Iron Making
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Lecture - 23
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So, after this moving back we come to the lower part of the blast furnace here and you can see this is a cohesive zone, which we have already discussed previously that many many times.

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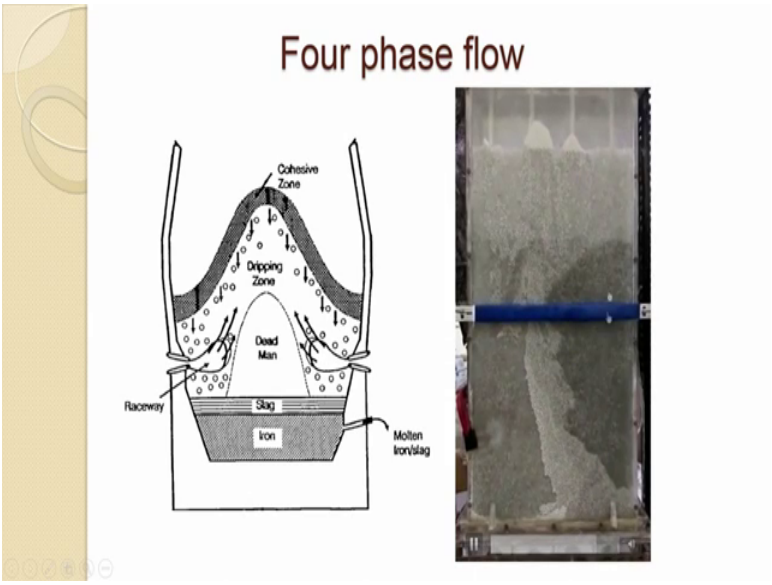

And in this region mostly the coke is the solid one or other thing is in liquid form. So, liquid iron and slag is trickling down through this coke bed matrix, gas is going up here is a cross flow and then going counter clockwise. So, gas is that rising up in the vertical direction and because the coke is getting consumed here, so the whole burden it is sending down, and because you inject pci pulverized coal injection through the tuyere.

So, you are having a really four phase liquid, fine gas and solid which are in the motion and that is why we call that one as a four phase flow. So, in that way this is a quite complex region. So, stability of this region is at most important in terms of creating the efficiency of the blast furnace and a smooth operation. This movie which gives you some idea about this four phase flow of course, in this one you would be having a liquid gas

and fines, in the experimental condition at room temperature and coke particle actually are these which are not moving.

So, as you can see that there is a sort of a flooding is occurring here. So, our gas is coming from this side and this is a fines is coming from the top, fines are deposited blocking the pores and forcing liquid to build up and then the flooding and bubbling has started in this. It is a classical example which we talked before about the flooding and loading things. So, you can see in this one how the loading and flooding is occurring in this, in this case the solid movement is not there is it stationary.

So, this is resembling the lower part of the blast furnace and deposition of the fine one can see even at the top, but liquid accumulation is not withstanding.

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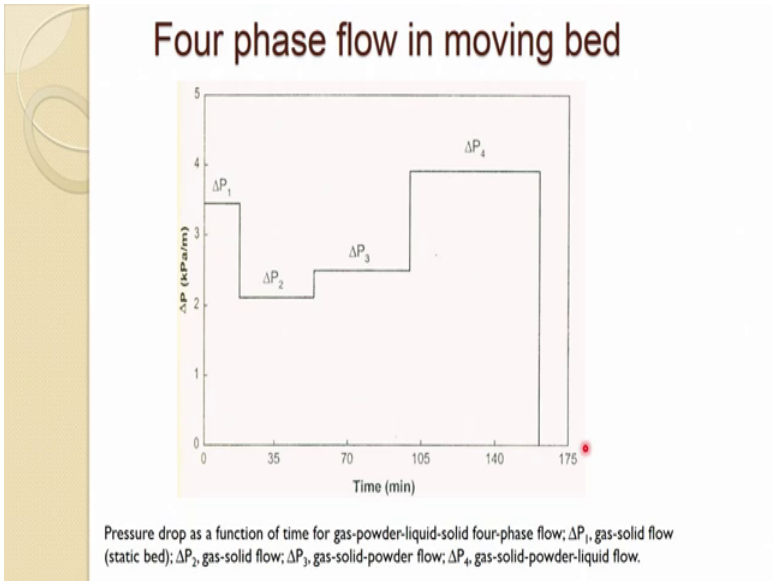

Pressure drop as a function of time for gas-powder-liquid-solid four-phase flow; ΔP_1, gas-solid flow (static bed); ΔP_2, gas-solid flow; ΔP_3, gas-solid-powder flow; ΔP_4, gas-solid-powder-liquid flow.

This figures now we will describe about the four phase flow how does it occur. So, your this y axis show is the pressure drop and the x axis shows the time and it is in the four phase flow. So, the first one is showing a static bed. So, in the steady bed the pressure is delta P 1 and after the time sometimes you start moving the bed. So, particles you put them into the motion. So, bed in is in motion.

So, in under those condition as your pressure drop actually decreases and this is quite true because as we have seen before in one of the slide, that is the moving bed the void fraction is more than the static weight. So, this is the condition when gas is flowing and

there is no movement of the particle inside the bed, in this condition the gas is flowing, but there is a movement of the particle. So, solid is in motion and naturally the void fraction and increase the pressure drop pressure drop would decrease and now at this point if we start injecting the fines.

So, naturally as we had seen before the fines are going to occupy some spaces between the particle board. So, there would be a less permeability and naturally is the pressure drop will increase, and that is where the pressure drop has increased when we inject a fine. So, gas solid powder flow in this one. And after some time when we inject the liquid then naturally liquid is also going to occupy quite a bit space as we had seen in the previous photo videos. So, pressure drop increases further when the liquid flow starts and that as you can see from this figure and after some time we stop the experimenter it comes to zero.

So, this is sort of a experimental graph of the pressure drop and how the pressure waves in various condition. So, naturally in presence of liquid the pressure drop is quite high its due to the especially due to the maldistribution of gases and fines.

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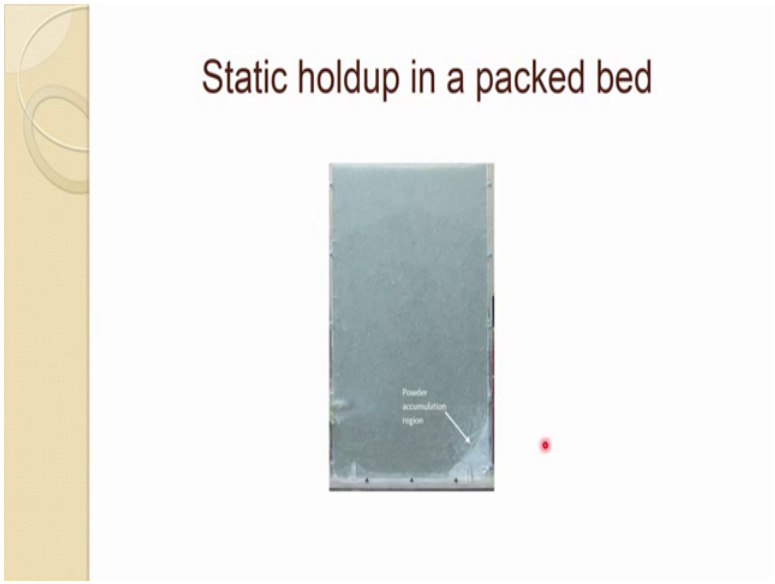

. So, this is one of the; you have seen the video just now and in that one if you what we have found if we do not put the liquid from the top you can see the accumulation of the powder. And between the particles we have talked about this a lot when we were talking about the pressure drop of PCI injection. So, this fine injection of powder injection is

representing the PCI the pulverized cold injection or any other material plastic or iron or fines or anything else. So, that this occupies the space between the particles, but it few places is accumulating in large quantity. So, opposite wall of the tuyere you can see there is a large accumulation of the powder.

So, this essentially what we call the powder holdup, its a its like what we had discussed about liquid holdup. So, we had a liquid static holdup and liquid dynamic holdup. In the same way we have powder static holdup and powder dynamic holdup. So, powder static holdup is the holdup, which is in between the particles the powder which is sitting in between the particle and not going through that it is just sitting there and it is stationary and that is the powder which is called the static powder holdup, the dynamic one just again like a liquid dynamic holdup the powder which is going along with the gas stream out. So, it is in dynamic position that is called the dynamic powder holdup.

So, we have correlation for dynamic powder holdup and dyna and static powder holder holdup similar to the liquid holdup, what we had discussed before. So, we are not going too much into the detail of it, holdup says that similar as we had discussed in terms of liquid gas and fine flow.

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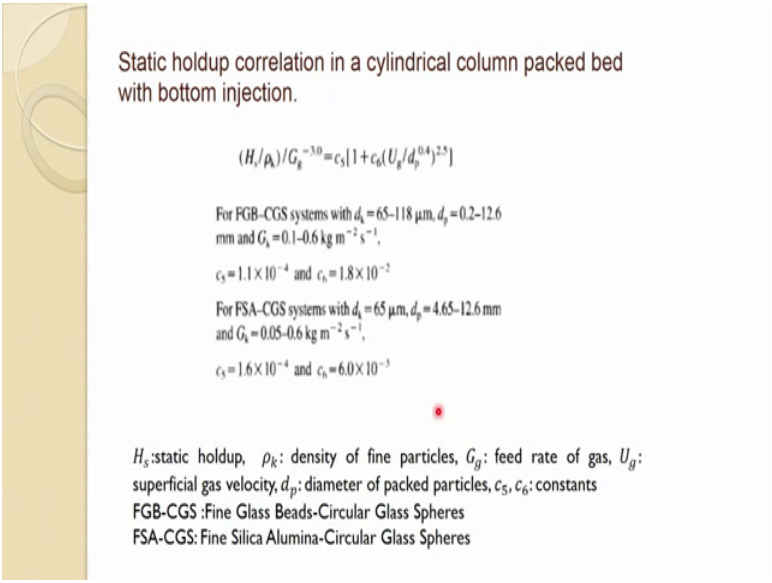

So, one of the correlation which is which gives the static holdup is this, but this static here H s is a static holdup, rho k is the density of the fine particle, G is the mass feed rate

of the gas c 5 and c 6 are constant, Ug is the superficial gas velocity and d p is the packing part particles size.

And this correlation is developed in a cylindrical packed bed system. So, in a cylindrical packed bed system its a bit different than a rectangular packed bed system. So, and in this was developed in ideal condition and you must remember that is in blast furnace conditions are not ideal when we say ideal condition. So, if I look if you look at this you can assume this one as a cylindrical, but you will see the gas flow and the fine flow is occurring from a small region and the way these correlation has been developed here it is a assumes a gas flow is occurring uniformly throughout the cross section of it. So, sometimes quite difficult to correlate the static fine hold up with this for this formula equivalent to the blast furnace holdup. In that case probably this rectangular one may give a better idea because this is a maldistribution of gas and fine over here.

So, this correlation they said is valid only for cylindrical system and it was developed for the fine glass bead and circular glass spare. So, packing material glass spheres and powder is fine glass and the second one packing material is these glasses spare, but the powder is silly fine silica alumina. So, based on those experiment this is done and these are the value of the constant for these two system, at the feed rate of market rate of gas in this range and the fine diameter in this range and particle diameter in this range.

So, one should be aware about these condition, when using this sort of empirical correlation.

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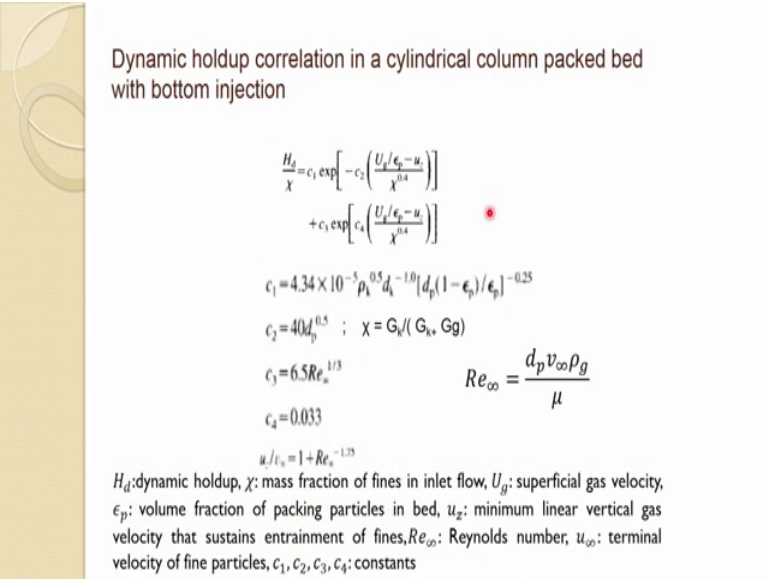

Similarly, there is a correlation under the same condition for dynamic holdup. So, it is the dynamic hold up and kappa is the mass fraction or fines which is nothing its mass flow rate of a fines and gas. So, it is a friction actually and c 1, c 2 c 3, c 4 are constant which are given here d p is the particle size and superficial gas velocity.

The void fraction the void fraction of the packing particle and uz is the minimum linear vertical gas velocity that sustains entertainment of fines and re infinity is the Reynolds number which is given by this formula, where u infinity is the terminal velocity of fine particle. So, and others are constant.

So, these all values are given over here. So, using these values under those limit which are mentioned the condition operating condition, one can find a reasonable at least the static holdup of the finds and dynamic holdup of the finds and this can be substituted in the ergun equation when we are making the pressure drop. If you remember when we did for the liquid holdup the pressure drop in the ergun equation we subtracted total holdup from the void fraction and that increased the pressure drop because it decreases the void fraction.

Similarly in this one the dynamic holdup and static holdup of powder can be taken as the total holdup of powder, which can be subtracted from the void fraction and that will decrease the voidage and thus will increase the pressure drop in the column.

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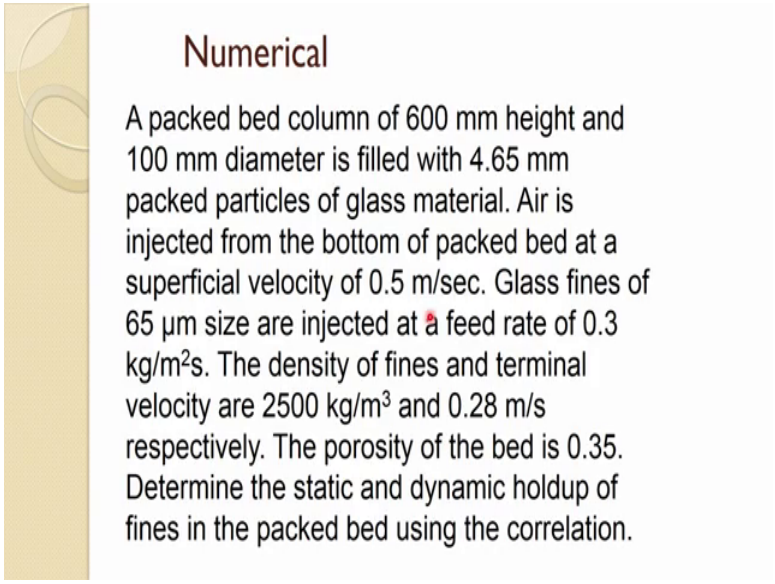

So, one can get a then good idea above the pressure drop in the blast furnace there is one numerical based on this. So, a packed bed column of six hundred millimeter height and hundred millimeters in diameter is filled with 4.65 millimeter packed particles of glass material.

Air is injected from the bottom of packed bed at a superficial velocity of 0.5 meter per second, glass fines of 65 micron meter micron size are injected a at a feed rate of 0.3 kg per meter square second. So, mass flow rate of the fines, the density of fines and terminal velocity are 2500 kg per meter cube and 0.28 meter per second respectively the porosity of the bed is 0.35 determine the static and dynamic holdup of fines in the packed bed using the correlation.

So, already we have the correlation and this problem part is pertaining to the cylindrical column; under millimeter of diameter to straight away we can use those correlation which we had discussed before and substitute the value.

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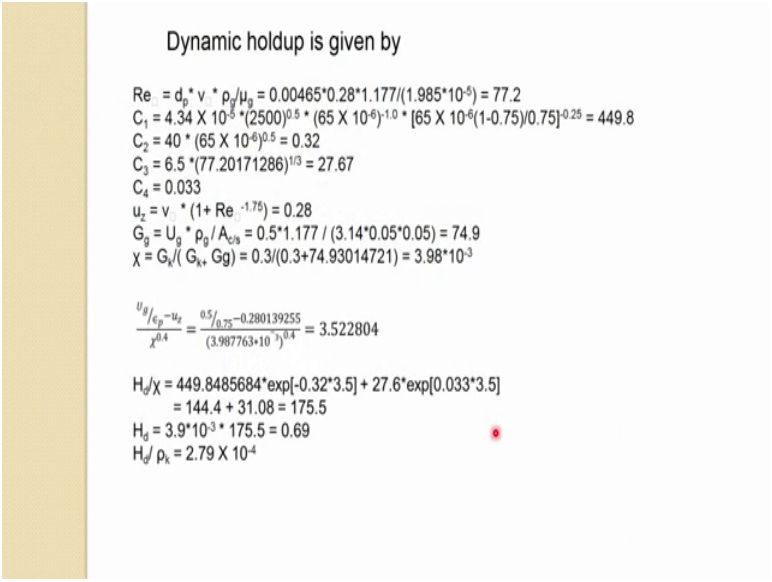

Now for the dynamic holdup as you know this uz and uv infinity is there it is related to the Reynolds number. So, first we have to calculate the Reynolds number here so, that we can get this value. So, Reynolds number when we substitute the particle diameter and the terminal velocity, which is given and gate density viscosity these are the standard though it is I believe not given here, but these are the standard one it room temperature one can have it because this and this is we can as you might room temperature all these things. So, glass materials giving. So, naturally it would be at room temperature.

So, room temperature value of the gas density and viscosity is this and the one can take. So, that gives to the Reynolds number value about 77.2. So, now, we can calculate the c 1 which is again fine density, then diameter of the fine particle diameter void fraction. So, that is how we have put it the fine density, fine diameter and then the other value we have put it in this one. So, that gives you 449.8 similarly we have calculated c 2 that is a particle diameter, I think here it should be a particle diameter which is given 4.65 c 3.

Similarly, can be calculated using this. So, Reynolds number we already got. So, 6.5 and that Reynolds number. So, you get c 3, c 4 of course, giving uz uv infinity to one plus. So, uz the linear the particle gas velocity you can calculate from this formula. So, u multiplied with u infinity and that is how it has been done. So, it comes to 0.28 and the mass velocity of the gas its given by this formula where the ug is the superficial gas

velocity, its giving out rho g its a gas density divided by the cross sectional area of their (Refer Time: 18:53). So, that is going to give you this mass flow rate mass velocity.

So, that is it come to this and the mass fraction of fines one you know g g g k and you already know because it is given the rate is here fines rate. So, you can one can calculate the mass fraction, which is of this now all the values are known we have calculated we can just substitute it into the equation, here did you know these both are same and then you multiply it. So, that is how it is being calculated this number first. So, 0.5 it is a velocity divided by it, it should be the void fraction which is given 0.35.

So, these states between 0.35 minus of a opposite of this and uz velocity which we have calculated divided by the kappa and so, you get this value this much. Now its simply substituting all c 1, c 2, c 3 and this thing into the equation. So, one can get the value of s dy kappa kappa value is known; so d. So, this has come to this one. So, kappa is this. So, dynamic hold up is about 0.69, 0.69 and in terms of h divide of k with some time it is represented. So, you divide by the density it comes to this. So, this is the dynamic void fraction of the points and similarly for the static one it is this is a static one c 5, c 6 is given we are taking for the glass this is our system.

So, these are the values for this and these all unknown or we have calculated it.

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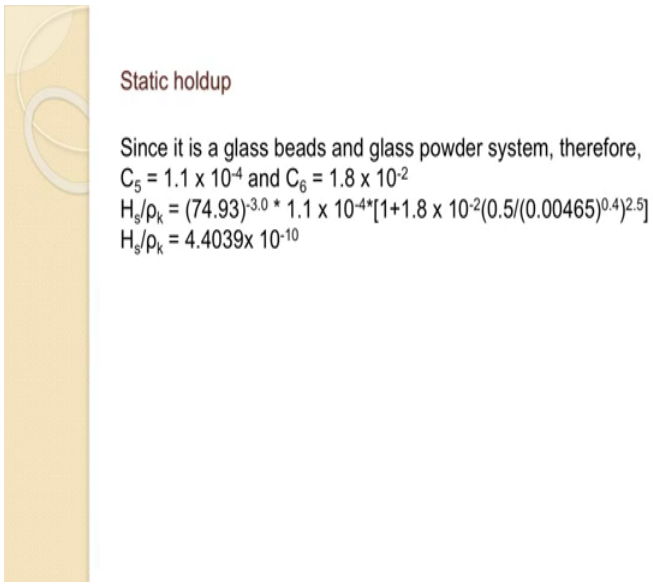

So, it is much easier now. So, c 5, c 6 given; so this is substituting the appropriate value into those static holder formula, it gives 3.91 into 10 to the power of minus 10. Now if you look at the value of static holdup and dynamic holdup, you would say certainly that dynamic holdup is much higher than the static hold up in this case, but remember as I pointed out before and the way this formula have been developed it is assumed that uniform gas flow is coming out from the bottom.

So, everywhere is a uniform gas flow. So, there is very less chances of the fine to deposit between the particle, when you are doing that sort of experiment in the lab. However, in actual blast furnace situation is very different it is a maldistribution only from the side the injection of the gas and fine is happening not from the bottom. So, it is not distributed uniformly across the cross section and that is where it gives this sort of sort of a hold up. So, its a big maldistribution of the gas and fines and one would not in fact, it has been observed the static hold up in there is condition is higher than the dynamic hold up. So, one has to be very careful in interpreting the data and using it.

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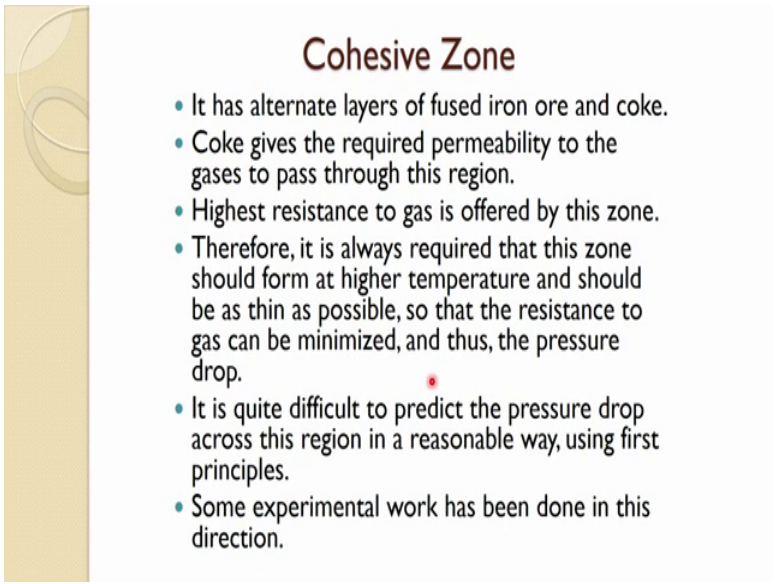

So, we have talked almost all part of the blast furnace except the hearth region and a cohesive zone.

So, now I would like to touch upon a little bit about the cohesive zone. So, this is about the cohesive zone which is a between the upper part and lower part in the middle. So, it has alternate layer of fused iron ore and coke; those you might have not remembered this

is your cohesive zone which we said. So, its and above this is the stake region and below this is the drop in zone. So, it is sitting in between that and the here temperature is about 1100 or 1050 like this and he said to 1300 1250 or like that here. So, it is started fusing or melting started here at this upper boundary of the cohesive zone and lower boundary of the cohesive zone or the melting is completed or liquid is there.

So, really this zone is like a fuse zone and that is what we are saying. So, it has a alternate layer of fused iron ore and coke because coke at that temperature resistance solid. So, coke gives the required permeability to the gas, gasses to pass through this region. So, from this region there is only coke which can led the gas pass up otherwise if coke does not coke also become like a fluid mass gas cannot pass. So, then probably one he stoke the operation. So, coke is playing a very important part in the cohesive zone, which is allowing the gases to pass through. So, highest resistance gas is offered by this zone, because here through the charge through the iron ore hardly anything gas will pass; so naturally whatever gas is passing through it through the coke.

So, there would be a highest resistance to the gas in this zone and therefore, it is always required that this zone should form at higher temperature. So, it can come down and should be a thin as possible. So, that the resistance to gas can be minimized and that is the pressure drop. So, these are the very important thing and the thing also dictate the quality of the raw material, and especially the high temperature properties of the feeding material. So, it is quite difficult to predict the pressure drop across this region, in a reasonable way using first principle.

So, due to this, the there have been many problem and its not that easy. So, many experiment has been done and based on some experimental work. So, been experiment we are talking here its mostly the hot experiment which have been done at that temperature the between let us say 1000 to 12 1300 or 1400 and some time under the pressure because it is a burden is there at the top, which is putting a pressure on the cohesive zone. So, under those sort of condition experiment have been performed and based on that some relation was proposed.

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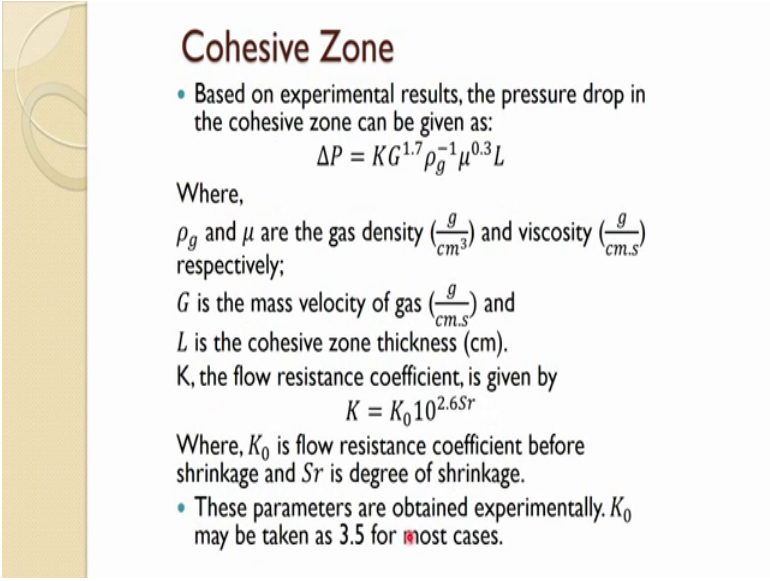

So, based on experimental reserve the pressure drop in cohesive zone can be given as by this formula.

So, this is a pressure drop K G. So, G is the mass velocity of gas, rho G is the density of the gas and mu is the viscosity of the gas and l is the sort of the cohesive zone thickness and k is the flow resistance coefficient which had to be determined and it is related to the shriek asked of degree of shrinkage. Because the in the cohesive zone its getting melted. So, iron ore and other metal sinks in that way. So, flow resistance is related to K naught 10 to the power 2.6 S r. So, where k naught is the flow resistance coefficient before shrinkage.

So, that is when the noise shrinkage. So, one can assume like a normal bed and S r is the degree of shrinkage. So, this S r is the degree of shrinkage. So, these are experimentally determined for different types of charge and thing and one can get the value of this most of the units in cgs. So, it is found that these parameters are obtained experimentally and cannot may be taken 3.5 for most of the cases. So, based on these one can get some approximate idea, about the pressure drop in the cohesive zone there is not much other work is done in that mostly experimental one. So, we are really lacking in the work in terms of fused packed bed.

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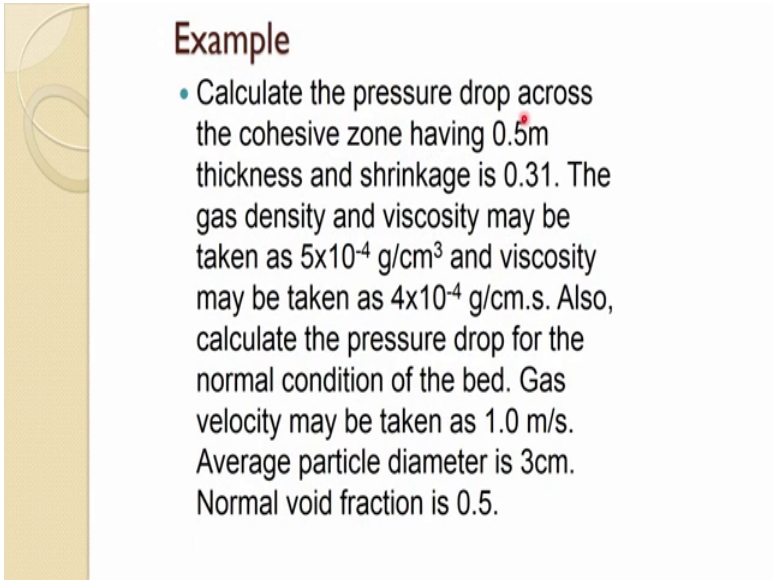

So, based on this there is one example. So, calculate the pressure drop across the cohesive zone having 0.5 meter thickness and shrinkage is 0.31. The gas density and viscosity may be taken as 5 into 10 to the power minus 4 gram per centimeter cube and 4 into 10 to the power minus 4 gram per centimeter second. Also calculate the pressure drop for the normal condition of the bed gas velocity may be taken as 1.0 meter per second, average particle diameters 3 centimeter normal void fraction is 0.5.

So, normal void fraction is 0.5 ok. So, now, we use the, that formula which we just now discuss. So, first I think we have to find out the flow resistance coefficient is using this. So, shrinkage is given and cannot we can take this.

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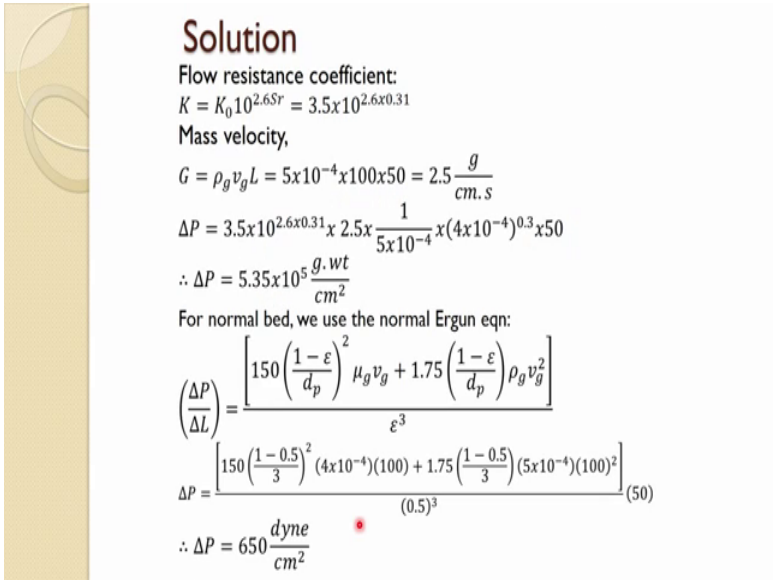

So essentially this gives to this value and the mass velocity of the gas and come for a second can be given by this comes to this. So, this is the gas velocity in cgs and at the thickness of the cohesive zone or the bed.

So, now we have almost all the values here. So, we substitute these values into this formula. So, essentially what we get 5.3 into 10to the power 5 gram weight per centimeter square. I think we have to look at this unit for normal bed we use the normal Ergun equation which is given by this which you are quite familiar with it; and void fraction is given 0.5 in that normal condition and all other things anyways given.

So, if you just put those values viscosity, gas velocity, diameter 3 centimeter voids fraction 0.5 and gas density velocity. So, you get the tail dialysis of 50. So, you get the pressure drop 650 dyne per centimeters square. So, you can see there is a big difference very high pressure drop is there those unit it is a little problem, but still if we see it could be the same unit, but the factor is very high. So, pressure drop in fuse zone or in the cohesive zone is very high then in the normal condition. So, that is why cohesive zone is very important.