Iron Making
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Lecture – 16
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So, as you can see in this slide.

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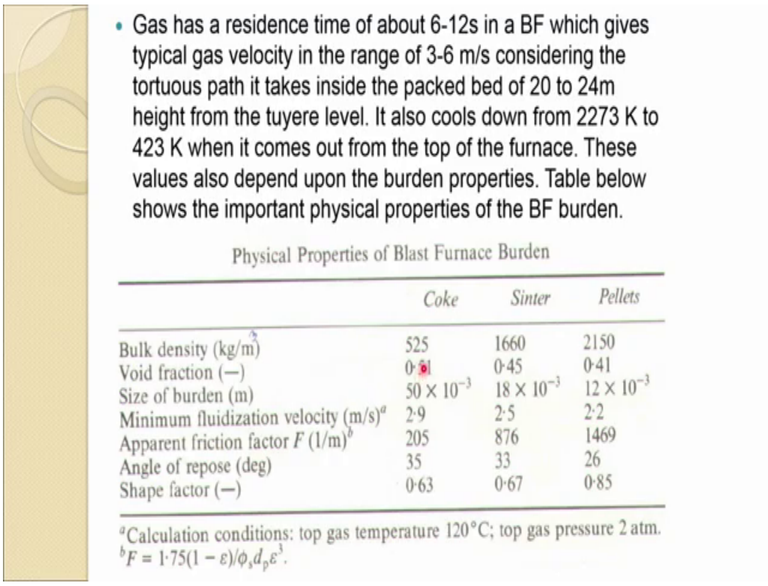

This void fraction of coke sinter and pellet, they are bit different and fact about 0.51 for coke and pallet is 0.41 and the size of the burden. So, coke is about 50 millimetre and the pellet is 12 millimetre. So, that is a big difference between this size of coke and pellet almost 45 times and that can create a problem in permeability, which we will see in the next slide.

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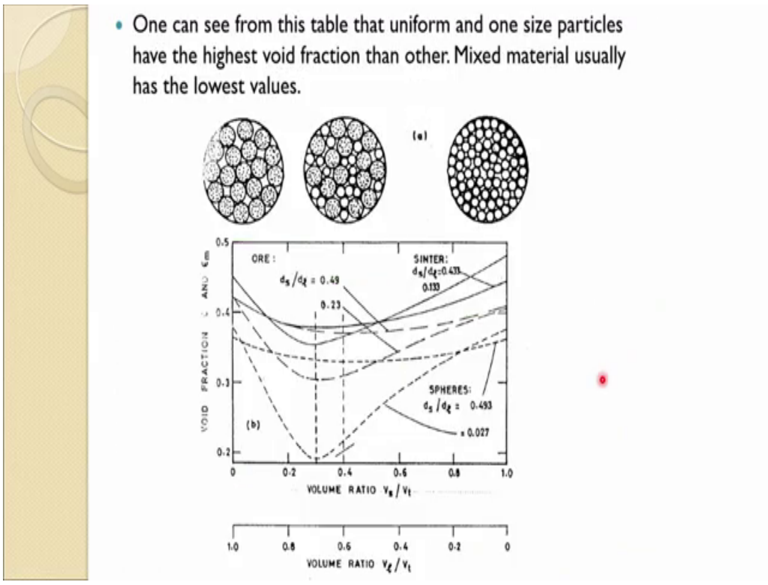

So, if you look at this. So, here you are having a uniform size a spherical particles larger size, these are a smaller size and this is a mixed one. So, as you can see when it is the mixed one.

Yours void fraction really goes down, quite low 1 when it is uniform then the part void fraction of the bed is quite high, this is showing the ratio of a smaller to larger size.

So, as you can see when it decreases your void fraction goes down, and that is where is create the problem of permeability and the blast furnace and one has to be very careful in selecting the proper size of material to put in, we will talk more about this distribution how does it affect the permeability of the bed in the following slides.

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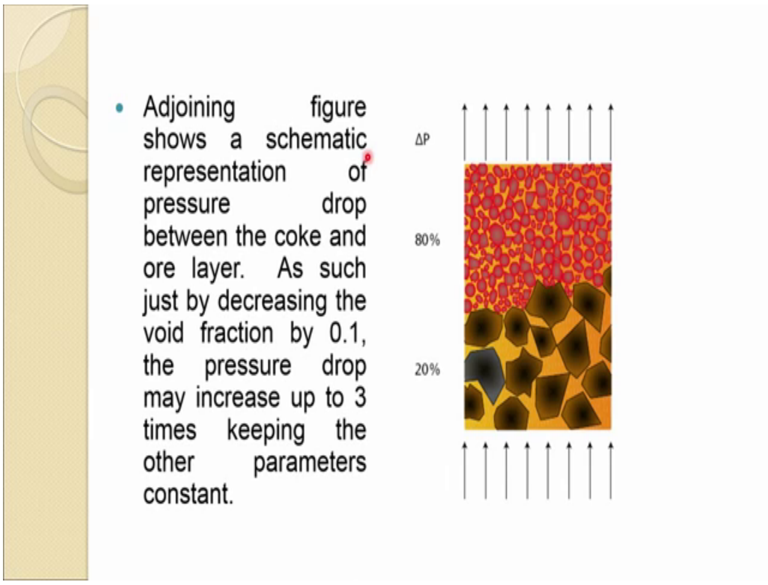

So, this figure shows about the schematic of an ore particle and this is the coke as you can see from the previous event slide that the size is almost 3 to 4 times different than the coke size. So, essentially one would expect a very high pressure drop in this smaller size particle then the larger 1. So, the black one is representing more as coke and this one more as iron bearing material sinter or pellets or even the ore.

And the pressure drop in that section is almost 3 to 4 times higher than this so. In fact, with you the void fraction even if it decreases by point 1 pressure drop almost by 3 times it increases. So, if you look at our this table, so you can see the void fraction for coke is about 0.51 and for pellet is about 0.41.

So, there itself it almost 3 times pressure drop would be there in this. Pellets of course, they are more spherical and one would expect this sort of void fraction usually for a spherical particle, but coke and sinter they are irregular in shape. So, void fraction not the pressure drop is less in this coke, but here it is high.

So, that is can create a problem in the blast furnace you have to put more air pumping powers and the other thing is not only that even about the reduction, and the passing of the gas utilization of the reduction power of the gas and heat exchange between the.

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A material and the gas.

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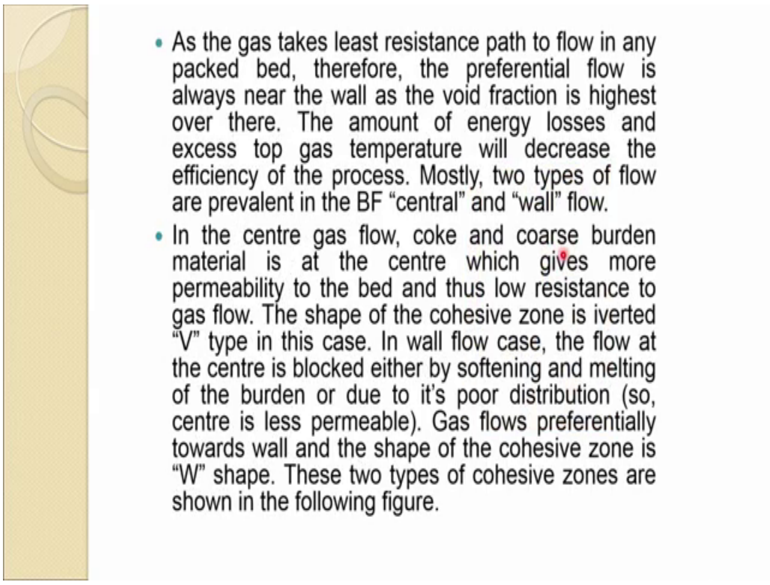

The another one is, so as the gas takes least resistance path to flow in any packed bed therefore, the preferential flow is always near the wall as the void fraction is highest over there.

The amount of energy losses and the excess top gas temperature will decrease the efficiency of the process; mostly 2 types of flow are prevalent in the blast furnace central and wall, wall flow. So, if you look at here if suppose this is a wall. So, point of contact, but the contact point here would be just like a point on the wall with the material.

So, you would be having a very high porosity near the wall. So, gas ; obviously, will take the least resistance path. So, it would like to flow through this and bypassing all these channels and that deteriorating the condition of the blast furnace in terms of reduction and proper utilization of the heat.

So, one has to avoid this preferential flow so, that there are ways by which it can be corrected. So, as mentioned here by 2 types of flow are prevalent central and wall and this can be done by proper charging of the material.

So, the centre, centre gas flow, coke and coarse burden material is at the centre, which gives more permeability to the bed and thus low resistance to the gas flow, the shape of the cohesive zone is inverted V type in this case. In wall flow case the flow at the centre,

centre is blocked either by softening and melting of the burden due to its poor distribution.

So, centre, centre is less permeable gas flow preferentially towards the wall and the shape of the cohesive zone is W. So, these 2 types of cohesive zone are shown in this. So, you can see the inverted V type cohesive zone.

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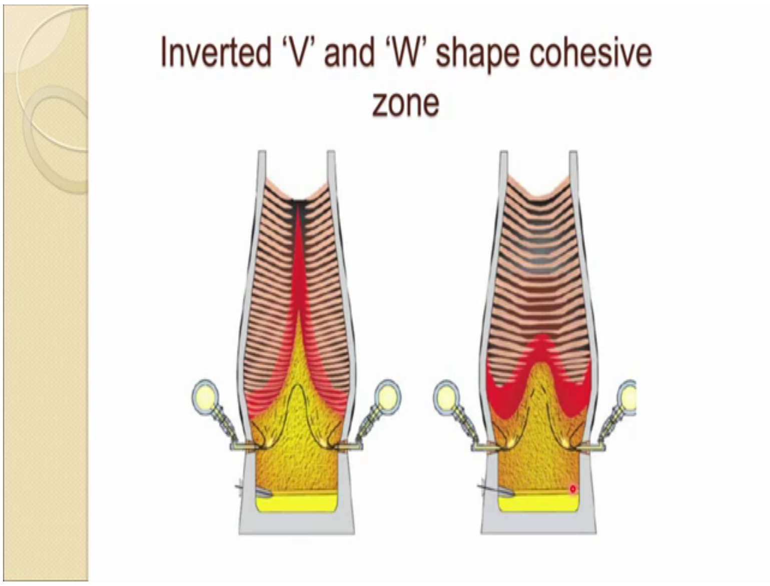

And this is a w shape cohesive zone. So, you put the more coarser material in this case at the centre, centre. So, central gas flow is there. So, gas can easily pass through this region; however, in this case as you put more coarser particle toward the periphery, and less over here.

So, you have a more central flow of the gases though you have also a good flow in the centre, centre, but not as good as in this case ; however, you can do the reducing power of the gases in this 1 better than in this.

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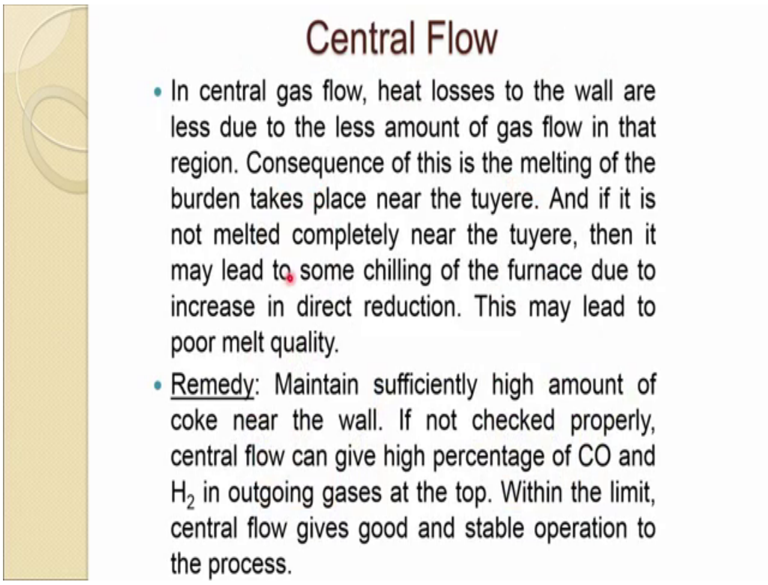

Now, how to so in central gas flow heat losses to the wall are less. Due to the less amount of gas flow in that region consequence of this is the melting of the burden takes place near the tuyere.

And if it is not melted completely near the tuyere then it may lead to some chilling of the furnace, due to the increase in direct reduction and this may lead to poor melt quality. So, you can of course, avoid this 1 by keeping a high amount of coke near the wall.

So, if not checked properly centre flow can give high percentage of co and hydrogen in outgoing gases at the top within the limit the central flow gives good and stable operation to the process.

So, essentially in this 1 as I mentioned most of the gases are going through the central region, and it is not reaching much toward the wall. So, wall side material is not properly reduced so, while it is coming down 1 will find that material near the wall is not properly reduced.

So, and it is extended till the tuyere zone. So, most of the reduction of this side will take place here, and that is more by directly reduction which is a endothermic in nature and that will give a chilling effect to the furnace. So, temperature will drop down and sometime even this may occur near the hearth.

So, hearth chilling may occur which is not at all desirable for chemistry of the metal and slag. So, one has to take a proper care of that one and also the full potential of the reducing gases are not used in this if it is quite porous then without much reduction of the burden they may path and top gases would be having a more hard potential more co and hydrogen.

So, reduction potential which is not good, so in one way you are wasting the reduction potential of the gases and the temperature also would be higher in the outgoing gases and these are the indicator to the operator with the furnace is running in a proper way or not.

So, one has to take a corrective measure for that and one of the measure is increased a this wall flow toward this and make a more uniform this reduction potential throughout the furnace as mentioned in the remedy.

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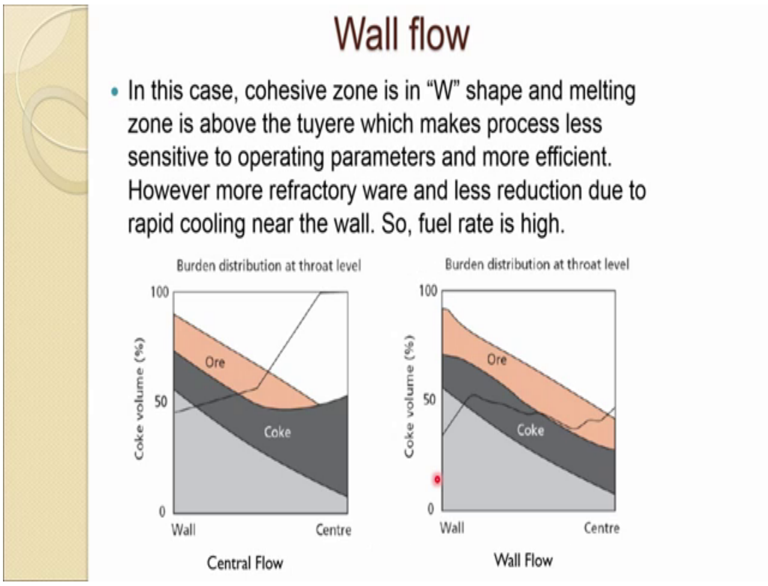

So, another in the wall flow what is happen in this case cohesive zone is in W shape, and the melting zone is above the tuyere which make process less sensitive to operating parameter and more efficient; however, more refractory ware it is a more refractory ware and less reduction due to the rapid cooling near the wall, so fuel rate is high.

So, in this case you will see because the due to the cooling effect of the gases though gas are passing through these. And due to the good velocity of the gas, where of the refractory can occur and because they have a close to the wall. So, cooling effect is also there which is again then reducing the reduction power.

So, this 1 also can may not utilize properly the reducing power of the gases. So, 1 has to take a sort of a combination in a proper way that it is reduction power of the gases is utilized properly, and not only that the heat exchange should be proper, so now and how do we do.

The, you can see the central flow. So, coke layer and more coke is deposited at the centre. So, this is a centre this is the wall and coke as you have seen already the void fraction is quite high for coke. So, the gas certainly will flow through this region in a much with less resistance.

So, preferential sort of a flow, but furnace will run more smoothly here and in this case you are not having that more coke at the centre. So, gas will distribute gas will go through this and through the wall also. So, it will have a better reduction and gas utilization would be better in this.

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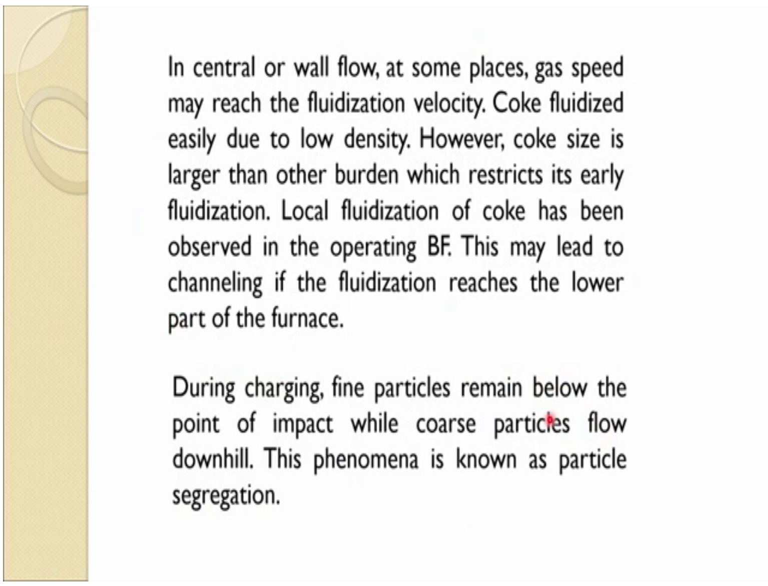

Now, how do you achieve this thing we will come to that in central or wall flow at some places gasses speed may reach the fluidization velocity, coke fluidize easily due to low density; however, coke size is larger than other burden which restricts its early fluidization local fluidization of coke has been observed in the operating blast furnace, this may lead to channelling if the fluidization reaches the lower part of the blast furnace.

During charging fine particles remains below the point of impact while coarse particle flow downhill, and this phenomena is known as particle segregation.

So, particle segregation is very important phenomena in the blast furnace charging and we will come to that, but due to this uneven flow which may occurs some time and some (Refer Time: 15:47) some preferential flow is going somewhere, few other places then we will find that local fluidization may occur.

And as we show in this figure the minimum fluidization velocity for coke is 2.9 for pellet is 2.2 sinter is 2.5. So, there is not much difference really in this because the coke size is quite high almost 4 times of the pellet and that is one of the reason otherwise coke can easily fluidized if the size is like that though the density of the coke is very less.

It is 525 bulk density, and for the pellets is 2150. So, that is the main difference.

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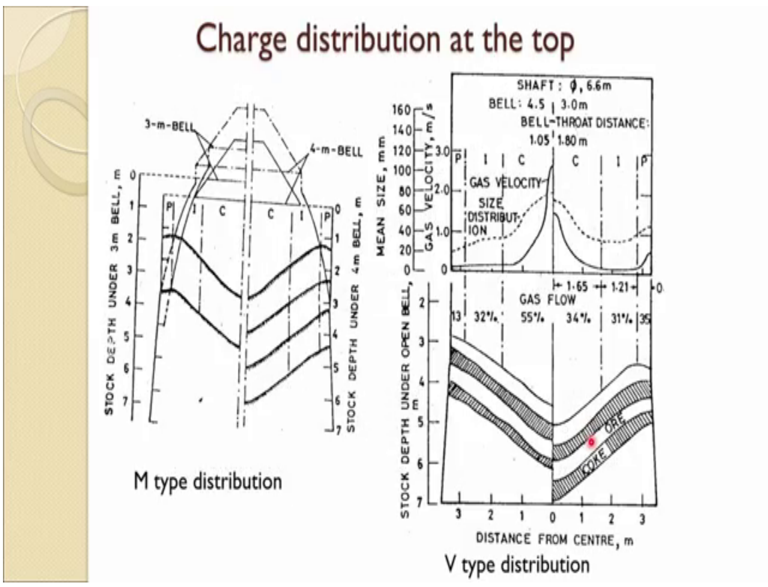

So, it show a bit about the charge distribution. So, as we said this W shape of thing cohesive zones you get it, when you have a bit coarse charging at the near the wall.

So, you are trying to get the reduction this side also and at the centre, and that type of charging is called the m type. So, where you are putting a bit coarser particle and near the wall and its shapes of the charge zone comes in this form which is like a M type. So, you have also coarse particle here and here.

And all this is pattern depends upon the angle segregation of the material fines which are present in the material, that is why these all properties are very important during the charging and selecting the material when we send to the blast furnace charging system.

Otherwise we will create quite a your problem in the operation, and the other charging which we saw in the previous slides also that is a V type charging and where they material can slides more to a coarser particle more toward the centre, and where it gives a central flow and this will give you the wall flow and.

This figure show that the gas velocity in the centre flow would be quite high as we explained before due to the higher (Refer Time: 18:38) thing. So, that this is the gas velocity and this is the mean size.

So, mean size is the also high and its size distribution this 1, so mean size is high. So, gas velocity is high ; however, in the m shape 1 you can see that at the both places velocity and the distribution is reasonable, it is not at 1 side is becoming very high like in the central flow, but in this even the wall side you are getting a good.

Velocity of the gas then here is almost 0 here you are get reaching almost point5 meter per second. So, that will utilize the proper heat exchange and reduction potential of the gas. So, mass transfer all these are important for the reducing purpose. So, this M type is more preferred.

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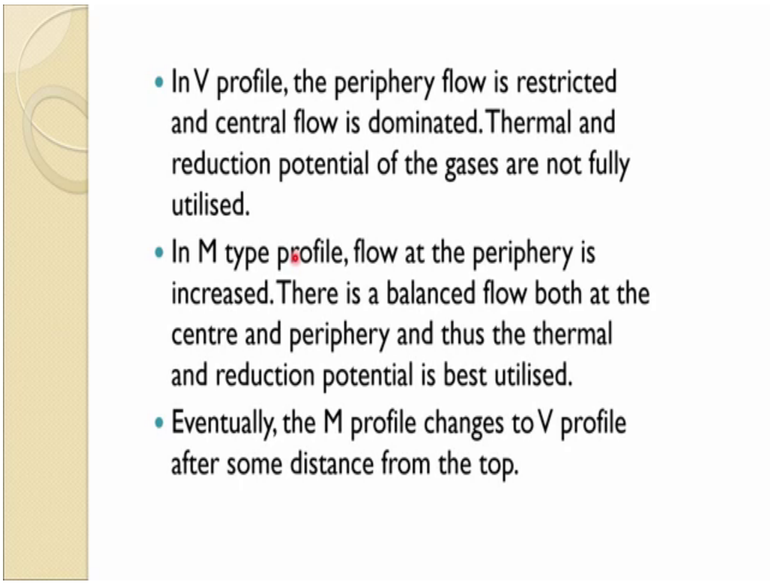

So, in V profile, the periphery flow is restricted and central flow is dominated. Thermal and reduction potential of the gases are not fully utilized. In M type profile, flow at the periphery is increased. There is a balanced flow both at the centre and the periphery and thus the thermal and reduction potential is best utilized.

And eventually the M profile changes to V profile after some distance from the top, but the by the time it reach it to that quite a lot thing you achieved in terms of thermal and reduction potential of the gases.

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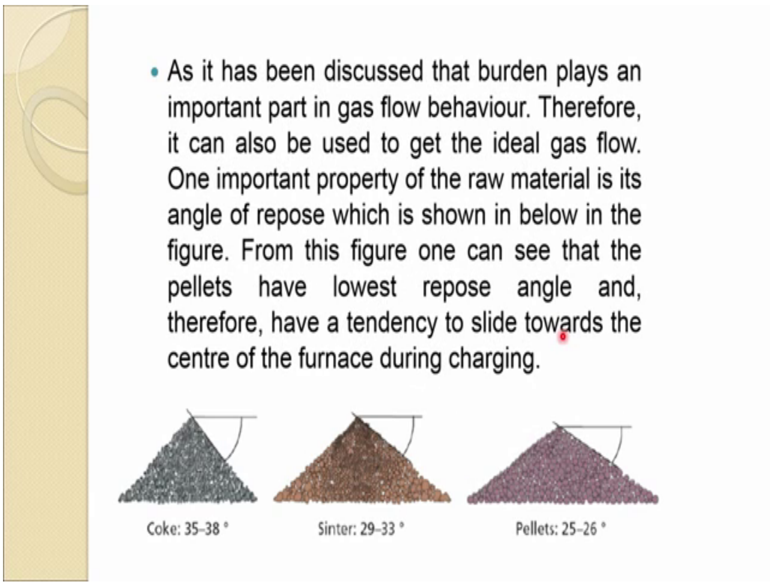

Now, another important property of the raw material is about the angle of repose. So, it has been burden plays an important part in gas flow behaviour as we have seen in the previous slides therefore, can also be used to get the ideal gas flow.

So, by proper distribution of the burden control of it you can get the ideal gas flow in the blast furnace which can be best utilized in terms of heat exchange.

And mass transfer or reduction potential of the gas, so one important property of the raw material is it's a angle of repose, which is shown below from this figure 1 can see that the pellets have lowest repose angle and therefore, have a tendency to slide towards the centre of the furnace during the charging.

So, as you can see the coke has a very high angle of repose. So, the angle of repose it is from the, but a vertical you measure it from the surface of the top surface of the charge which is top horizontal line. So, this angle for coke it is quite high though for.

Pellet is much flatter, so pellet due to become flat when you were charging and in that way; however, the coke would be more above to that is this layer will not become that as flat as pellets.

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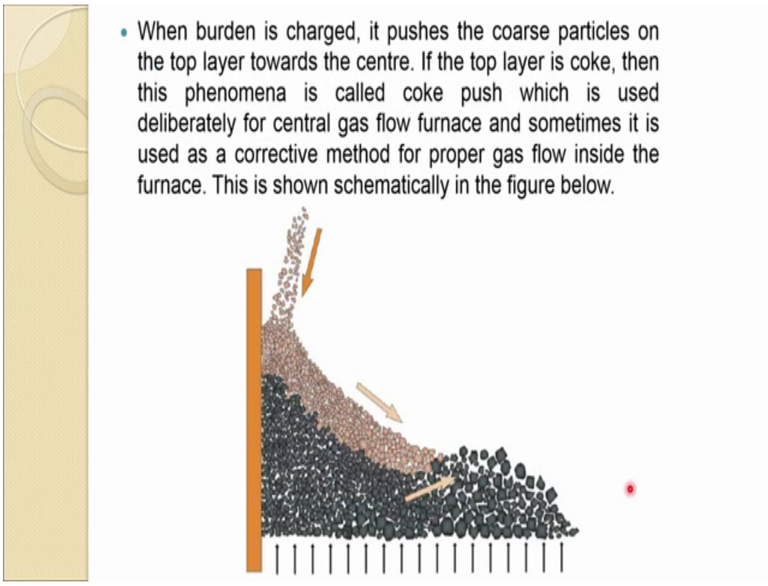

So, we will see, so when usually when burden is charged you can see in this 1 this is more about the pushing of the coke, but mostly you will look at the profile of this will go bit like this while profile of the coke would be much sharper. So, when burden is charged precise the coarse particle on the top layer toward the centre if the top layer.

Is coke then this phenomena is called coke push, which is use deliberately for central gas flow furnace and sometime it is used as a corrective method for proper gas flow inside the furnace.

So, as I mentioned previously this gas flow can be controlled as using your proper size burden distribution, this is one of the way if you really want to increase central flow, you charge in such a way the other material, that it precise the coke larger size particle cokes towards the centre. So, permeability increases toward the centre.

So, gas flow increases in that you can do also other way around. So, it indicates your charging mechanism is also very important not the charging mechanism, the charging equipment should be much more flexible by which you can control the distribution of the material wherever you want it. So, that is a very important thing that you should have a proper equipment of the charging.

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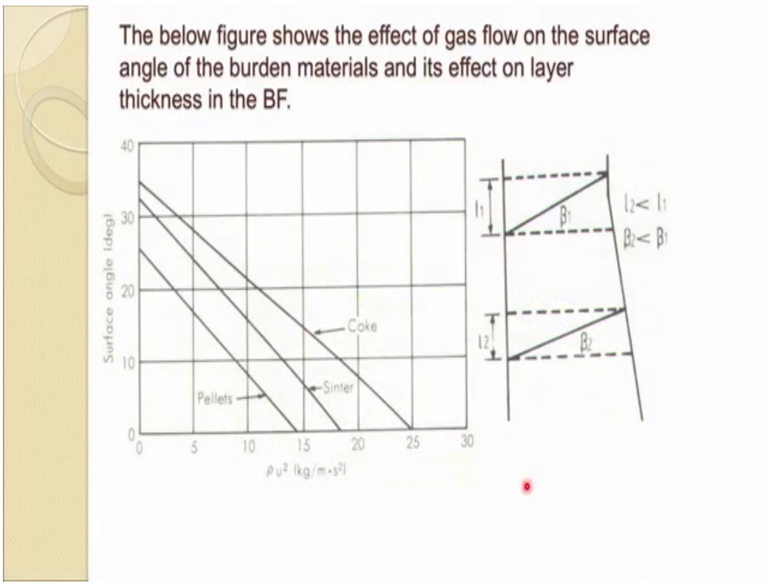

This next figure; showing the effect on the surface angle the effect of gas flow on the surface angle of the material. So, as you can see that when the gas flow increases of course, in rho u square term essentially the your surface angle decreases for coke sinter pellets. So, flow of the gas also affects quite a lot about the angle of the burden material and again can change the distribution.

So, in that case that also can change the layering angle. So, like in this case beta 2 is less than beta 1 the angle then you will see the thickness of the layer has decreased, then in this case though of course, it is also the angle of this.

So, this contribute toward that also, but beside that of course, the layer thickness decreases as you go down due to increase in the diameter 1 thing of the blast furnace. So, layer becomes more and more flatter, than like this what probably you are seeing it here as you can see it they are become flatter as you go down ok.

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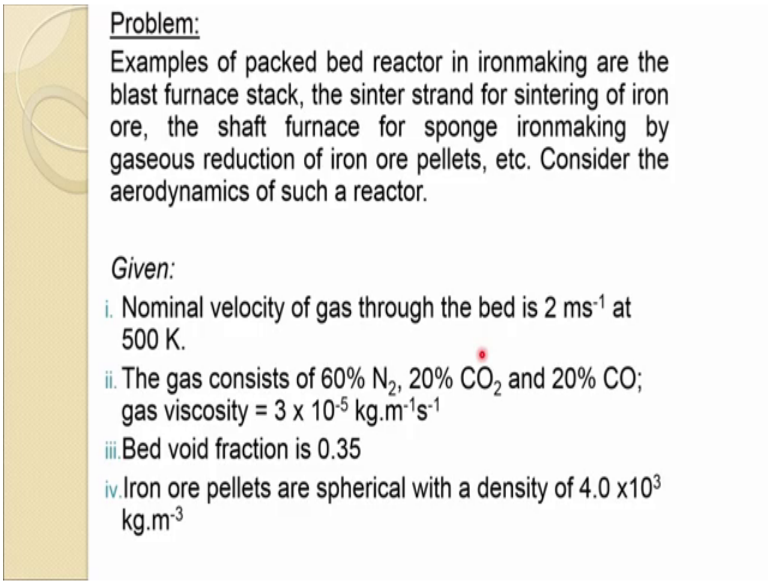

We will have a 1 problem based on the some size distribution, we will talking more about the size distribution in the material, so, and it is very difficult to have a uniform or 1 size. So, usually you have a distribution of the particles, in this example some size distribution is also taken into consideration.

So, in packed example of packed bed reactor in iron making are the blast furnace sinter strand, sintering and sponge iron making by gaseous reduction of iron ore pellets. So, this is 1 of the example that is given that velocity of the gas through the bed is 2 meter per second, at 500 degree Kelvin. The gas consist 60 percent nitrogen, 20 percent CO 2, 20 percent CO, and gas viscosity is given.

The void fraction of the bed is 0.35 and the pellets are in a spherical shape, has the density of 4000 kg per meter cube.

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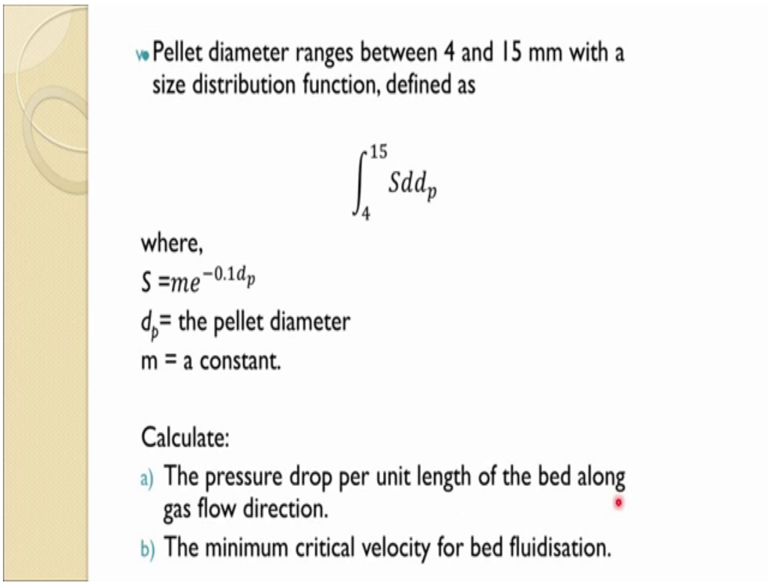

And the pellet diameter ranges between 4 and 15 millimetre with the size distribution function defined as given below. So, S is represent by this function, d p is the pallet diameter and m is a constant over here.

So, one had to calculate the pressure drop per unit length of the bed, along the gas flow direction and the minimum critical velocity for bed fluidization. So, I think you are already familiar with this. So, we will see how this can be solved now the distribution of the particle is given and not directly the particle size or average particle size. So, we have to calculate first about the average particle size from this.

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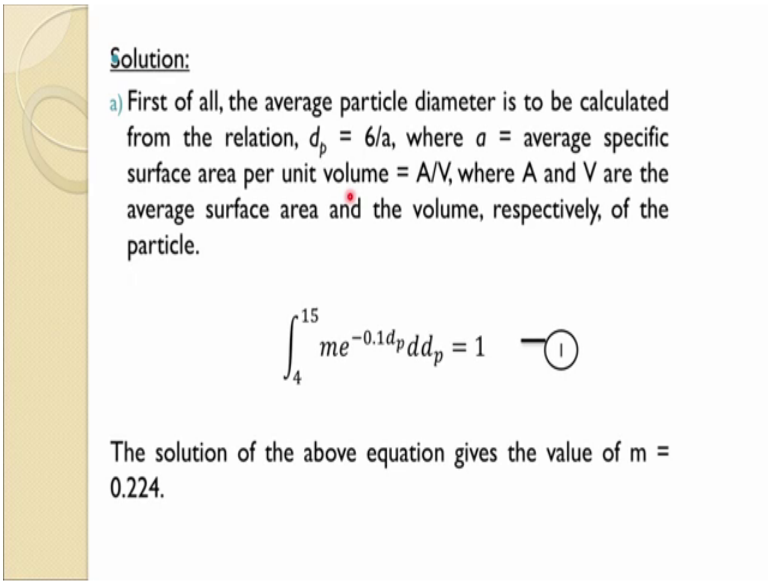

So, the average particle diameter is to be calculated with the relation 6 by a where a is the average specific surface per unit surface area per unit volume. So, 6 A by V, so A is the area and V is the volume, here and the distribution to be 1.

So, if you put 1 and integrate it within this limit so, 4 is the minimum size and 15 is the maximum size. So, solution of this gives you the value of m 0.224.

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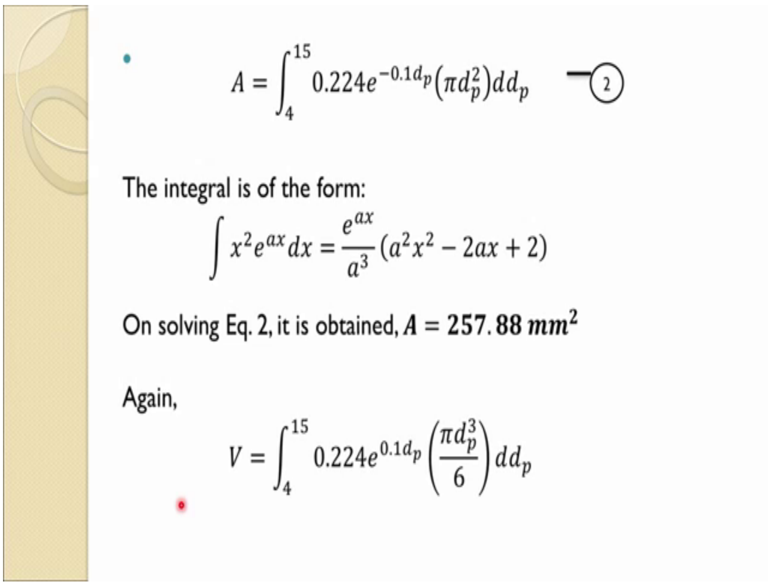

So, if you put this value over here and then you can calculate the area with pi d p square dd p, and if you integrate it within this limit this is sort of this integral. So, probably you might have to recall from your undergraduate of first year mathematics.

Then you can solve this equation and that will gives you the area of 258 millimetre square, and in the same way you can calculate the volume its particles and 4 by 3 pi r cube sort of that volume and if you integrate within that limit again.

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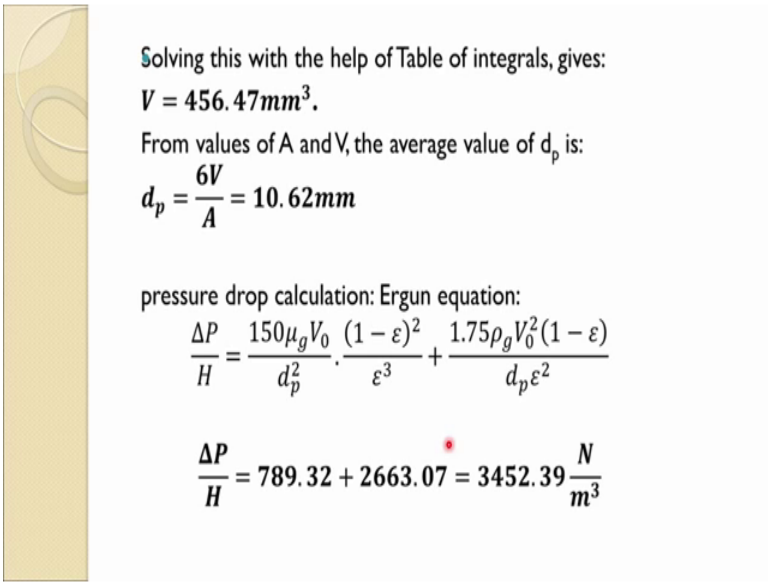

Then, so in this when you have to use table of integrals this and as you can get the volume about 456 56 millimetre cube. So, from this value now we can calculate average diameter of the particle which comes 10.6 millimetre.

So, now once we got the average diameter of the particle. So, this average diameter remember it has been defined, here where a is the average specific surface area per unit volume in that term average diameter it define. So, then you know from the ergun equation pressure drop can be calculate in a packed bed.

So, which is use this ergun equation which you are already familiar with it, and void fraction is given particle diameter just now we calculated viscosity is given and of course, even the velocity is given of the gas which is 2 meter per second and that is actually a superficial gas velocity, so if we put all these.

So, all the terms are known which gives you the pressure drop of 3452 normal per meter Newton per meter cube, and that is the pressure drop in the bed now. So, that gives the answer of the first question pressure drop per unit length of the bed along the gas flow direction and minimum critical velocity of the bed fluidization.

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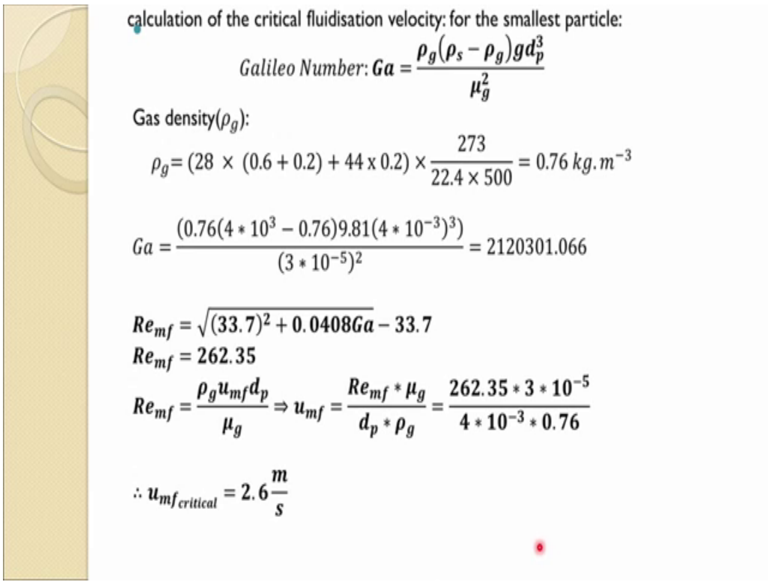

So, for the fluidization as you know the first you have to find out the Galileo number and that we have to take now it is asking about the critical minimum critical velocity. So, minimum critical velocity has to be related to the minimum particle size diameter.

So, we have to consider 4 millimetre that the particle diameter which is the minimum 1 with respect to that, we have to calculate the minimum critical velocity, because this is the 1 which will fluidize first.

So, if we calculate the Galileo numbers. Now because gas also has this mixture not the one which has the 60 percent nitrogen 20 percent co and 20 percent CO 2. So, CO it also has the same molecular weight as nitrogen, so 28.

So, with the respective percentages it can be converted 1 can easily with the volume of the gas and another thing, one can get gas density about 0.76 kg per meter cube so.

Now, we got rho s rho g rho s is given already about 4000 kg per meter cube viscosity is also given. So, everything known so if we put these values and into this formula get the Galileo number of 2.1 into 10 to the power 6.

And once you put this Galileo number again you are aware of our this formula which we sort of deduce it from the first principle in the starting. So, if you put the Galileo number in this you can get the minimum fluidization Reynolds number at the minimum fluidization, which comes around 262 and from that as you can easily calculate the minimum fluidization velocity.

So, everything again is given because the Reynolds number. So, your minimum fluidization velocity would be 2.6 meter per second. So, when the critical velocity which means your this reactor should not operate more than 2.6 meter per second velocity and as such it is given the nominal velocity is 2.

So, below fluidization velocity anyway it is operating. So, no none of the particle will fluidize in that condition.

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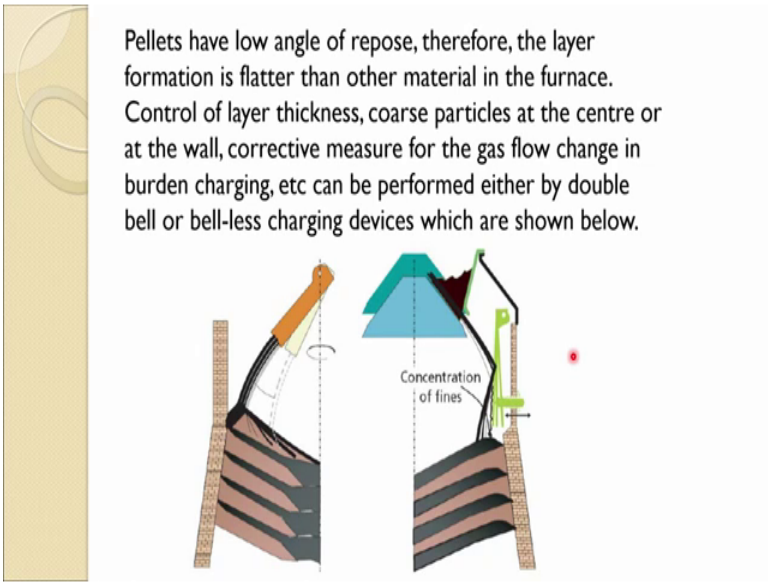

So, I think you got the idea from this size distribution, how it can affect and, how you can select the velocity. So, this velocity operating velocity is not related to the larger size particle it is much related to a smaller size particle. So, you should be operating your reactors with the smaller size of particles. So, they should not get fluidized.