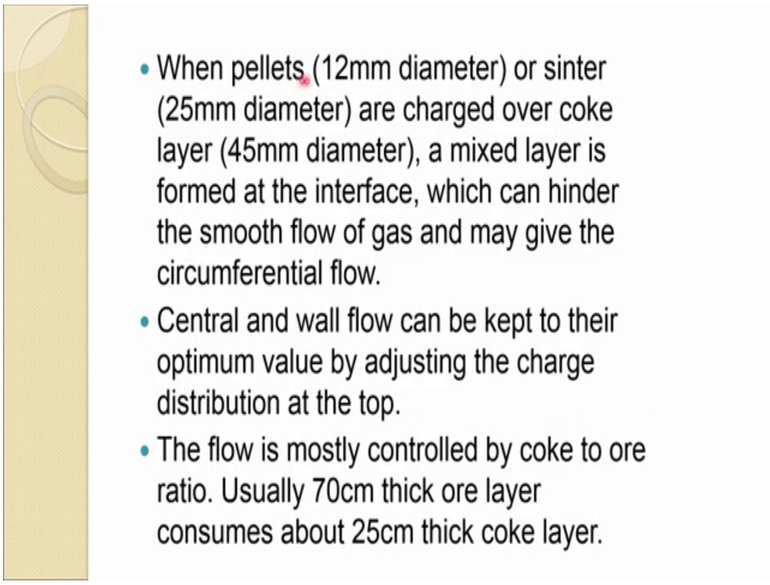

So, when pellet 12 millimetre diameter or sinter 25 millimetre diameter are charged over coke layer which is about 45 millimetre diameter a mixed layer is formed at the interface, which can hinder the smooth flow of gas and may give the circumferential flow.

As you know the this is a big particle on which you are charging let us say this is smaller as I said 4 times difference. So, between the voids these pallet us can settle between the coke voids and that we reduce the permeability, especially at the interface. And when this happen at the interface then the more resistance to the gas flow and then there is a preferential circle circumferential flow in that.

So, central and wall flow can be kept to their optimum value by adjusting the charge distribution at the top. The flow is mostly controlled by coke to ore ratio. So, usually 70 centimetre thick ore layer consumes about 25 centimetre thick coke layer.

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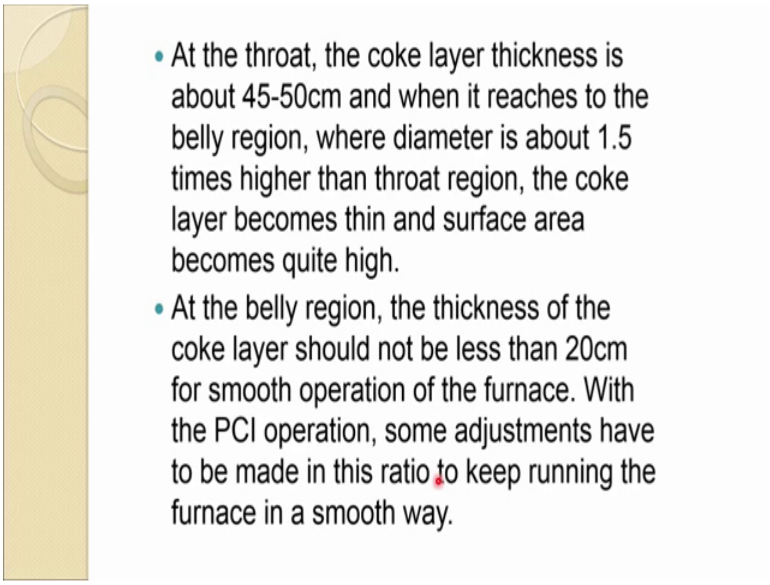

So, as you can then imagine the resistance offered by the ore layer; So, at the throat the coke layer thickness is about 45 to 50 centimetre and when it reaches to the belly region the where the diameter is about one and half times higher than the throat region the coke layer becomes thin and surface area becomes quite high. This we discussed in terms of repose angle also layering charge charging that I as you go down it becomes much flatter and then of course, also thinner because same volume is spreading in the higher area.

So, at the belly region the thickness of the coke layer should not be less than 20 centimetre for a smooth operation of the furnace. With the; when you are saying a 20 centimetre and you know already the charging is about charging size of the coke is about 45 millimetre to 50 millimetre which is about let us say 5 centimetre. So, you are talking about 3 to 4 layer of the coke which is quite thin in that way. So, one should keep at least about 20 centimetre for the proper permeability and the smooth operation of the furnace.

So, with the PCI operation some adjustment have to be made in this ratio to keep running the furnace in a smooth way. So, with the PCI operation actually is your coke consumption reduces, but you cannot compromise really with the minimum thickness of the layer near the bosh region or lower part of the blast furnace. So, some sort of compromise has to be made. So, a smooth operation of the furnace occur in that.

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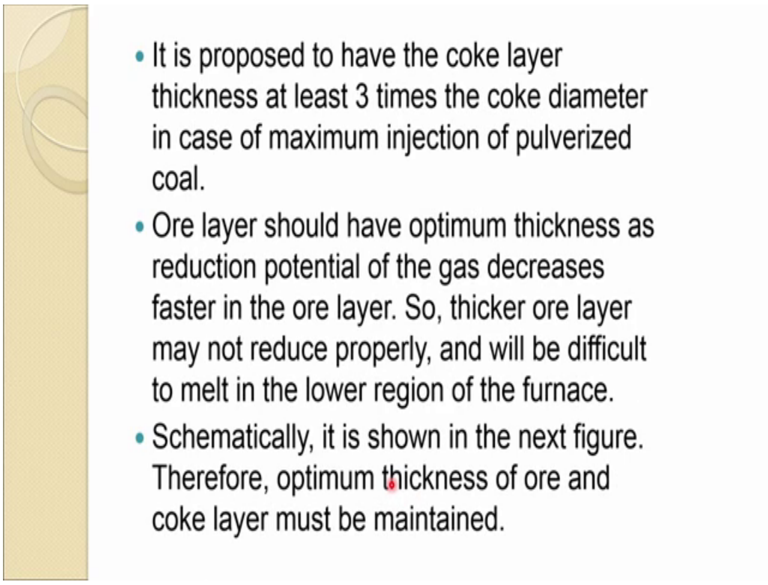

So, it is proposed to have the coke layer thickness at least 3 times the coke diameter in case of maximum injection of pulverized coal. So, ore layers should have optimum thickness as reduction potential of the gas decreases faster in the ore layer. So, thicker ore layer may not reduce properly and will be difficult to melt in the lower region of the furnace; schematically shown in the next figure. So, even for that ones you need a optimum thickness of the ore and coke layer should be maintained.

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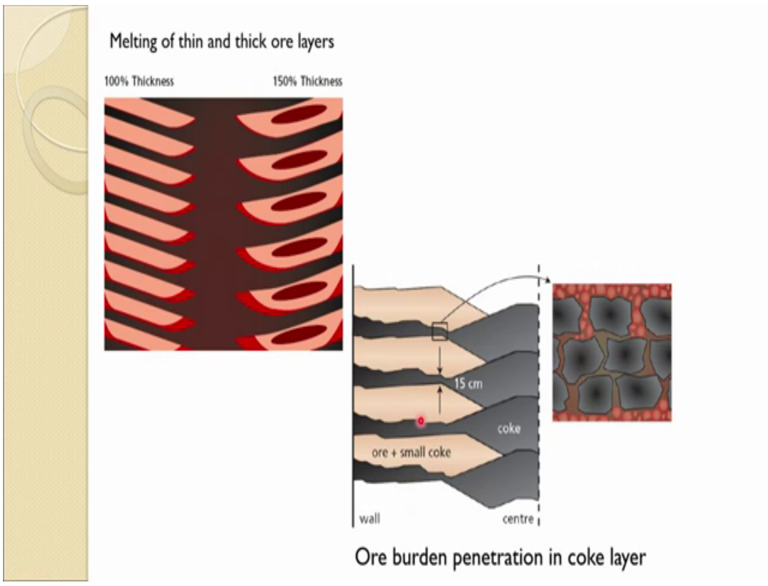

So, this shows about the ore layer thickness. So, normal 100 percent thick and if you are increasing the thickness, essentially what is happening at the centre of it is not getting reduced properly and this travels down. And then this reduction will occur in the lower part of the furnace where the director reduction and then more heat would be consumed endothermic and as we discussed the chilling and other effect can come into the picture and operation may not be a smooth one.

And also it should be a proper descent from top to bottom if you do not have a proper descent; of the material again you have a mall distribution of the gases. One possibilities shown here where if this coke layer thickness decreases what will happen the ore layer will or a smaller particle will penetrate into that more void fraction you penetrate into that and that will stop or will give more resistant to the gas. And pressure drop will increase again the smooth function of the blast furnace will disturb. So, one have to, once the aim should be the thickness layer should be maintained even in the descent and it should not become in an erratic way.

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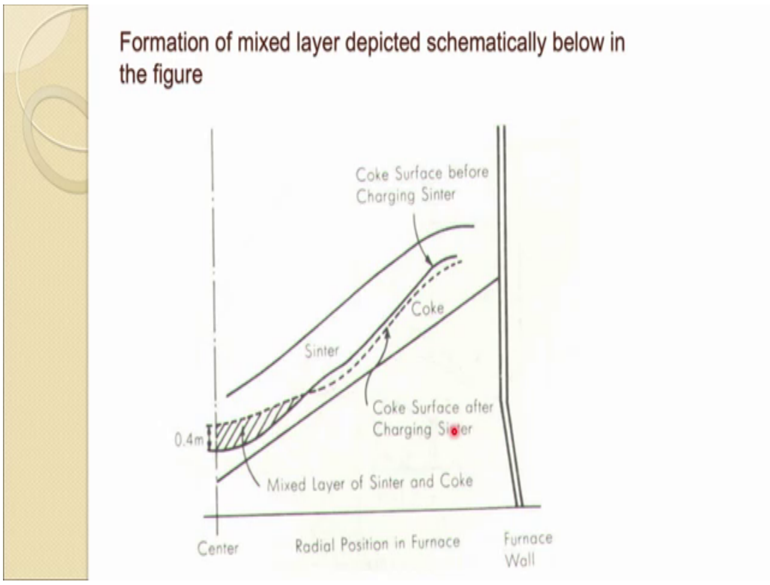

So, in formation of mixed layer; so, when actually you are charging the material say on the top of the coke layers you are charging the sinter. So, at naturally at the impact point, this coke will displace which you have seen in the previous one. And during the charging of the sinter and coke is at the bottom you will see previous profile of the coke layer was this after charging the sinter it became like this.

When it will come over here you will get a mixed layer of the sinter and the coke. So, this portion in one way really giving more resistance to the gas flow because your void fraction has decrease in this. Because let us say if it is pellet the void fraction is 0.41 and for coke void fraction is a 0.51. So, certainly pellet will settle down within the void and that will create or give rise to the gas resistance to the gas flow.

So, these are few situation which may arise in charging and one should avoid and take proper care of these thing because this will lead to the mall distribution of the gas flow and eventually then your reduction and the heat transfer ok.

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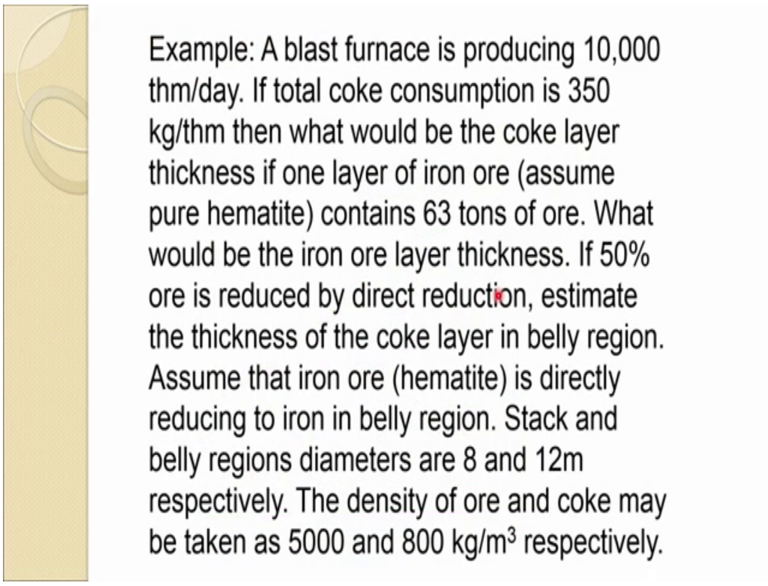

So, one example based on this is a given here. So, a blast furnace is producing 10,000 ton hot metal per day.

If total coke consumption is 350 kg per ton of hot metal then what would be the coke layer thickness if one layer of iron ore and you can assume iron ore is a pure hematite contains 63 tons of ore. So, when you are charging a 1 layer that is containing about 63 tons of ore. What would be the iron ore layer thickness?.

If 50 percent ore is reduced by direct reduction, estimate the thickness of the coke layer in belly region. So, 50 percent do assume it is reduced by direct reduction. Then what would be the thickness in the belly region? Assume that iron ore hematite is directly reducing to iron in belly region. Stack and belly regions diameters are 8 and 12 meter respectively. The density of ore and coke may be taken as 5000 and 800 kg per meter cube respectively.

So, here you have to find out the coke layer thickness, and your ore layer thickness in the belly region and even the stack region. So, how would you do?.

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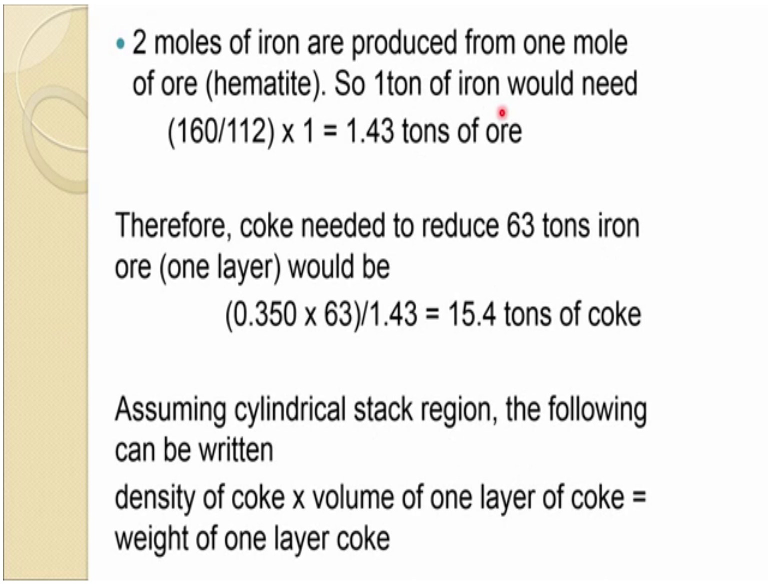

Now, assumption is already said if your ore is hematite it is a pure hematite. So, under that condition two movements of iron are produced from one mole of ore, so hematite FE 2 O 3. So, one mole of ore will give you two moles of iron. So, in terms of ton is.

So, 1 ton of iron would need a normal stoichiometry ways you can calculate it. So, it will gives you 1.43 tons of ore, so 160 is weight of the hematite and 2 moles 12 112 is for iron and you are going for a 1 ton. So, you need 1.43 tons of ore. Therefore, coke needed to reduce 63 ton iron ore, because in one layer it is given 63 tons iron ore is there. And we know now with so many tons of ore is needed for 2 moles of iron and it is also given for to reduce these you need 350 kg per ton of coke is needed per ton of hot metal and for 63 ton and with this you can know how much coke is needed to reduce 63 ton. So, 15.4 tons of coke is needed.

Now you know the amount for the coke also you can assume the cylindrical stack region. Then you can easily find out the thickness of the layer by a normal volume, you know in the volume of the one layer of the coke. So, density of the coke into the volume of one layer of coke equal to the weight of one layer of coke. So, weight of one layer coke we already found it 15.4 ton.

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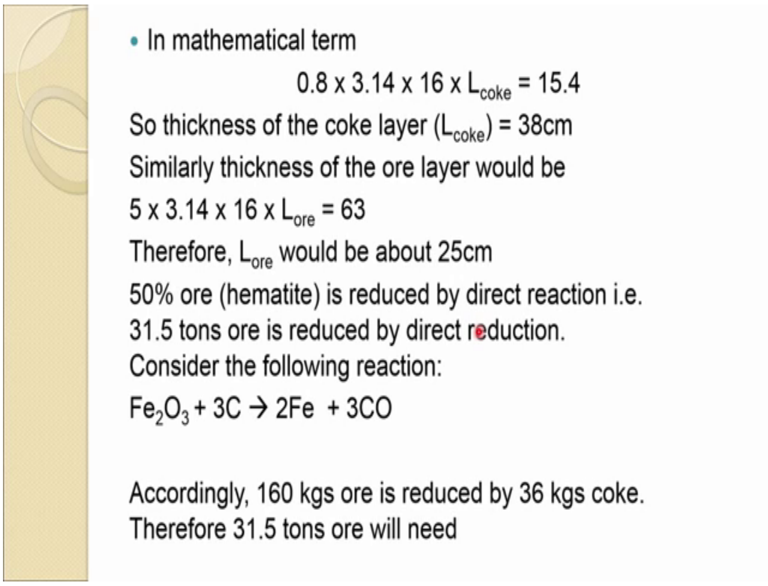

And we know already the diameter of this stack region. So, and the volume of that would be the pi r square L, L is nothing with the thickness of the coke layer. So, as you equate that one you get the coke layer thickness about 38 centimetre. And similarly you can find out the thickness of the ore layer which would be about 25 centimetre. And this is actually in the stack region, and so a stack region the radius is 4 meter and that is how this is coming here.

Now, 50 percent ore is reduced by direct reduction that is in the belly region, so which means 63 ton we are putting. So, 50 percent of it thirty 1.5 tons ore is reduced by direct reduction. So, and it is also given the direct the reduction is mostly you can consider is from hematite directly to iron. So, we can write this reaction. So, according to this you to reduce 160 kg or you need about 36 kg coke, so reducing 31 point ton or we will need about 4.25 tons of coke.

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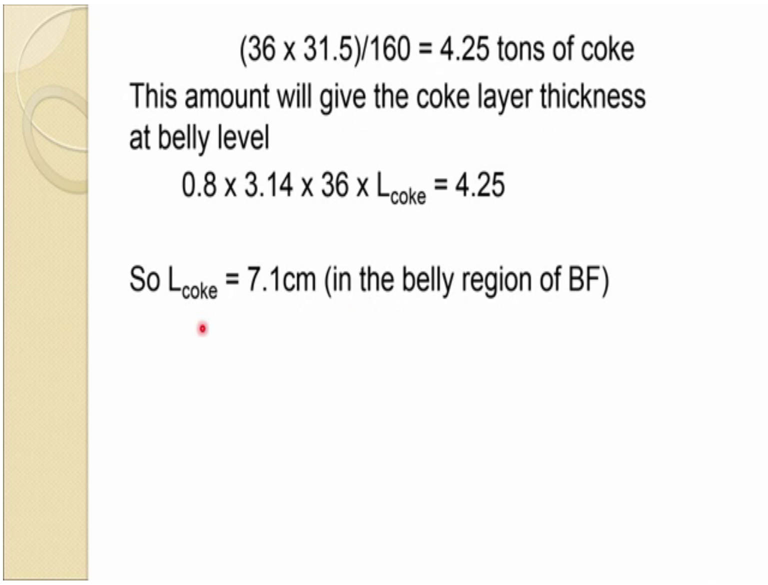

And now again you can calculate the volume of that and equate with this tons of coke you can get the value of the coke layer thickness in the belly region which comes about 7.1 centimetre thickness in the belly region of the blast furnace. So, that is keeps you some idea how you can calculate that on the reaction and other parameter which is given the layer of the material in different different region and you can try to maintain it.

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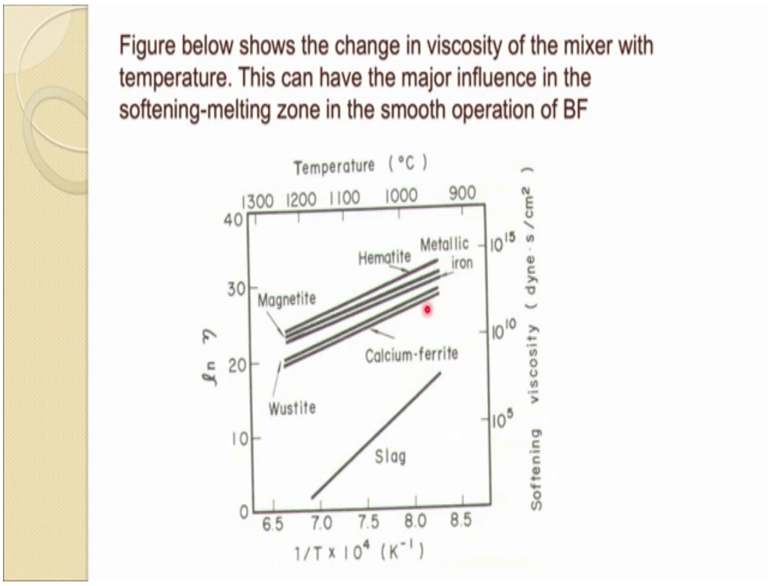

This figure shows the change in viscosity of the mixture with temperature and this can have a major influence in the softening melting zone in the smooth operation. So, as we said the gas flow is very important.

Now, we are coming to the cohesive zone. And the cohesive zone which you know we had discuss few times and it is shown in the starting actually. In this figure where we are having a inverted V type or W type so this is the cohesive zone where the ore especially is in semi fluid stay.

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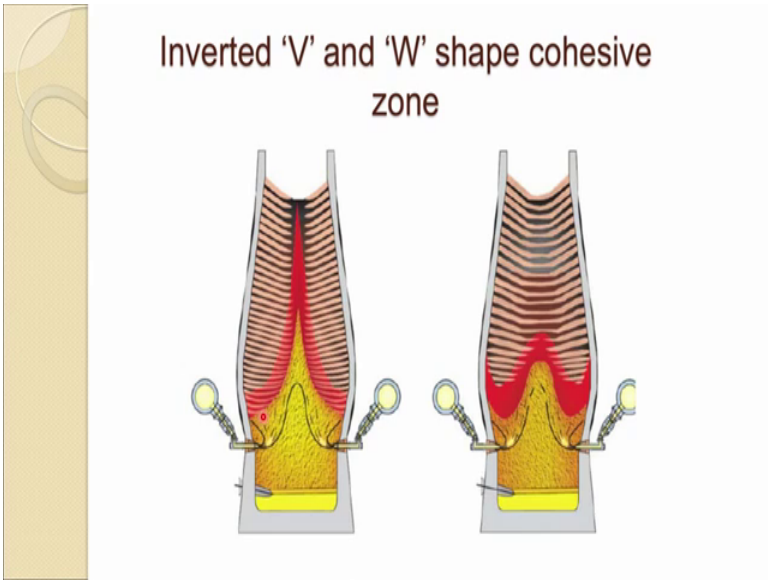

So, I like a messy zone what we call it. So, this brown one is becoming fluid. So, when it becomes fluid which means the gas cannot flow through that, already ore has a very low void fraction. So, gas already feels quite a big resistance and now in this condition where it has fluid the gas cannot flow through that.

So, reduction of course, becomes a problem and not only the reduction main thing how the gas has to be flow. So, that is the reason you have to maintain this layer thickness of the coke. If it get disturbs then case cannot flow from here because this is the only material which is solid now. And I had also voids a good amount of voids about 50 percent or 0.51 as you have seen it.

So, most of the gases they are passing through this coke slit now, so this zone is very important to maintain the viscosity the melting point softening melting point and we are talking about that. In fact, we talked a little bit about this zone before also in the materials property that materials softening melting temperature should be as I as possible.

So, this zone should reach more downward side and also softening and melting, these are two thing. It should be narrow the softening is at which it becomes a fusion becomes or it is started bet melting or liquid temperature. And melting is at which it flow it become totally in the liquid form. So, that range of softening and melting should be narrow.

So, in that way the cohesive zone thickness would be narrow, and which means the you can reduce the resistance of the gas or gas will have a less resistance than the (Refer Time: 22:02) this cohesive zone.

So, this figure shows that how this viscosity is changing with the temperature for the mixer. So, for hematite at a higher lower temperature viscosity is quite high, even from magnetite is quite high. For wustite it is still high, but not that much but if you look at the select formation that viscosity is really low.

So, that can easily flow and what you need it and you need also quite a good viscosity in that one. So, as soon as its fusion occurs it materials should be it should flow through the coke void and will offer less resistance to the gas. So, high temperature properties of the materials are also very important.

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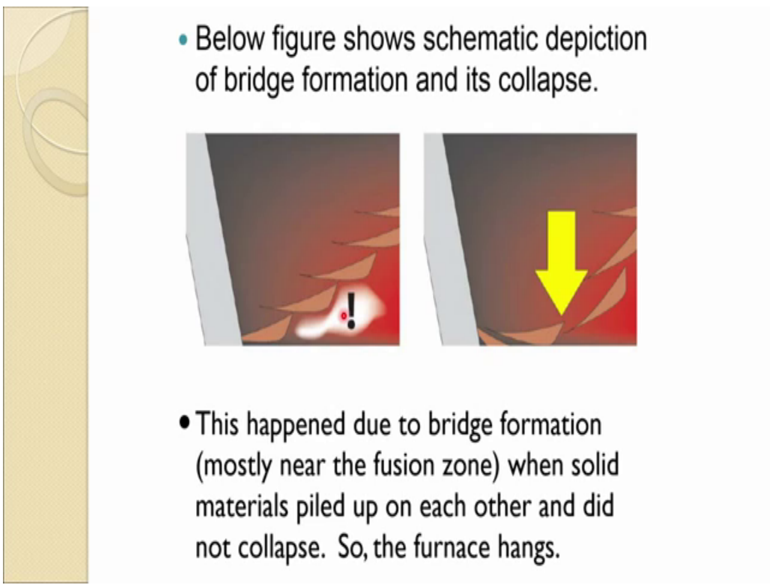

Now, this figure shows some of the phenomena. I think we will talked a little bit about the slip, slipping or hanging we talked in terms of when the forces upward forces are, greater than the downward forces of material will not descend hanging may occur. And we said few causes of it also sometime happens bridge formation occurs.

And that occur more near the fusion point, the particle are getting fluids of something. So, R formation occurs. And when R formation occurs the below it is mostly the void and this keep on building. And the void also keep on increasing as you can see in this figure this is more as a schematic where the figure which is showing. So, and on here in one way the arc is forming and it keeps on building and that situation deteriorate.

And once this become bigger and material bred keep on increasing suddenly falls and that is called slipping and that and that disturb the whole thing.

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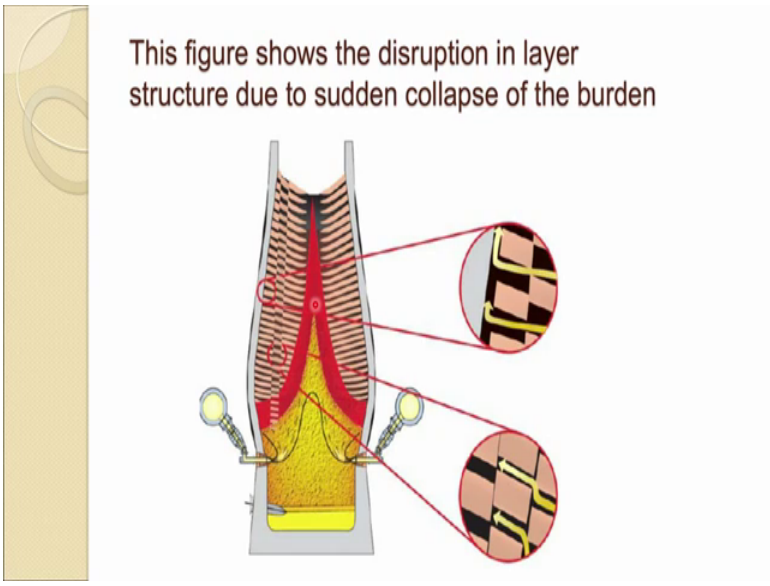

The next figure you will see what may happen. Due to the slipping the layer is texture get disturbed, and once the layer structure get disturbed you have a very big problem with the gas flow. Gas is feeling more resistance like in this one the layer structure as gone this now case has to troubled not only the longer part even the resistance it has though fetch through that.

And which means the high pressure drop and operation of this will get disturbed it will not run in smoothly and then you have to change again the layer structure from the starting itself. So, this only can be corrected by putting again proper layering at the top. And when once you put it at the top to reach up to here it may take 8 to 10 hours. So, you are really furnace or at least for 8 and 10, 8 to 10 hours is not going to run in a smooth way, all your chemistry of the slag and metal will get itself products and will get disturbed, everything and it takes quite a lot time to bring it the furnace to the normal operation.

So, this sort of disruption can occur, and one has to avoid that.

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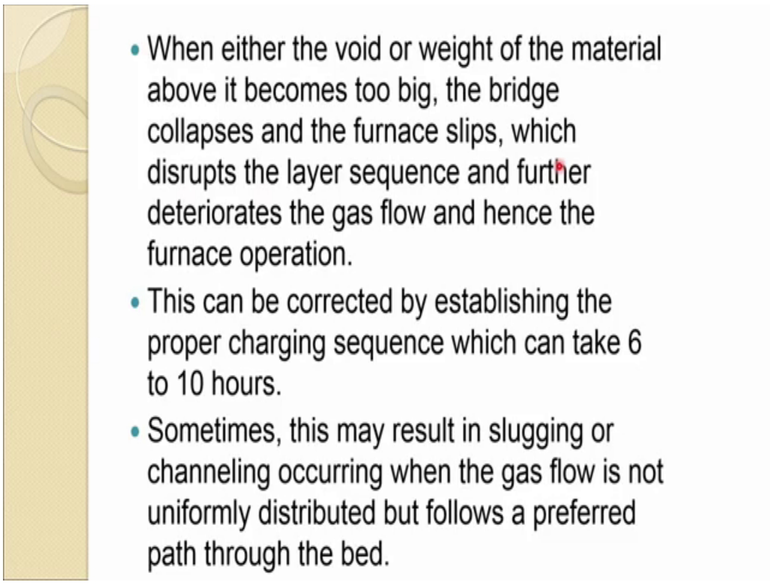

So, when either the void of weight of the material above it becomes too weak the bridge collapses and the furnace slips which disrupt the layer sequence and further deteriorate the gas flow and hence the furnace operation. This can be corrected by establishing the proper charging sequence which can take 6 to 10 hours as I said.

So, really quite a loss in the production the efficiency of the process, and sometimes this may result in slugging or channelling occurring when the gas flow is not uniformly distributed, but follow a preferred part through the bed. So, it can even go to the channelling mode where the gas is flowing through a least resistant part in one preferred direction, then you are not able to utilize the proper reduction potential of the gas and heat transfer capability.

Slugging also occurs mostly in this sort of reason that this actually phenomena is also can be known as slugging, where the this gas has to bubble through. So, it goes up the whole material are taken away and then it collect, so that is sort of slugging can occurrence which is again it not good for the smooth running of the furnace.

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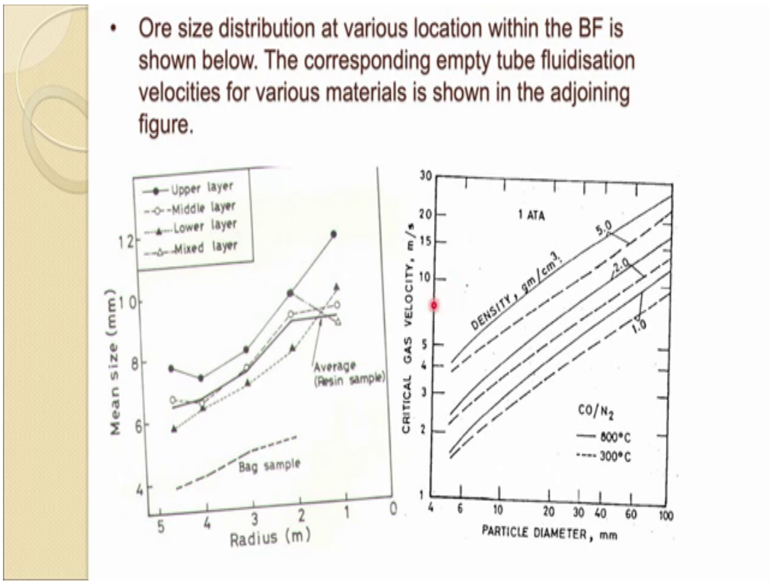

This figure shows the size distribution at various locations within the blast furnace and corresponding empty tube fluidization velocity for various material.

So, as you look at is because this is radius of the furnace versus mean size, and in the upper layer, middle layer, lower and mixed layer. So, lower layer when you say this is belonging to the lower part of the furnace and in the middle section in the upper section.

So obviously, in the upper section you are charging it mean size would be higher which you can see from this top most curve. So, your this is high, but as you a layer goes down reduction method thing takes place. So, their size decreases and of course, at the bottom one size decreases further. So, you can also think that permeability also decreases and this shows for the mixed layer this one which is coinciding mode with that.

And as you look at the respective this and in terms of density; so, you have typical density of iron ore around 5 so that fluidization velocity for that with respect to the particle diameter you can see in meter per second. So, usually we show about 20 millimetre or particle diameter. So, to fluidize you need about 10 meter per second.

On the other hand coke is coming sort of in this range, where you have the fluidize reaction velocity again the size is this. So, you have about 6 7 and then you have for sinter and other. So, this gives a some idea for the different density of the material what would be the fluidization velocity. So, furnace should operate below that limit.

And that is one of the reason that you cannot have a very small particle of coke otherwise they will get fluidized here. And these are also a two temperature it is given. So, as the temperature actually increases as you can see your sinter fluidization because the density becomes lighter. So, you need a higher fluidization velocity for the fluidized the same diameter particle than at the lower temperature.