Fluidization Engineering
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Lecture - 31
Fluidized bed reactor design and its performance

So, welcome to massive open online course on Fluidization Engineering. So, today's lecture will be on fluidized bed reactor performance and its design. And I think we have discussed about different hydrodynamics and transport phenomena like heat transfer and mass transfer in fluidized bed with different flow patterns.

And here in this case we will discuss something about the how efficiency or what is the efficiency of the fluidized bed based on different flow patterns that will be discussed here.

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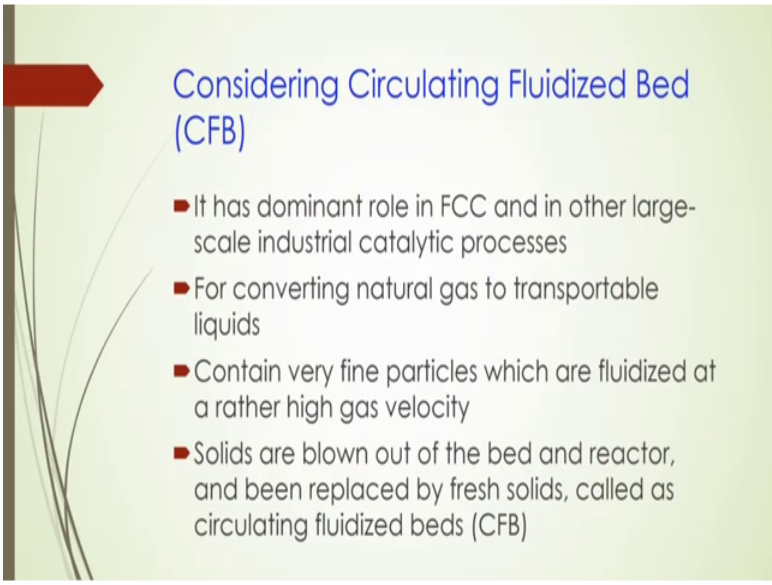

Now, for this we first considered the circulating fluidized bed here, this case this because this circulating fluidized bed are more dominant in FCC and other large scale industrial catalytic processes and in that case this circulating fluidized bed are actually used for converting natural gas to transportable liquids.

So, this type of fluidized bed that contains very fine particles which are fluidized at a rather high gas velocity and that case sometimes their gas velocity will be so high that it will be greater than twenty times of the terminal velocity of the or settling velocity of the particles. And in that case solids are blown out of the bed and reactor and been replaced by the fresh solids which that is why it is called that circulating fluidized bed.

So, this case we will discuss about this circulating fluidized bed based on different flow patterns and what are their performance in this case will discuss.

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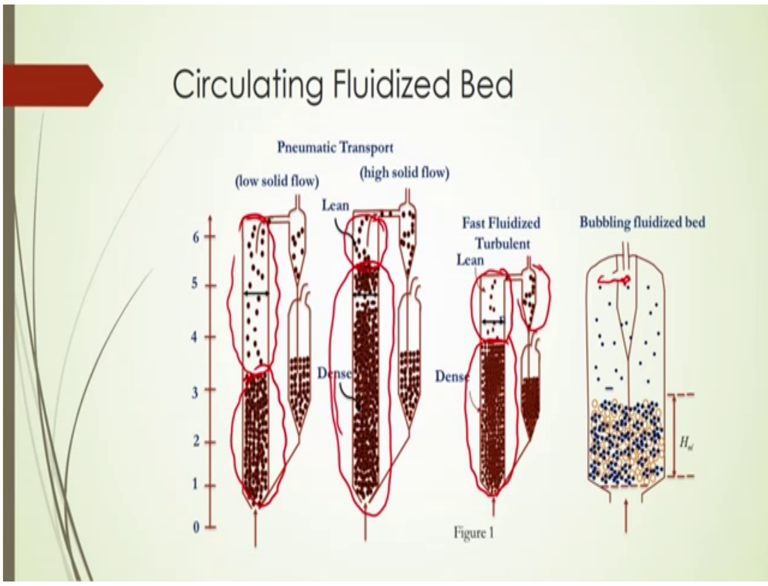

And again let us see first what are the different, actually phenomena of the circulating fluidized bed. Here in these slides it is shown that this circulating fluidized bed are shown here based on the formation of here that dense phase and lean phase. So, in this case for low solid flow if we are considering the pneumatic transport cases that circulating fluidized bed they are in this case we will see that here that for low solid flow here this circulating fluid bed here.

This is this region this region is called the dense region and this region is called the lean region and from this portion this solid particles which are coming out it will be separated by the cyclone separator and then it will be reused here and sent to the again fluidized bed for its reuse.

And in this case for low solid flow it is seen that here that lean region will be higher compared to this dense region even compared to the other different circulating fluidized bed. And for high solid flow in this case see this is the region for this dense region and this is the small region where this lean phase of the solid; that means, lean region of this fluidized bed are exist. So, this is called at this circulating fluidized bed which will be working as a pneumatic transport processes and at high solid flow rate.

Whereas, in case of first fluidized bed in case of turbulent flow you will see that there will be this is the dense region and this is the small region portion here. So, in this case there will be a turning position turning also phenomena and the intermixing of the solid particles even if it is the binary mixers are used, they are there were use that means, the intensity of the mixing will be high enough in this case relative to the other bed. And in this case that again the solid particles which will be coming out from this bed. It will be again reused by using this cyclone separator after separation.

And bubbling fluidized bed in this case you will see that here the internal separation of the solid particles being by being done by that cyclone separator which is installed inside the bed. And there the formation of bubbles in this case the bubbling fluidized bed and small fine particles are coming off because of that creation and other mechanism to become the corser particles two finer particles that has already been discussed earlier also. So, in this case there will be what is that again the solid particles can be reused by separating by this cyclone separator here.

So, these are the different I think type of the circulating fluidized bed. Now, let us consider that this only circulating fluidized bed to discuss the performance of the fluidized bed based on its reaction or any other operation there.

Let us see here consider a first order catalytic reaction where this reaction will be taking place inside the fluidized bed different types of fluidized bed, even in fixed bed, even bubbling fluidized bed, and first fluidized bed and the pneumatic conveying transport fluidized bed there.

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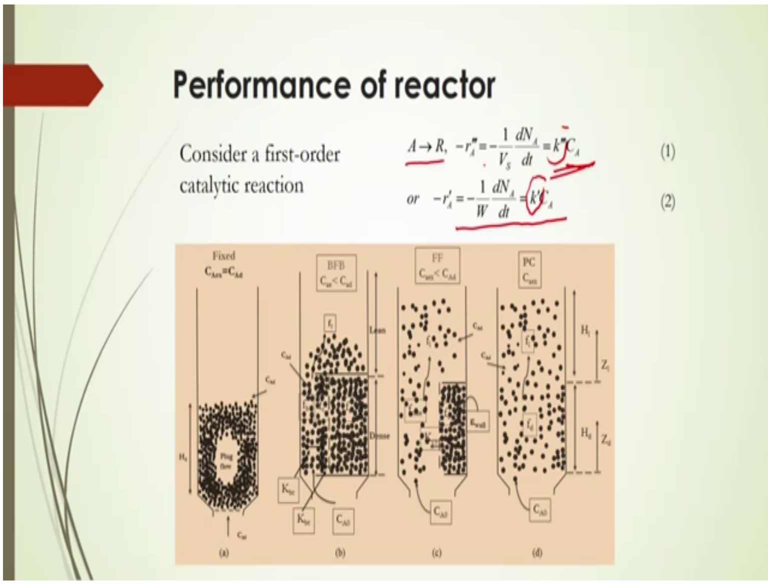

Now, if the first order catalytic reaction then based on this equation number 1, we can write that A is converted to R at the rate of here the r A triple dashed that will be the 1 by V s is the vessel volume by dN A by dt; that means, in the a rate of conversion or that is rate of reaction here that will be dN A by dt that will be is equal to some constant into C A. That is this C k double dash, triple dash is called that reaction constant or rate of reaction constants or you can say that the rate of reactions there. Rate constant, it is called also rate constant of the reaction.

So, this is based on the volume, volume concentration, volumetric concentration you can say and also here the weight percent concentration this is represented by k dashed.

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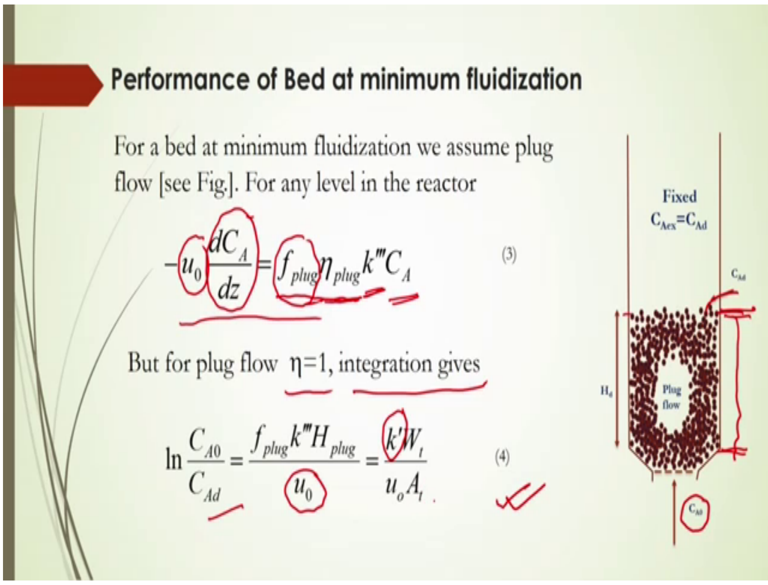

So, for a bed at minimum fluidization if we assume the plug flow they are then for any level in the reactor as per this then now you can write the equation number 3 on this minimum fluidization condition here; minus u u 0 minus u 0 into dC A by d z into f plug into eta plug into k triple dash into C A. Here u 0 is called the velocity at which this reactions of that is occurs and in a fixed of fluidized bed and where you can consider that there will be a plug flow phenomena.

So, based on that how this concentration will be changing at a steady state condition at a different location, and based on that you can say that what will be the axial distance for that fixed bed and what will be the rate of change of concentration along this axis that will be represented by this dC A by dz. And it will be balanced by this what here f plug into eta plug f plug means what is the what is that here total what will be that you can say here fraction of the here gas that is taking place or in the reactions and the plug flow of phenomena or you can say plug flow of fractions or you can say volume fraction of that gas occupied by the what is that by that is volume occupied by the gas.

And eta plug is the efficiency of the plug flow and k triple dashed is called the rate constant and C A is the concentration of the component A. But for plug flow although is the efficiency should be a 100 percent, so eta should be is equal to 1.

Then after integration of this equation three you can get this equation number 4, which is actually expressed in this way that ln C A0 by C Ad. C Ad means what, this the concentration at this outlet of this dense region of this fixed condition that means, here at fixed bed here this is the bed fixed bed now from this fixed bed at this outlet condition what will be the concentration of the component A that, and what will be the concentration of A initially supplied there.

So, it will be ln into C A by C Ad that would be equal to f plug into k triple dashed into H plug; that means, what will be the height of this that is fixed bed are divided by u 0 is the velocity of the gas there. And it can be represented also based on the weight percent and the rate constant should be is equal to k dash instead of k tripled dash here to be k dash into W t by u 0 by A T.

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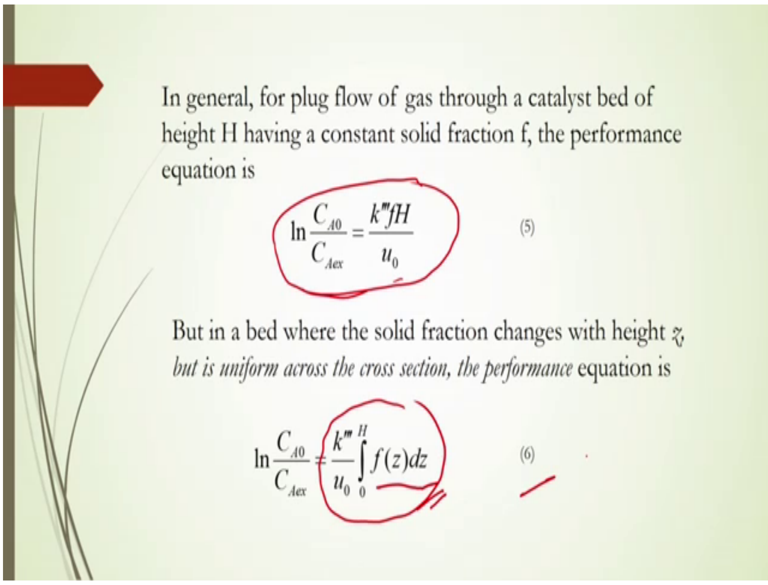

And in general for plug flow of gas through a catalyst bed of height H having a constant solid fraction like f, the performance equation can be represented by this here ln into C A0 by C Aex into k triple dash into f into H into by u 0. Here f is called the solid fraction, that the solid fraction at a certain height how much solid should be occupied in the bed.

So, in this case this equation five can be represented for the plug flow of gas through a catalyst bed of height H where the solid fraction should be constant. But in a bed you see in the practical cases that in any fluidized bed operation solid fraction may not be constant there so in that case solid fraction will be changing with height z, so but is uniform across that cross section they are to be considered then the performance equation can be represented by this equation number 6. So, here ln C A0 by C A here C Aex e x means here exit you can say the concentration of A at the exit of the any fluidized bed you can say and C A0 the initial concentration.

So, it will be represented by this general equation of based on the fraction of solid they are inside the bed that fraction of solid which is a function of z here. So, this f z into dz the where this 0 to h; that means, the height and at a certain height what should be the fraction of the solids there you can obtain here. So, instead of this k triple dash f H in equation number 5, it is represented by k triple dash here u 0 here this f H to be represented here 0 to H f z dz they are simple.

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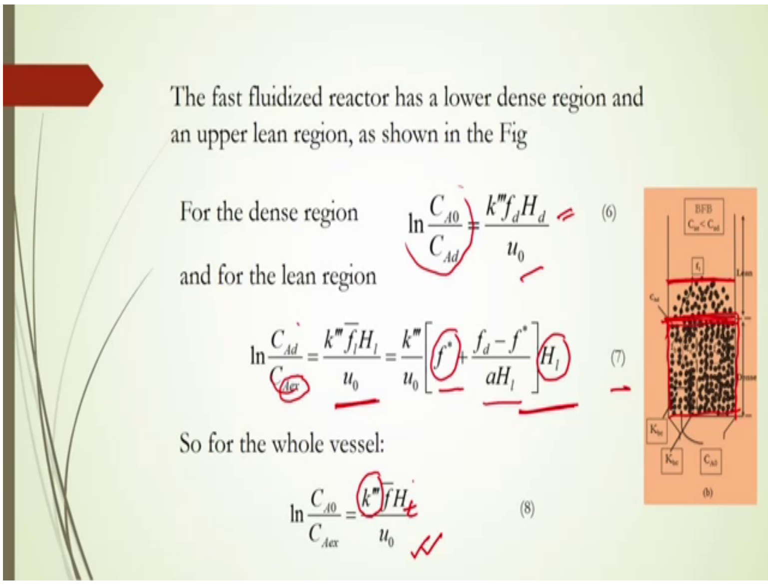

And then in case of fast fluidized bed reactor you will see that there will be a lower dense region whereas, it will have the upper most of the region with a lean region. So, in that case here for the dense region you can say what should be the solid fraction in the dense region that will be represented by f d. So, here in this figure it is shown that this region is the it is called that this region it is called that dense region.

So, what will be the solid fraction in this dense region it will be represented by f d, and what will be the what will be the solid fraction in this lean region that will be represented by f l. So, if you know the solid fraction in the dense region then you can get the ; that means, final concentration; that means, from the outlet of the dense region will be is equal to k triple dash f d into H d by u 0. Here H d is called the height of the dense region instead of total height of the bed it will be considered up to the dense region here whereas, for the lean region here again that ln C Ad by C Aex here the initial concentration in this lean region will be C Ad and the final concentration from the outlet of this lean region it will be is equal to C Aex.

So, this ln C Ad by C Aex that will be represented by this equation here k triple dash f l bar H l by u 0 here see very interesting that in the dense region the solid fraction is almost remain constant whereas, in the lean region the solid fraction will be changing with respect to height in the lean region.

So, that is why you have to find out what will be the average solid fraction in the total lean region there that is represented by f l bar. But since it is a function of; that means, height or z you can say then it will be equal to f star plus f d minus f star by a H l these the equation has already been discussed in previous or earlier lecture in entrainment model they are also how this solid fractions or solid distribution they are along the axis of the fluidized bed. So, based on that is represented by these f star plus f d minus f star by a H l into H l.

This f star is the called carrying capacity fluidized carrying capacity that means, capacity here what is the outlet; that means, concentration of the solid particles there. And H l here capital H l is the total height of the lean phase capital H l. So, instead of here only a total height then it will be represented by capital H l. So, in this the dense region and lean region we are getting the too height here H d and H l.

So, based on which we can represent this equation number 6 and 7, only by changing this solid fraction solid fraction in the solid dense region it will be f d and height of the dense region is the H d whereas, in the lean region this solid fraction will be taken as average solid fraction that is f l bar which will be represented by f star plus f d minus f star by a H l.

And height of the a lean phase will be equal to capital H l. So, for the whole vessel we can write this equation number eight here as ln C A0 by C Aex. What is the C A0? That is initially what will be the concentration of the component that is supplied and C Aex is the component concentration at the outlet of the fluidized bed that will be coming through the bottom part and through the region of a dense region and the lean region and then after that it will be coming out from the bed.

Now, this then ln C A0 by C Aex within finally, k triple dashed into f dash into H l by u 0 for the whole vessel. Here H t is the total this is H t H t is the total bed height here there. So, this f bar it will be is equal to what is that to average solid concentration for the whole bed here. So, this average solid concentration will be is equal to here this f d plus f l bar there.

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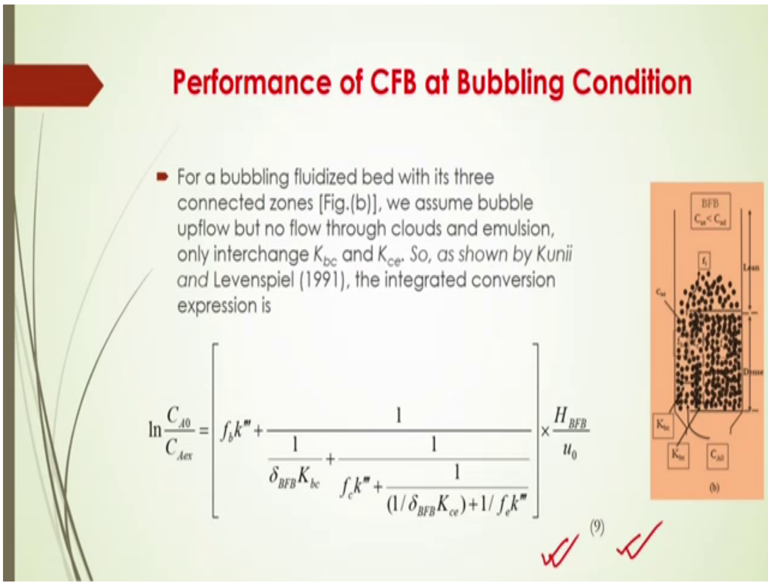

And for a bubbling fluidized bed with its let us consider that performance of the C f b at bubbling condition it has C here.

So, for a bubbling fluidized bed with its 3 connected zones, 3 connected zones here figure b here see with its 3 connected zones, as your bubble up flow but no flow through the clouds and the emulsion. So, we know that we have already discussed that bubbles whenever it will be moving up there will be some cloud region emulsion region. So, assume that here bubble up flow they are but no flow through clouds and emulsion and any interest and only interchange that is K bc; that means, bubble to cloud and K ce cloud to emulsion there will be no inter change there.

So, no there will be a there will be an only interchange of this bubble to cloud and cloud to emulsion but there will be no flow. So, as shown by Kunii and Levenspiel the integrated conversion expression can be written by this or can be expressed by this equation number 9. So, here ln C A0 by C Aex is equal to f b into k triple dash plus this.

So, this equation number 9 is a of that is performance equation based on the interchange of the that is component A from the bubble to cloud and cloud to emulsion there.

And during this flow of this component A from this bubble to cloud and to emulsion there will be several resistance for that during the transfer of the component into bubble to emulsion there. And we will discuss that reaction mechanism for that how that resistance will be acting on that.

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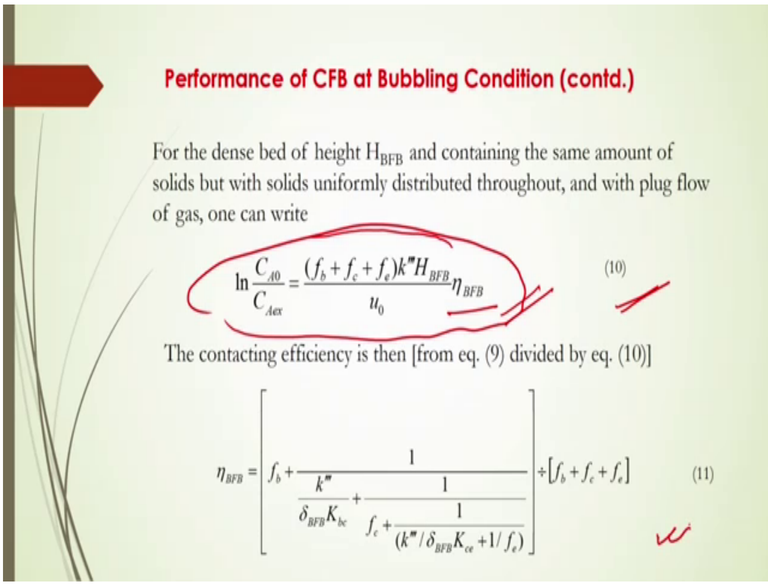

Now, for the dense bed of height H BFB and the containing the same amount of solids but with solids uniformly distributed throughout and with plug flow of gas then one can write the equation number 10 here. So, in this case we are considering that there will be dense bed of height H BFB (Refer Time: 20:32) bubbling fluidized bed, height of the bubbling fluidized bed and the same amount of solids that are containing.

But the solids of course will be uniformly distributed throughout the bed and with the plug flow condition of the gas. In that condition we can write here ln C A0 by C Aex then it will be f b plus f c plus f e. What does it mean f b? f b means of the solid fraction in the bubble phase, and a solid fraction in the cloud phase and the solid fraction in the emulsion phase summation of these all fractions into k into triple dashed into H into BFB BFB divided by u 0 into eta BFB.

So, this is actually if we consider that bubbling fluidized bed are acting as a what is that plug flow condition; that means, 100 percent almost x efficiency or you can say ideal condition then you can represent this equation 10 for this bubbling condition.

So, if we consider if we compare this equation number 10 with equation number 9 here as for that mechanism of transfer of components or interchange of components from bubble to cloud to emulsion by equation 9. Then if we consider this 9 and equation number 10 then you can see what should be the efficiency of the bubbling circulating fluidized bed there, that can be expressed by this equation number 11.

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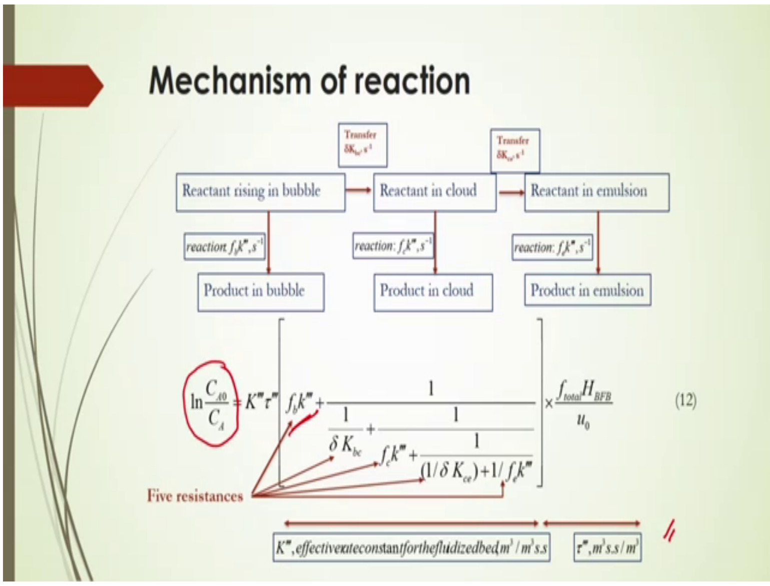

Now, let us see that we told that the mechanism of the reaction that how part of the different resistance that coming during that reaction.

So, here in this case you will see let us see that reactant that rising in bubble they are and whenever it will be reactant will be transferring from the reactor in reactant in cloud then there will be a transfer coefficient of delta into K bc. And then from the cloud to even if we it goes to that reactant in emulsion then the transfer coefficient will be is equal to delta into K ce in here.

And then again the bubble to then in this case whenever reactant will be in the bubble bubbling bubble phase then what should the reaction product; that means, product in the bubble can be represented by this f b into k triple dash here. Whereas, reaction in the cloud and for the product in cloud then the rate will be is equal to f c k triple dash and whereas, the reactant in emulsion to the product in emulsion then what will be the reaction rate here it would be f e into k triple dash.

So, in this case if we consider all these things here reaction in bubble and production product in bubble and also reaction in cloud and product in cloud and product in emulsion and way and considering this transfer of reactant from this bubble to cloud and cloud to emulsion. Then we are getting different resistances like here 5 resistances we can get here. So, here one is this f b k triple dash as shown in this equation by this arrow. So, different 5 resistance we can get here.

So, based on this resistances we can write this performance equation like ln into C A0 by C A this resistance into f total where H BFB by u 0. Here f total means the solid fraction for that whole bed here. Now, k triple dash is the effectiveness constant for the fluidized bed here and tau here a triple dash this is a meter cube per second to second by meter cube here this is the what is that, here it is called that what is the resistance time for that reaction.

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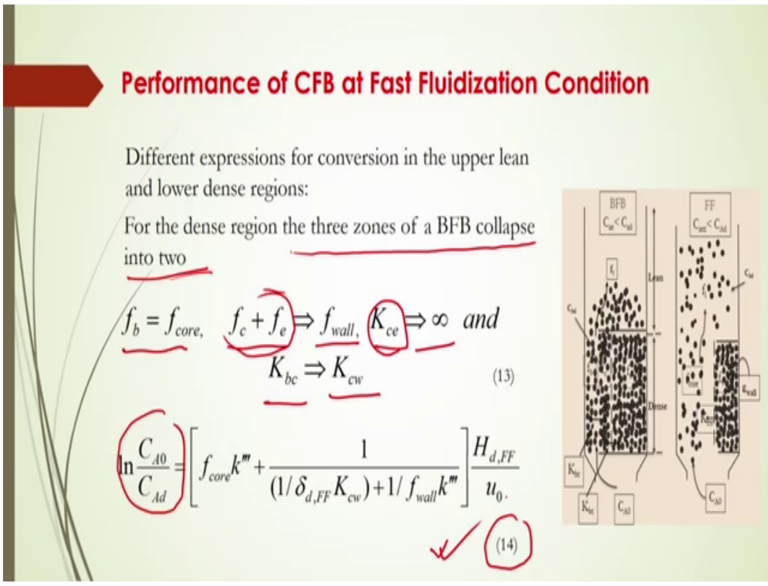

And for the first fluidized fluidization condition if we consider that performance of that first circulating fluidized bed then in this case as per Kunii and Levenspiel different expression for the conversion in the upper lean and lower dense region can be expressed there. And for the dense region and the it is seen that the three zones of the bubbling fluidized bed collapse into two regions there.

So, this is the mechanism as per concept of Kunii and Levenspiel they are it is very interesting that in that case they have observed that for the dense region the three zones of bubbling fluidized bed it will be collapsing into two regions. So, in that case f b should be in the core f core as far figure shown here and f c and f e both will be collapsing to the f wall here and K ce; that means, here transfer coefficient from cloud emulsion it will be infinity and the coefficient from bubble to cloud that will be equals to; that means, here interchange coefficient of component from cloud to wall region there.

So, based on these if we substitute this what is that parameters in the equation then performance equation then you can have this equation 14 for the performance of the circulating fluidized bed for fast fluidizing condition there, and this is expressed by equation 14.

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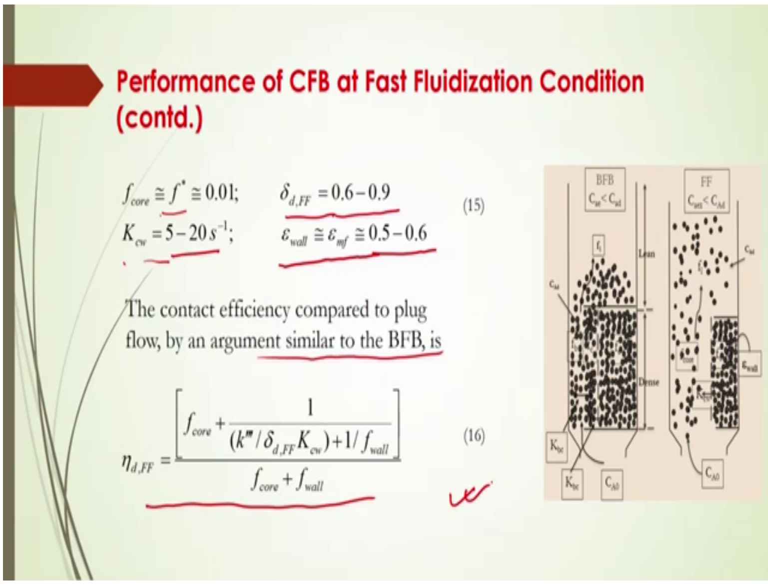

In this case a very interesting that f core should be here f core f b is equal to a f core f core should be is equal to almost equals to that f star that is carrying capacity there, so it will be is equal to 0.01. And delta d FF that will be equal to 0.6 to 0.9 and K cw will be is equal to 5 to 20 second inverse, and of the of solid fraction in the wall region it will be equal to 0.5 to 0.6. This is actually based on the results that is published by Kunii and Levenspiel and it is shown they are in books.

And the contact efficiency compared to the plug flow by an arrangement similar to the bubbling fluidized bed then we can get here the efficiency of this circulating first fluidized bed by equation number 16.

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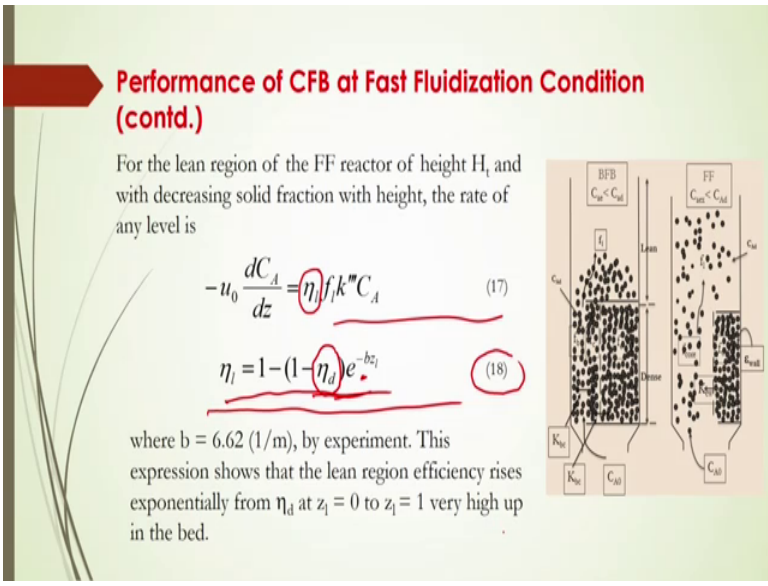

Now, for the lean region of the first fluidized bed reactor of height H t and with decreasing solid fraction with height the rate of any fixed any level rate of ; that means, reaction at any level we can represent by this equation number 17.

And in this case efficiency of the lean region can be represented by this equation number 18, where in this case you will see very interesting that the efficiency in the dense region. It depends on the efficient the dense region if dense region efficiency which is; that means, it is it gives you ideal condition then you will see only the efficiency in the lean region will be here is equal to 100 percent also.

So, in this case here very interesting that never be any what is that fluidization condition obtained in the dense phase region that you cannot get that 100 percent efficiency in the dense region. So, for that the lean region of course the it will be depending on that efficiency of the dense region there, because there will be continuously intermixing of the solid particles and they are the attrition mechanism some solid parts that will be coming out from the what is that dense region and then the dense region will not be exactly the fixed condition and will not perform as a plug flow condition. So, what should the efficiency of that lean region based on the efficiency of the dense region that can be expressed by this equation number 18.

So, what I what then we have to actually calculate for these fast fluidization condition for this for its efficiency. So, you have to know these what is that eta l; that means, what is the efficiency for lean region. So, lean region that will be depending on this and then and also it is seen that this it will be depending on the height of the lean region also.

There is one coefficient called b, b is generally 6.62 by experiment that is given by Kunii and Levenspiel and this expression shows that the lean region efficiency rises exponentially from that is eta d eta d means part efficiency from this dense region at z 1 is equal to 0 to z 1 is equal to 1, and very high up in the bed.

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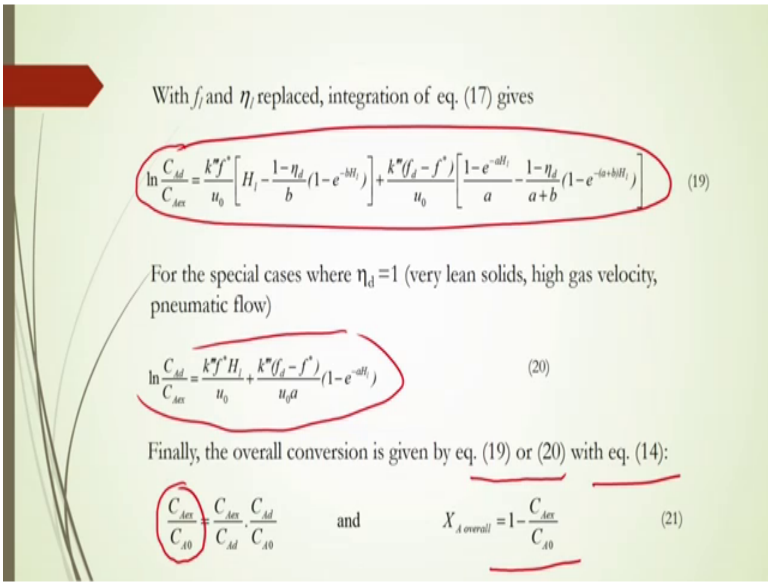

Now, with this f l solid fraction in the lean region and the efficiency in the lean region if we replaced and then after integration of equation 17, one can expressed the performance equation by this equation number 19.

Now, for the special case, where eta d is equal to 1; that means, very lean solids high gas velocity and pneumatic four flow in that case you can say that equation number 20 will give you the performance equation of this; that means, fast fluidized bed condition of the circulating fluidized bed. And finally, the overall conversion who should be given by this equation number 19 or 20 with the equation number 14 that can be represented by this C Aex by C A0 that is equal C e; C Aex by C Ad into C Ad by C A0 and X will be is equal to 1 minus C Aex by C A0. So, in this way we can represent this what will be the conversion of that reaction. Once we know that exit concentration of the component in the fluidization condition at a different of different flow patterns.

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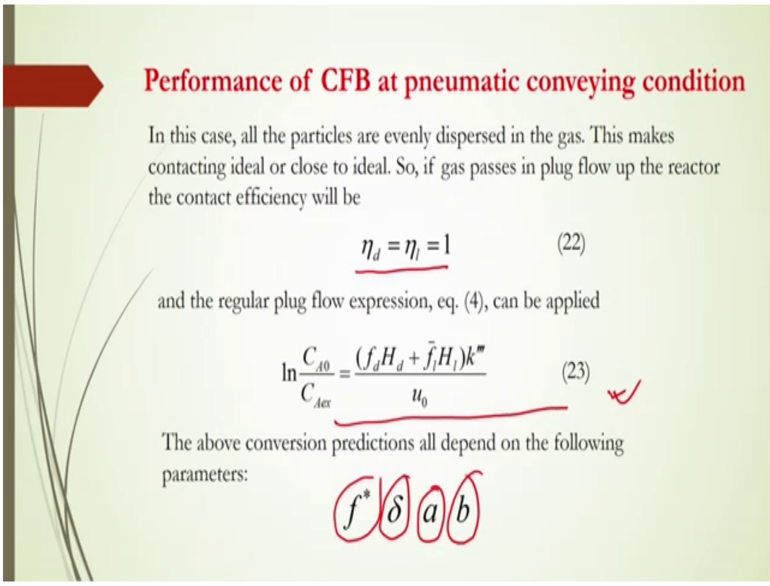

Now, in case of pneumatic conveying condition you can consider that the eta d and eta l should be is equal to 1 and if you substitute this equation then we can get this equation number 23 for its performance equation.

Now, for the regular plug expression equation 4 then can be applied here now the above conversion predictions all will be depending on the following parameters like f star delta a and b value. See these are parameters once you know these parameters of f star delta, delta means bubble fractions they are and a and b are the that is decay constants and they are based on the equations there earlier shown.

So, if you know these equations then it is easily possible to calculate what should be the performance of the circulating fluidized bed.

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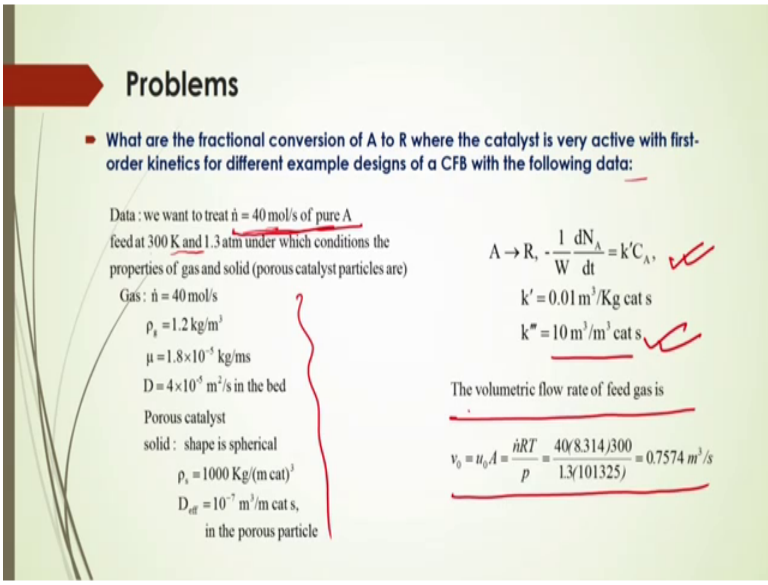

Now, let us have an of problem here let us let what should be the actually fractional conversion of A to R, where the catalyst is very active with first order kinetics for the different examples of designs of circulating fluidized bed with the following data here.

Here some datas are given here in dot is given here suppose this few component is transferred at a rate of here 40 moles per second and at 300 K and 1.3 atmosphere under this condition of fluidization then what should be the fractional conversion A to R at a different fluidization condition that you have to find out. And some here datas are given as per these.

So, in this case, the reaction condition is given like this the reaction constant here it is given that a k triple dash is given 10 meter cube per meter cube per catalyst surface and the based on this data the volumetric flow rate of the feed gas is 0.7574 meter cube per second volumetric flow rate. So, based on this data let us see what are the different performance or conversion performance of the fluidized bed.

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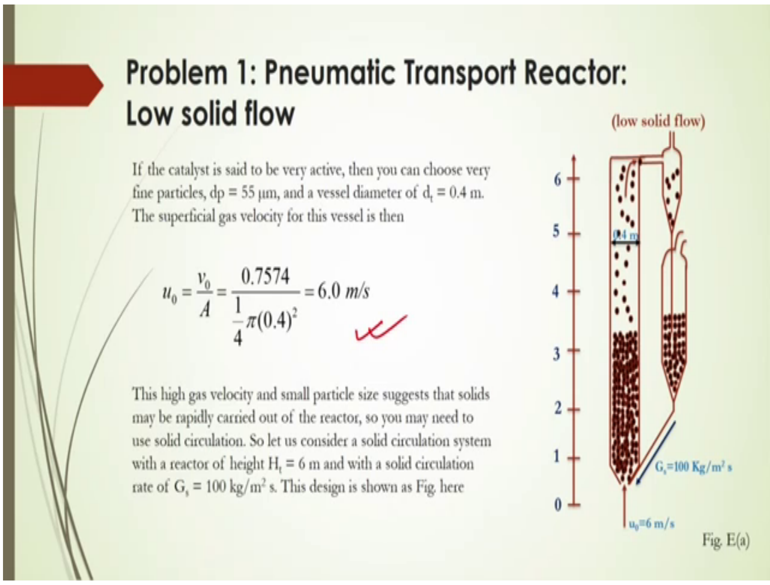

Now, if we consider that pneumatic transport reactor for the low solid flow, it is seen that if the catalyst is say to be very active in that case then you can choose very fine particles where particle diameter is 55 micrometer we are considering. And a vessel diameter of here let it be 40 centimeter, and then superficial gas velocity for this vessel can be calculated what will the volumetric flow rate by cross sectional area and it will be coming at 6 meter per second.

Now, in this case this high gas velocity and small particle size sometimes will suggest that solid may be rapidly carried out from the reactor and so you may need to use solid circulation. So, in this case let us consider a solid circulation system with a reactor of height here in this case a height of 6 meter and with the solid circulation rate of here related be 100 kg per meter square per second.

Then the design of the circulating fluidized bed for this pneumatic transport condition will be like this here. Let us see what will be the different flow pattern and design different what is that velocity and also what is the conversion there.

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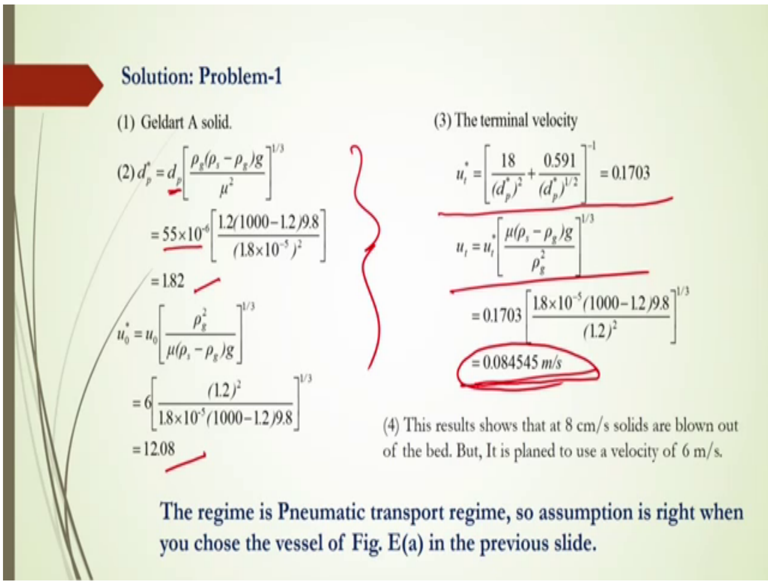

So, if we consider that Geldart, a type solids they are and particle diameter of star here it is here d p star as per calculation d p star if we know that d p here 55 micro meters, then d p star will be 1.82 and then u star again if you know the u already it is given u here. So, if you substitute here you will get that u star as per that what will be the terminal velocity because these are these are the equations which will be required for the calculation of terminal velocity of the solid.

So, finally, this terminal velocity of the solids will be calculated by this equation and once you know this terminal velocity after substitution here this 0.084545 meter per second. What does it mean here? This terminal velocity of the solid is this solid this result. So, that this 8 centimeter per second solids are blown out of the bed here.

So, in this case but it is planned to use a velocity of 6 meter per second, 6 meter per second it is too high. So, the reason is pneumatic transport of course, so assumption is right when you choose the vessel of like here shown in this case in figure a then you can say the previous slide here it is shown that is figure. So, the assumption is almost correct here that ok, the velocity is high enough to this terminal velocity.

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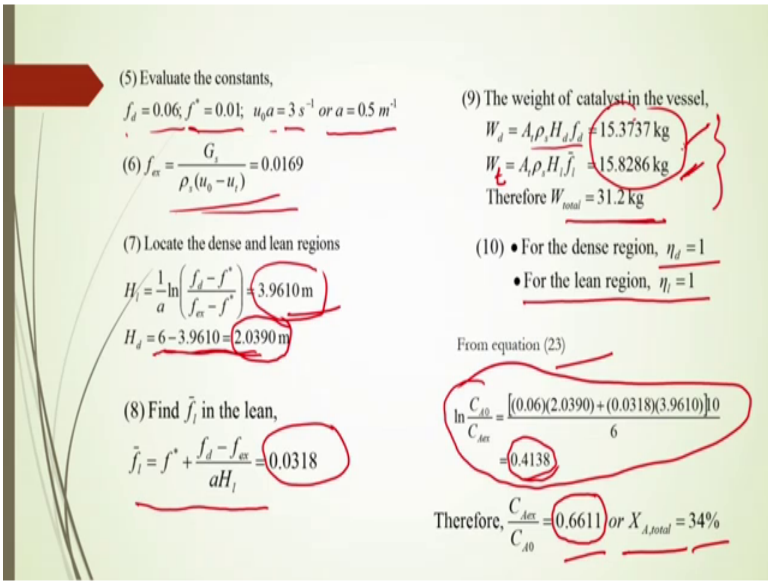

Now, if we evaluate the other constant like f d here it is given 0.06 and f star is 0.01 and u u 0 a is 3 centimeter sec that is inverse then, what is that a that is decay constant will be is equal to 0.5 meter inverse. So, all this decay constant how this decay constant will be depending on the velocity already we have discussed earlier. So, the derivation is not given in this lecture but we have already discussed about all these things how to calculate these decay constants there.

So, once we know that decay constants here from this velocity then we can calculate what will be the exit concentration of the solids they are in the bed that will be calculated by this equation. The exit concentration will be is equal to 0.0169. And after that what you have to do you have to find out what will be the location for this dense region and lean regions.

Now, dense region will be represented by H d and dense region lean region will be represented by H l, H l should be calculated by this equation here and it is coming after calculation this 3.69 whereas, H d total from the total bed height that is 6 meter if you subtract this H l from this total height of the bed then you will get the dense region here it will be almost equals to 2 meter there.

And after that you just find out what would be the average solid fraction in the lean region. So, it will be calculated by this equation here shown and it is almost equals to 0.0318. After knowing this f l bar; that means, summarize solid fraction in the lean phase and the height of the lean phase, height of the dense phase, and the exit concentration of the solid from this bed and then once you can obtain what should be the weight of catalyst in the bed there. So, weight of the catalyst will be represented by this here simple what is that the volume into a volume fraction of that dense phase there and solid.

So, A t into rho s into H d into f d. This is your that means, weight of the solid in the dense phase, and weight of the solid in the lean phase that will be is equal to this then here a total weight will be is equal to summation of this two. So, it will be is equal to total weight of the solids will be is equal to 31.2 kg.

So, for the dense region you can consider that it has will be equal to 1 whereas, in the lean region it will be if it is plug flow condition then eta l will be equal to 1. So, from equation 23 then we can calculate what will be the performance there or you can calculate whatever the exit concentration by this equation and then you will get this ln C A by C Aex that will be is equal to 0.41 and from who is you can calculate what the C Aex by C A0; that means, what are the exit concentration to the initial concentration ratio that will be 0.66. So, once you know that then what will be the X A; that means, conversion of that A in the reactor that will be coming as 34 percent here.

So, this is one example how to calculate the conversion efficiency of the pneumatic transport circulating fluidized bed by this method.

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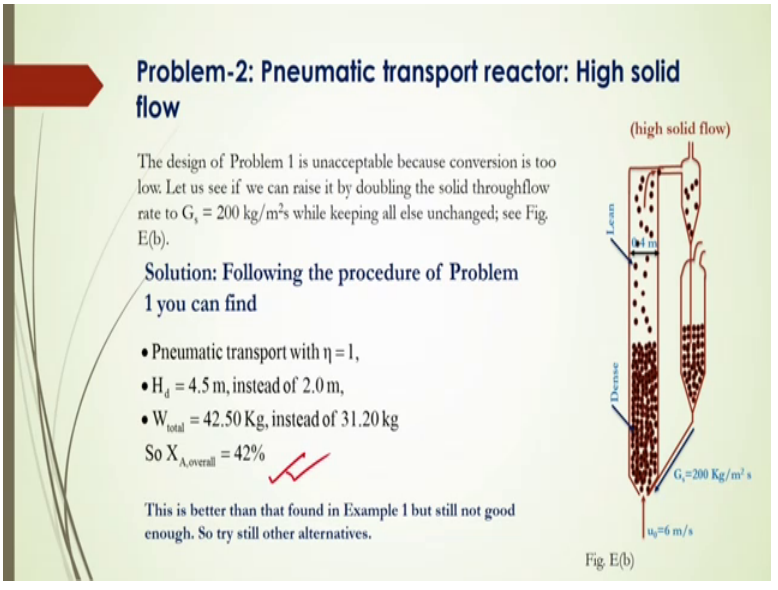

Similarly, for high solid flow if you consider that solid plug is 200 kg per meter square second instead of 100 kg per meter square second then you will get this solid fraction is 42 percent. So, in this case you are getting better performance of this pneumatic transport reactor if we consider that higher solid flow rate.

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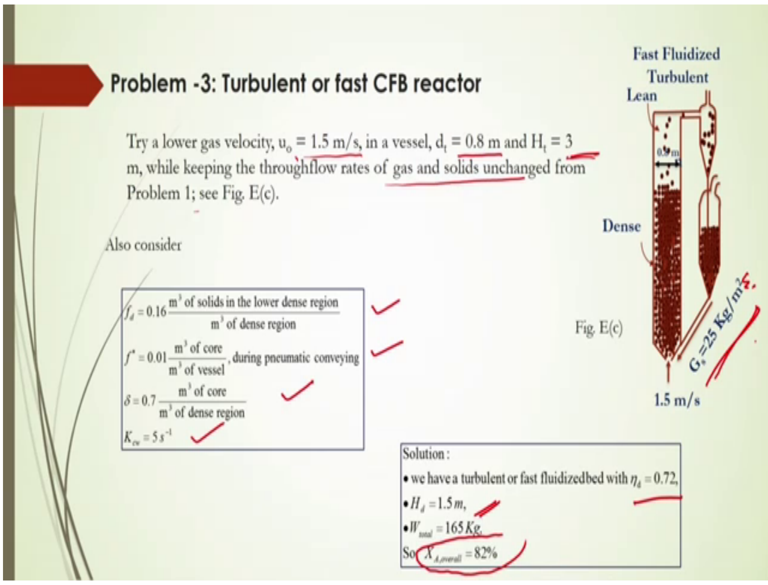

But in case of turbulent or first circulating fluidized bed reactor, if we consider the gas velocity as 1.5 meter per second and in a vessel of diameter 0.8 meter and height is 3 meter then what should be the performance of the reactor. Exactly the other gas and solid flow rates will be keeping constants as per problem 1, then that case f d should be equal to these, f star is equal to this and delta will be equal to this case c w is equal to this.

So, if we know all these things and go we if we go the procedure of the calculation for that previously what we discuss and then we can get the eta d will be is equal to 0.72 and height of the dense region will be is equal to 1.5 meter whereas, the total solid catalyst can be all c or can be also calculated by this equation number here or whatever earlier shown by this equation and then we can say this will be the total solids of 165 kg here.

So, overall conversion will be is equal to 82 percent. So, in this case for this certain gas flow rate or gas velocity of 1.5 meter per second and the and tube diameter or you can say a bed diameter of 80 centimeter and what is that height is what is the 3 meter then you can get this efficiency of the turbulent or fast circulating fluidized bed as 82 percent there.

In this case very interesting that the solid that is flow rate will be 25 kg per meter square second. So, this is called mass plugs of the solid, so this mass plugs will be maintained here. So, based on this data we are getting 82 percent conversion.

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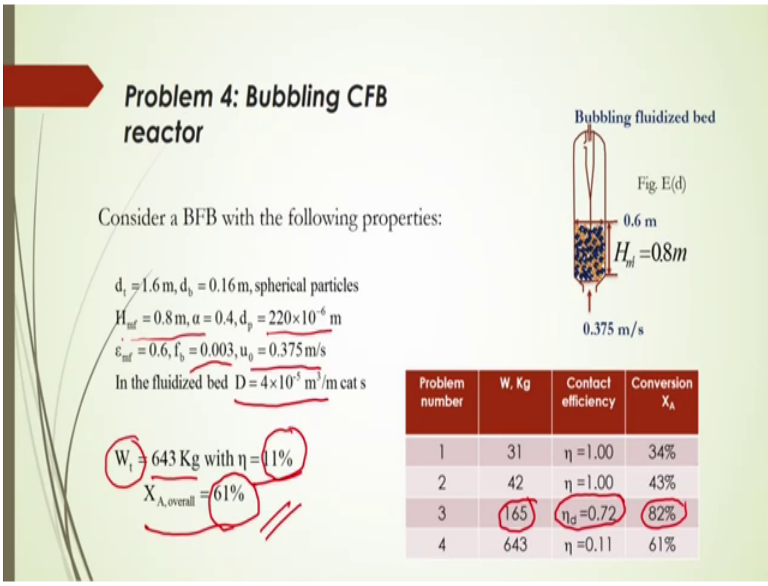

That is in the bubbling fluidized bed if we know that that cube diameter and bubble diameter is there, and also that minimum fluidization height and the porosity and also gas volume fraction and the particle diameter minimum porosity and also part of the fraction of solids in the bubble phase. And if we know the gas velocity; that means, they are in the bubbling fluidized bed. For that we have to know also what should be the diffusivity of the what is that bubbling fluidized bed of the component there.

So, after again the calculation procedure here this it is seen that the total weight of the solid in this with efficiency of the fluidized bed as 11 percent and conversion is 61 percent there. So, within that; that means, the similar fashion calculation you will get this type of conversion and if we change that what is that weight of the solid; that means, mass flow rate of the solid inside the bed then you will see you will get different efficiency of the column, contact efficiency of the column, and also the conversion of the column in the bubbling fluidized bed.

And it is seen that if the weight is 165 and the dense efficiency, dense bed efficiency in the fluidized bed is 72 percent then it is seen that 82 percent conversion can be possible there.

So, there may be other combination of these solid mass plugs and also the height of the bed and lean phase, and also bubble burst size and other what is that fluidizing condition of the bubbling phenomena then you will get different contact efficiency and the conversion efficiency there.

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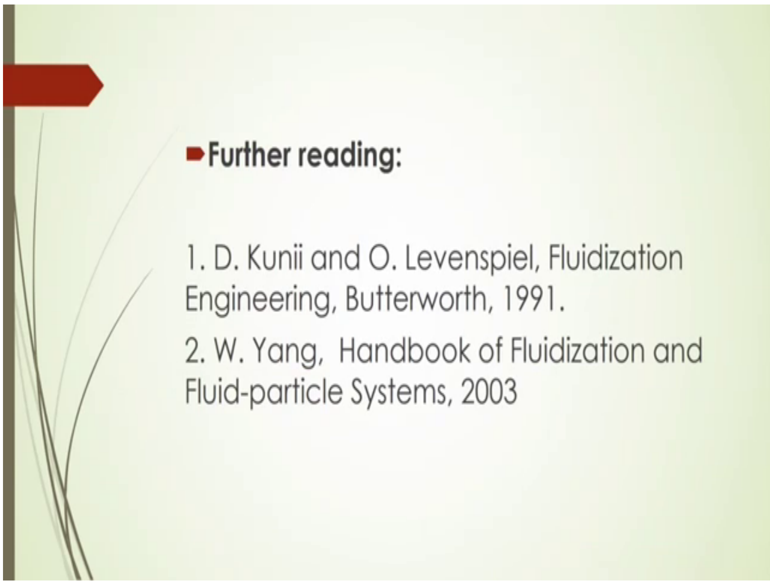

So, here in this lecture then we have actually discussed about what should be the performance of the different circulating fluidized bed based on their flow patterns. And the equations for this performance calculation it will be used for calculation of that performance for these different flow patterns fluidized bed you can calculate it with the different operating conditions also, and you will get different performance of the fluidized bed.

So, all these performance depends on that different hydrodynamic parameters like here in this bubbling fluidized bed bubble size also you will see the solid mass plugs, even entrainment characteristics, even what are the components that you are get by using and also what will be the diffusivity of that component in the gaseous medium in presence of solid and also what with the size of the particles that you are being used then you are using then what should be the performance for different particle sizes. And also if you change the diameter of the bed how it will be changing this performance you can calculate based on the performance equation given in the slides.

So, I think these solid axial will be helpful for calculating the different performance equation like conversion like what was the solid mass to be actually loaded in the plugs, and what will be the mass plugs of the solids to be maintained, and what will be the diameter what will be the particle size, what will be the bubbling bubble size. So, that you can get the optimum conversion of the solid particles and based on which you can also design the fluidizing fluidized bed.

So, I think this will be helpful for getting the fundamentals of or understanding or calculation procedure for the design of bubbling fluidized bed or any other fluidized bed with different flow patterns. So, you can go through other references like this textbook for Kunni and Levenspiel, and Yang that is handbook of fluidization and fluid particle system to get more information about this.

Thank you for this lecture.