Chemical Reaction Engineering 2 (Heterogeneous Reactors)
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Lecture 41
Continued (Davidson Harrison Model and Kunii Levenspiel Model)

Okay, so yesterday we have discussed about this fluidized bed and bubbles in fluidized bed. Now I gave you this, okay. You take in this the first figure. Can you see the first figure? Give them. Please see the first figure. What do you see first figure? First figure is small figure put on side. Yes, did I draw this figure on the board? Yes, I have drawn this figure you know yesterday on the board but he has drawn the actual lines later which will also predict those points, okay.

So this is more informative than yesterday what I have given because yesterday I want pose the problem. But in this, solution also is given. You can see the top most line and top two lines in fact. What are the top two lines? For small d P. Small d P means what kind of bubbles you get? Very small bubbles particles, okay. You know delta A particles, okay. Small bubbles and more number of bubbles. So they move much faster, okay.

And so if you analyse this in terms of large diameter and small diameter of the particles which will automatically take care of your bubble size then you can also predict whatever we have discussed yesterday, okay. So that is figure 1. Figure 1 I think you know what we have done and as I told you see there he has written also 39 experimental studies. So without bubbling model we do not know how to predict that because they are all over the graph, okay.

So now with bubbling bed model that means you know when you take the bubbles into account then we can try to predict. That is what we have to derive now, the bubbling bed model, right? So for that that is the first figure and what is second figure? Second figure is just a picture of how the fluidized bed looks like with bubbles, okay. You can see lot of information is there on that.

If you see that you know that row of bubbles just going up you have small bubble, while it is moving up you know it grows and when it is growing its wake also is increasing. That means it is taking more and more particles along with it to the top. And once it goes and then breaks there you see there is a thick arrow. Yes, those are the solids. U s is given there if you look very carefully. U s is the solid velocity which is coming down, right?

So the general assumption in fluidized bed is that there is a continuous movement of solids in the fluidized bed where particles are taken by the bubbles in the wakes and then they go, leave the solids there because something is going from the bottom, to fill up that gap something else have to come, okay. So that is why recirculation for solids and then you will have good mixing because of the bubbles, right?

And if you do not have good mixing the beautiful property of same temperature same concentration will not be there for fluidized bed. So that is the reason why you know that is the basics again. We are talking about basics whenever we talk about these things you know. Our basic thing mixed flow reactor is we should have same temperature same concentration in a mixed flow reactor which is equivalent to our fluidized bed reactor. So that is that figure.

And figure 3 if you see that is the actually if you take one bubble what is really happening in that one bubble and before understanding that bubble, okay, that figure 3 you can come to figure 4. This is what yesterday I have explained to you, figure 4. The first one is you know out of the six figures the topmost top row first figure you have u b r equal to zero. What is the meaning? They are stationary bubbles. They are not moving, just going there and the gas in the emulsion at minimum fluidization velocity is simply going through the bed.

Bubble is stationary there, right? So as I told you yesterday this gas will use this bubble as a short circuit and then it will try to go through that. See that these are the stream lines which are going through that. These are the gas stream lines, the arrows which are going through that, right? And now you see if the bubble started moving not u b r equal to zero first one. U b r not equal to zero second one. In fact u b r by u f equal to point 6. You see now how the streamline are taking turns.

And one of the streamlines at the edge of the bubble is already circulated, okay. So now you see when u b r equal to u f, the next figure that is u b r equal to u b r by u f equal to 1. There the gas already started recirculating but still there are no clouds, right? Even at u b r equal to u f still there is no cloud there. You could observe no. That you will observe in the next figure. When u b r equal to 1 point 1 u f, just 1 point 1 u f you can see the cloud forming, okay.

You can see the cloud forming and Davidson has also derived an equation for calculating cloud radius. R c by r b whole cubed equal to you have u b r and u f, those two velocities. U f is u m f by epsilon m f, okay. That yesterday I have written there. So that is how the cloud comes. And when the bubble velocity is increasing now you see in the next figure u b r is 7 times u f. If u f is 1 centimetre per second, u b r is 7 centimetres per second.

That means bubble is going much faster so it will make more of the gas circulating within the bubble and also cloud reduces. And you see u b r by u f greater than 100, cloud thickness is almost zero. So that means most of the gas now started recirculating, please carefully observe, within the bubble itself. So when most of the gas is started recirculating within the bubble where is the possibility for the gas to come out and then react with solid?

That is the reason why you have gone to that worst even above mixed flow because absolutely no contact between the solids and then all the gas is going within the bubbles. And particularly when you have the flow rate through the bed is maybe 100 times u m f, 50 times u m f, 60 times u m f. Actual bubble velocity is 50 times to 100 times u m f. Then the bubbles will go much faster.

Then you will have very thin clouds but most of the gas is circulating within the bubbles itself so absolutely there is no contact between the solids and the gas. So that is the reason why there is no reaction at all. Yes?

Student: Circulation of gas.

Professor: Yes, that is true. That is happening. But when you go to the last figure cloud disappeared. So most of the gas is only circulating within the bubble.

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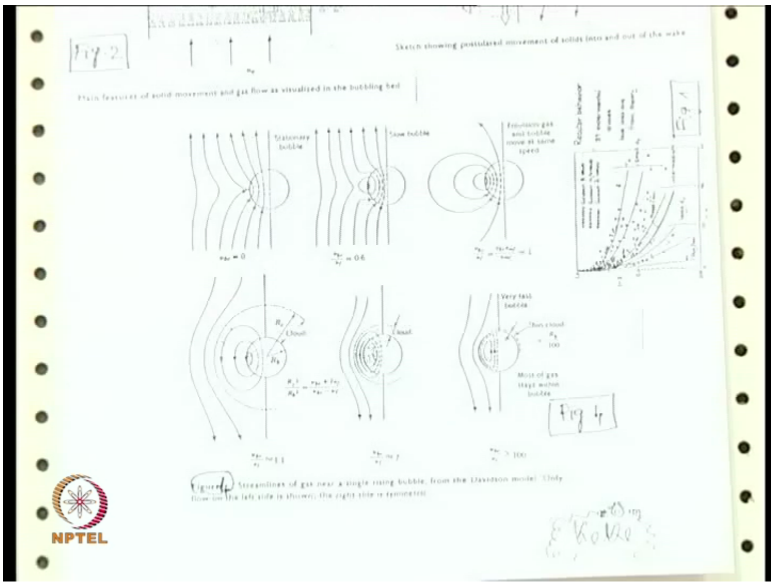

That is worst scenario.

Student: In reality how can you see the boundary of the bubble and the cloud? What is there in the cloud exactly?

Professor: Cloud is gas, sorry not cloud. Bubble is gas, cloud is particles.

Student: Particles in the cloud are different from the particles?

Professor: They are slightly different because the bubble is just moving. When it is just moving, the particles are there just on the roof, right? So whatever particles which are not falling through down, okay, and when it is just pushing, those particles if you see the local voidage, that will be slightly smaller than the outside, okay. That is the only difference. And you can see that one because you asked very good question. See the next figure next side, figure 5. That is the actual bubble that was taken by photograph.

You see all other places slightly you know you have that dark area, right? And then yes around that you have more dense particles and away from that is slightly less dense particles. And another beautiful thing what you can see is you know the wake. How the solids are going with the wake? See Davidson theory was beautifully measured also with experiments. And can you see the next one. Next one means 5 b. Those are the streamlines in fact, okay.

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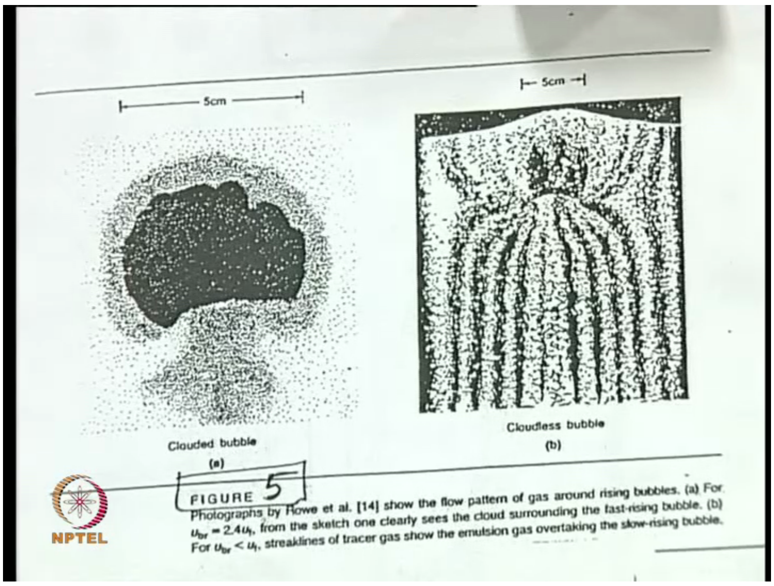

So in fact this is one of the greatest you know I think I say discoveries in chemical engineering with respect to fluidized beds. Really beautiful that theory, Davidson, okay. And of course Davidson and Harrison these are the two people. I think I have to just write that also. These are the two people from Cambridge University who have done this but the first person is Davidson alone has done lot of work on the bubbles, okay.

If my remembrance is correct I think Davidson was mechanical engineer I think but he liked so many chemical engineering problems he shifted to chemical engineering and first started doing work on gas liquid systems. I think he was working in ICI if I remember correctly and then you know he developed some bubble columns for ICI at that time. I am talking about 40s and 50s. And this theory is mostly by 60 to 67 we have thorough theory for even gas solid system bubbles.

He knows liquid gas system, okay. That is normal all of us know how the bubbles go in the liquid, okay. That is everyday phenomena for us. When you are taking any drink, okay, so you can see how the bubbles come up and when you see any aquarium you can see lot of bubbles coming up, so all that. But we never get excited you know when the bubbles are coming because I think maybe we look at only fish, when I can eat that fish, okay. And we are losing the beautiful part of the bubbles which is very important for us, okay.

So that is the reason maybe we never bother. But I think he has done lot of work and then afterwards he extended the same theory with some assumptions for the bubbles in solids. And many people did not believe. Even now many people do not believe that there are bubbles in the fluidized bed. But if you come to our lab I can show you, okay. Yes, I think ask Gunjan when he has removed the packing and then he can show beautifully the bubbles how they are coming.

And some of the bubbles will crawl near the surface where you can see, right? And this photograph was done with two dimensional column. Two dimensional column means they take just two plates like this, okay. And then bottom there is a distributor plate.

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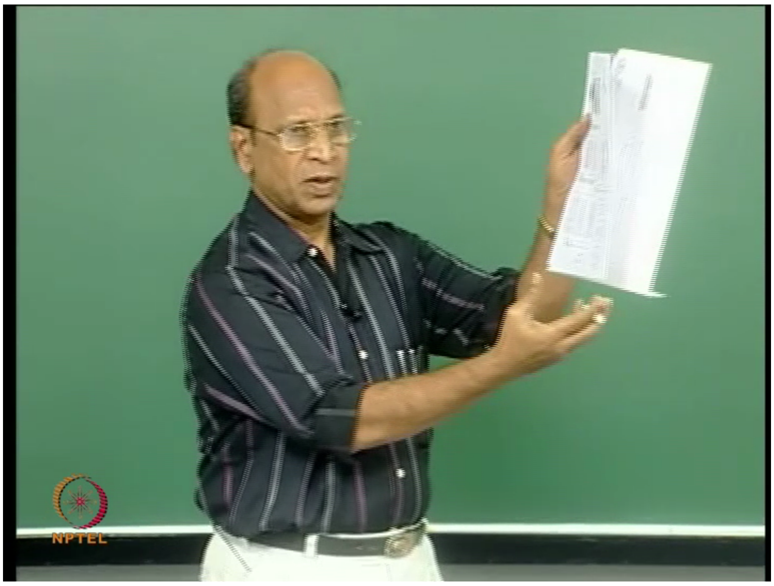

They inject one bubble. When that bubble is moving slowly then of course they can control that (mo) movement with slow injection and then this photograph is taken when this bubble was slowly moving, right? I mean it is beautiful no. I think sometime back this PhD students used to conduct quiz. I only pushed them. And I was HOD I think. So they used to three years they conducted this quiz for chemical engineering students. Including B Tech they used to come but PhD students I asked them to take the lead, okay.

So in fact faculty members gave different questions, I gave this as photograph and asked the students to identify what is it, okay, only without writing anything just this photograph and then showing. I think just one or two people said atomic bomb, okay. Correct. Yes it is really atomic bomb as far as fluidization is concerned because if you do not understand this we do not know anything, how to characterize fluidization at all, okay. Good.

So this is the one and now yes you see this side all the figures we have explained, right? Yes and if you see now figure 3, please go to the other side. Figure 3 now and I told you after figure I will come back. So there it will give you more clear picture about how the solids are moving even in the clouds or how the solids are moving slightly away from clouds and how the recirculation of gas is taking place. You know at least physics you please remember I say. Physics please remember.

The inefficiency of the fluidized bed is due to the bubbles where fast moving bubbles will not allow gas to come out of the bubbles. So that there will not be any contact between the solids and this gas. So then where is the reaction? The other part of the bed, the amount of gas going is very small. I told you if normally in the industrial reactors we use 20 times 30 times 40 times u m f. But how much gas is going through the emulsion, the other part of the bed? Only 1 u m f, right?

So that is the reason why very small amount of gas is going through the solids and you not have much reaction because there should be more concentration. See the rate of reaction depends on concentration of gas, amount of gas, okay. So when most of the gas is going in the form of bubbles very small amount of gas is going through the solid that is emulsion. Where is the reaction? You do not get that kind of high reactions, okay.

So that is the inefficiency in the fluidized bed and that is why people you know try to do that I told you no shallow beds can be used for example. That means where there is no time for the gas bubble to form, grow and then move up, right? So shallow beds means if the diameter is 1 metre, you take only half metre height, okay, half metre height solids. So then you will not have this kind of big problem. You will have still small bubbles coming and going very quickly out but I think they will not destroy the bed so much.

Some people started shaking the bed because by shaking the bed you may also have bubbles. Bubbles not forming at the distributor plate itself. I told you how these bubbles may be forming is you have one perforation, the gas will try to go into that. It is not able to go because lot of solids are there then it slowly started pushing the solids. Like when you want to go through the crowd what do you do? You push all the people there a little bit forward, okay.

So that means you are creating a void when you are pushing them for you to move. So that is what gas also is trying to do. When it is trying to do then at one time it will form sufficient volume where by buoyancy it will detach from the perforation. From then onwards it grows. So by shaking your perforated plate or the entire column what is happening? You are not allowing that kind of you know the gas pushing the solids is not happening, okay.

So that is what some people did and some people did that, okay we will take the large height of the beds but put distributor plates in between for example (())(16:39), okay. So idea is bubble at the bottom will grow and then come and hits the (())(16:48) in between so it may break and again another bubbles may form. But at least that bubble is destroyed. So, all these techniques also have been done to improve the performance of fluidized bed, okay. So that is the one. So if you go to the next page.

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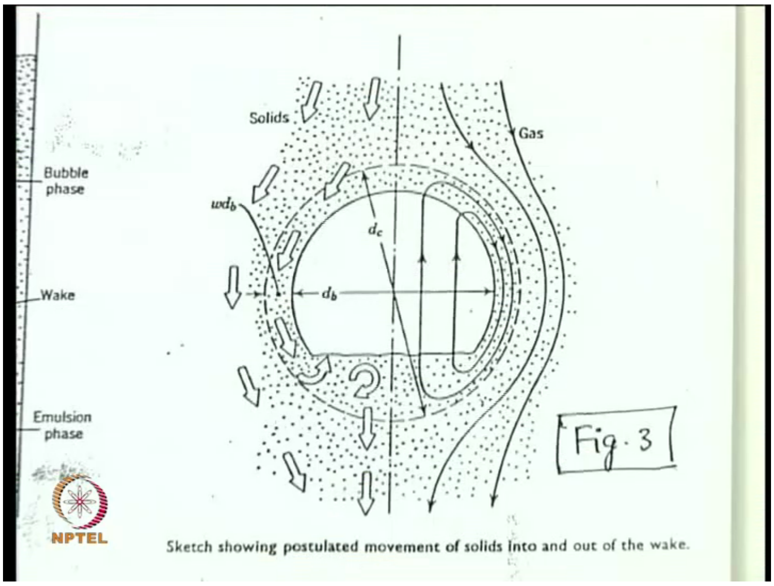

Yes figure 6 is same thing what we have done earlier also that means you know how slow bubbles the gas is bypassing through the bubbles for slow bubbles. That is the right hand side of figure 6 and left hand side what you have is bubbles going faster so circulations are within the bubble and within the cloud, okay good.

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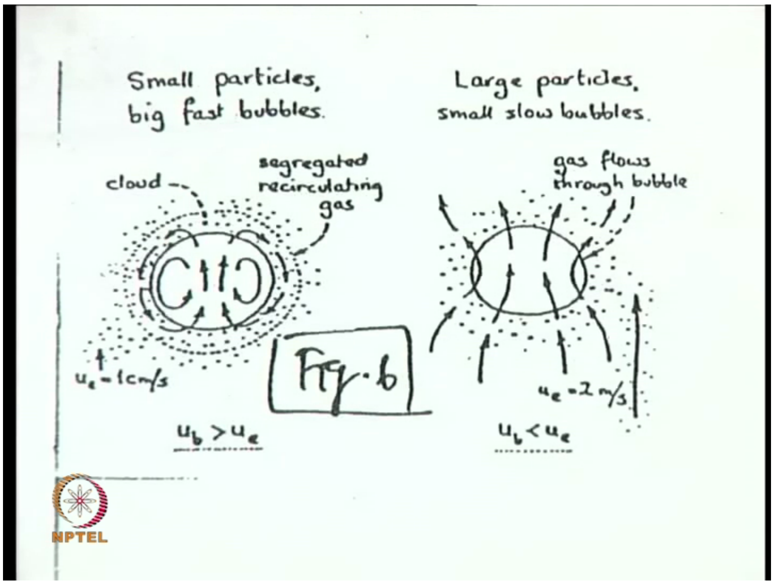

So then figure 7 now is the picture for the bubbling bed model. In fact Davidson Harrison what they have done was that they thought that bubbles and solids they have separated like our two phase region. The other day I have drawn that two phase region model, okay. That model they have followed, right? So with knowing clearly how much is there in the clouds and wakes and all that but they consider clouds wakes everything in the solids. Only bubbles are moving.

Then they also proposed a model which was not very good in the prediction wise but they never accept that. In fact Cambridge University people never accept Levenspiel model, okay. There are two groups in the world. One is that Cambridge group, another one is this Kunii Levenspiel group, okay. Kunii Levenspiel model.

This is Davidson Harrison model that is two phase model and this one, two region model and this Kunii Levenspiel model is three phase model or three region model where they have taken separately bubble phase and they have taken wakes and clouds where definitely there is more contact, right? When compared to the emulsion in this region there is more contact of gas with the solids because they are moving with the entire gas, okay. So that is another region and from there it goes to emulsion.

Now if imagine the first thing what I have told you in the beginning, how do you develop this rate of a reaction for heterogeneous systems, okay. You write all the steps together, right? Now here step 1 is the bubble gas, if there are solids there is some reaction in the bubble. Then transfer of this gas to the clouds and wakes because those are the nearest ones, okay. So then this transfer that is mass transfer to the clouds and wakes now because there are solid particles reaction conditions now there is reaction in clouds and wakes.

Now whatever gas is left further it will be transported to emulsion and from there it cannot go anywhere. It has to react under steady state conditions. You see but here beauty here is this is parallel steps and also series steps. Series and parallel steps both are coming here. What are the series steps? Series steps are mass transfer steps from bubble to mass going to the clouds and wakes, from clouds and wakes to emulsion. Parallel step is in all these things the reaction going on in bubbles, reaction going on in clouds and wakes, reaction going on in emulsion.

So that is the overall concept of this entire bubbling bed model. So then it is only mathematical details, okay. And you have to really excuse me here in the sense that I am going to write some parameters for finally writing bubbling bed model but some of the parameters actually takes one or two chapters in those books for the derivation, okay. But we have to blindly accept that, right? Thinking that they are now very well established.

I am not cheating you but they are very well established but definitely I also agree with you that if you have a physical feeling there for that equation, the pleasure is different, okay. That is what I say. Really you enjoy only when you have the physical feel for the problem what you are doing. And some of the classes you may enjoy because you think you have understood. You are also part of the phenomena. Then only you start enjoying that. But for that much effort is required from your side.

It is not only from teacher side, okay. I mean teachers also can kill your enthusiasm. If everything is confusing to you then definitely you will try to understand in first 1 2 weeks and if you are not able to follow anything switch off. What switch off? Brain, okay. Till now it will be open, the moment you enter the classroom switch off. You will be laughing you will be enjoying and all that. That is different but still it is lock, okay. So when after class is over, go and again switch on the brain so nothing will go.

I mean exactly it is two way you know reversible reaction. If teacher is lousy also can kill you, if you are yourself is not interested in learning then that also can kill you, okay. So that is why I mean all my teaching is always to try to bring at least one more person for interesting side. That is all one more, in every class one more one more one more, okay. I do not have 40 people now here. I would have taken 40 classes, okay. So that is the model but let us now take, I am sure just now temporarily.

Student: Concentration in gas inside the cloud is also uniform.

Professor: Yes.

Student: (())(22:29)

Professor: No, in the direction where it is going, okay, what they have taken is they have taken one slice in the bed at any one cross section and then you write the balance here. That balance is I have one bubble, the bed height is so much. In between you take thin slice because along the height of the bed we have to integrate anyway. So d z you take and then write the balance for this that is if there is one bubble there in that slice so the reaction is going on in the bubble.

If there are solids, people found that there are very small number of solids. Sometimes you can neglect, sometimes you can also add. It is not going to change the value that much, okay. But normally we will add to see. So reaction, then transfer to the clouds and wakes in the same level, horizontal direction. Why it has to go? Because there is concentration gradient.

Student: According to this there is only.

Professor: Which figure you are referring to?

Student: Figure 9. So there is a different concentration in the emulsion and a different concentration in the cloud. But there is no concentration difference within the cloud.

Professor: Within the cloud we do not expect. Sorry within the cloud yes c s is no it is not. Assumption is that you have uniform concentration throughout the cloud, right? Not only cloud even in the wakes, wakes and cloud. Yes and emulsion there is only one concentration and in the bubbles there is another concentration which is c a b.

Student: (())(24:09) The cloud radius is comparable to the bubble radius.

Professor: That is slow bubbles. Which figure you are referring?

Student: In that the valid assumption is that the concentration inside the cloud would be equal.

Professor: Yes, see the validity automatically comes when you have the experimental data being verified there, right? Even then this is not perfect model I tell you. There are still many assumptions in this. When you derive the equations which I am going to derive you will have hell and what is that finally we are trying to do? There are many assumptions. But with all those assumptions figure 1 if you see I think figure 1, the side figure, there is small figures side.

Yes, that one. You see the first line that is predicting for the small diameter particles. You see how much scattering is there around that line. Those are the actual experimental data, okay. So that is why there are assumptions. You may feel that yes there may not be uniform concentration throughout the cloud, okay. So but you cannot do better than this. That is why this model is accepted and any delta x improvements you can always do with more and more mathematics, okay. Any other questions?

And the figure 10 where the equation is there that will only I think you know Levenspiel has used same thing only but the bases have been changed. So this equation we are not going to derive. I think other equation we are going to derive that equation which you have to use if it is given in the examination, okay. That is the equation. So this equation is from his old book and in the recent 3rd edition where you have the book, 3rd edition Levenspiel.

So I cannot use this equation because I think if you want to go through the book I better draw that particular equation, okay. So that is the reason why except that all the other figures are valid for our discussion, okay. But you will get very similar one but only thing is that material balance is not proper because you know here he has used the balance based on volume of the bubbles all the time. I told you rate of reactions can be expressed in various ways for heterogeneous systems.

Weight of the solids, volume of the bed, volume of the bubbles that is voidage, so all that. But here it is volume of the bubbles but in the book he has used volume of the bed. That is why there is an extra factor coming delta. Delta is the fraction of bubbles per unit volume of the bed. So that is the way that equation will be slightly different, format exactly same thing. Same format you have but terms will be slightly different, good okay.

So now I am sure you think that you have understood but you may not remember after sometime, right? So that is why let me give some notes at least for those people I think you know who want to read again. Before the examination and all that at least this will be there. You are not lost totally unless otherwise you read the fluidization book or Levenspiel CRE book edition 3 where he has beautifully summarised also, right? So it does not mean that you know do not take this and only go and read that, okay.

So but please write. One small writing nothing will harm you. Your health will be perfectly okay by writing this thing what I am going to tell you. But still if you read it is fine. So hydrodynamic model, the discouraging results, you can just write just below that. The discouraging results with the previous approaches, what are the previous approaches? You can write if you want. One parameter model, RTD model, CTD model, two region model, that is in the bracket, okay.

Let us reluctantly to the conclusion that we must know more about what goes in the bed if will develop a reasonable predictive flow model that is hydrodynamic flow model, okay. In particular we must learn more about the behaviour of rising gas bubbles since they probably cause much of the difficulty.

Next Para you can write, two developments are important in this regard. The first one is Davidson remarkable theoretical development and experimental verification of the flow of gas in the vicinity of a single rising bubble in a fluidized bed, okay. Yes, from where, the flow in the vicinity of a single rising bubble or before that? Okay, I will read from the beginning.

The first is Davidson remarkable theoretical development and experimental verification of flow of gas in the vicinity of single rising bubble in fluidized bed which is otherwise at u m f. That means the fluidized bed is at u m f, okay. Only bubble is rising. He found that for fast rising bubbles the gas recirculates within the bubble and the cloud.

That means here important thing what you have to note down is that bubbles have clouds and the gas is trying to recirculate within the cloud and then also within the bubble. But under extreme conditions all the gas only may circulate within the bubbles. So that will be the worst condition where to get very low performance in fluidized bed, okay. That is the one. So I think there are many things but still I think I will just cut down that one. The first one was that you know the model development for the bubble itself.

Second finding on single bubbles is that every rising gas bubble drags behind it a wake of solids defined as alpha equal to volume of wake divided by volume of bubble, yes alpha, okay. That you can write. Alpha varies between point 2 to 2, okay. One to is T O another t is T W O, okay. Point 2 to 2, okay. Yes, so this is one.

And Levenspiel very beautifully says that please continue point 2 to 2 depending on who reports the results. Really it is so wake. Really here I think Abhinav was asking you know all this perfect things are there but I think measurement also is very difficult to find out. That means just imagine alpha is volume of wake by volume of the bubble, right? So what is the meaning of 2? If alpha is 2, what is the meaning?

Student: (())(33:13)

Professor: So I mean how can it be? That means you know you have a small person trying to carry you know two tonnes three tonnes on his head or just hanging you know trying to lift which is very difficult. So many solids to be lifted up. Yes, volume that is the related you know. I mean what you contain in that volume? Yes that is what. But you know those are solids only, right, nothing else in the wake. So solids will have some density. Whatever density that we can see but definitely the volume sizes also indicate indirectly the weight also.

So just to tell this that it is not that easy to measure the wake volumes and all that. That is why you cannot expect perfect matching of experimental results with the theory, okay. So in fact you know all multiphase system this is the problem. That is why I like chemical engineering because there are so many things. Even now for you if you are really interested in fluidized beds I can tell you hundred and ten problems in gas solid fluidized beds, not one or two, even now, okay.

So I mean every question that you ask, every doubt what you ask is a research problem. Like he was telling you know, sir how can it be true that there is a concentration same throughout the cloud? That is the research problem for us. You can actually send a single bubble and change various velocities and try to measure those concentrations in the entire cloud from bottom to the top around the bubble, okay. Like this one, this very wake point 2 to 2.

So what is the exact amount? Can you measure? Because as technology is increasing then you know sophistication in measurement also increases. So we will have now excellent measurement techniques. So without disturbing any bed at all you can try to measure from outside. No intuitive measurements, only from outside, okay. So that is called non destructive testing and all that. So just watch from outside and then you can get maximum information by using some kind of gadgets you know.

Like finally it goes to like you know science fiction movies, right? Like this all the planets also may move. Yes that is the kind of the movies they show like this. I think now recently I started seeing one Axe advertisement. Axe advertisements are all crazy advertisements you know. So one boy will be say that so from I think you know the latest one is from some planet also she pushes like this, she says like this, then her racket will come to India. So finally she comes to his room, okay.

So that kinds of science fiction you know from smelling you know diffusion, how fast the diffusion must be. This fellow is not even you know completely sprayed. He just starts there then she smells that there in some other planet. My God, it is instantaneous diffusion throughout the universe. That is fantastic. Even light cannot travel so fast but Axe smell can travel. So wonderful you know his imagination very good, okay good. So this is another one.

These two are the important findings because for us there are clouds, wake where there is some amount of solids. Now I think cached on this information Kunii Levenspiel developed their own model. Before that Davidson developed another model using only bubbles and all the solids like exactly two region model what we have discussed earlier, okay. But they have not used so many parameters. Like six parameters they have not used but they simplified the parameters and it was to some extent for some reactions it was able to predict.

Then came Kunii and Levenspiel. Kunii is from Japan and Levenspiel is from USA. Both of them met it seems in one of the chemical engineering conferences because I think their story also is very nice because both of them travelling from Chicago to somewhere or so by train. So I think Kunii son or daughter, small child, I think went and scratched Levenspiel because in the train when they are moving. That is the starting point I think. She was the catalyst. So then they became friend. You know normally that happens you know.

For us also when you are travelling what is the centre of attraction generally if you want to make friendship with someone? Children, okay. You will go and say like that. Then mother and father automatically will become friends to you. So it is exactly same thing happened for Levenspiel and Kunii. I read this long time back in one of the articles, okay. From then onwards their collaboration is fantastic. And that book Kunii Levenspiel is one of the excellent books for fluidization. And the title is Fluidization Engineering.

I do not know whether you heard of that or not. Davidson Harrison also wrote this big book but (())(38:08) movie, okay, because they only tell the facts, truth always hurts and all that you know poverty. Who will read that book? Okay. Who will go to (())(38:20)? How many of you seen (())(38:22) movies? Okay. Not even one no. Kavya you are interested? You have seen that movie, okay good. Then you should read Davidson Harrison book.

But whereas Kunii Levenspiel book with beautiful examples, nice presentation I can tell you Kunii is a lousy writer. The papers written by Kunii alone if you want to read you can never read even abstract, okay. Abstract maybe 10 lines or maximum 5 lines, okay. The papers I am telling you cannot. But it is Levenspiel who changed him also for presentation. Wonderful presentation again, Kunii Levenspiel book library also it must be there. You can just go and see what beautiful way the bubbles he represents and all that.

Of course you can see that in 3rd edition of Levenspiel also where he has just copied from there to this book. Levenspiel clarity is fantastic. I think in my opinion he is the truest engineer. But many people in the US it seems they would not like chemical engineers because he will try to simplify thing. He will not use complications, right? So that is why and if you read his papers also his research papers almost many papers I can tell you 60 to 70 percent of the papers will have worked out examples in the papers.

Research papers normally no one gives worked out examples. And all this information what we are going to discuss for Levenspiel model also came in 6 to 7 papers. In every paper, okay, there is at least one worked out example where that gives you the clarity. The moment you try to put numerical values, calculate and then get the feeling you will automatically get the feeling. So I think Levenspiel is great who made CRE very simple. Before that there were two books.

Wallace book or that kinetics for chemical engineers or so and before that Hougen Watson, these two books. I think no one read also that. Maybe Wallace is slightly better but when Levenspiel book came only it went to throughout the world as chemical reaction engineering subject after he wrote that book. All of you got this, okay. Oh yes, I will also give you.

You can distribute, you have this with you. I thought I will give in the next class but do not throw them out. These are the problems in fluidized bed reactors and also slurry reactors this advance booking, okay, because I have not done both now, right?

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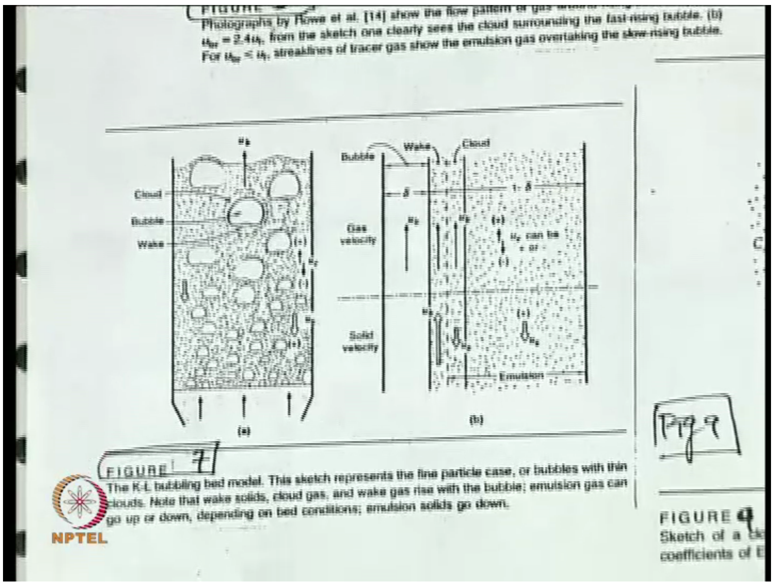

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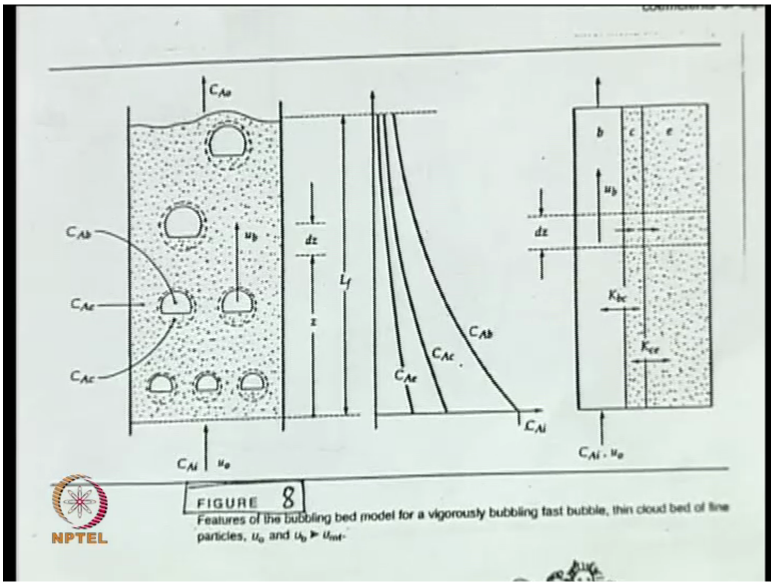
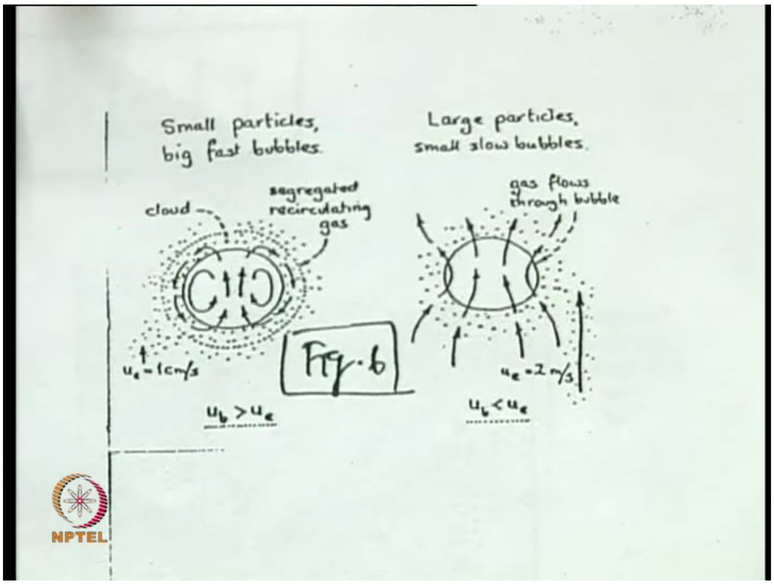
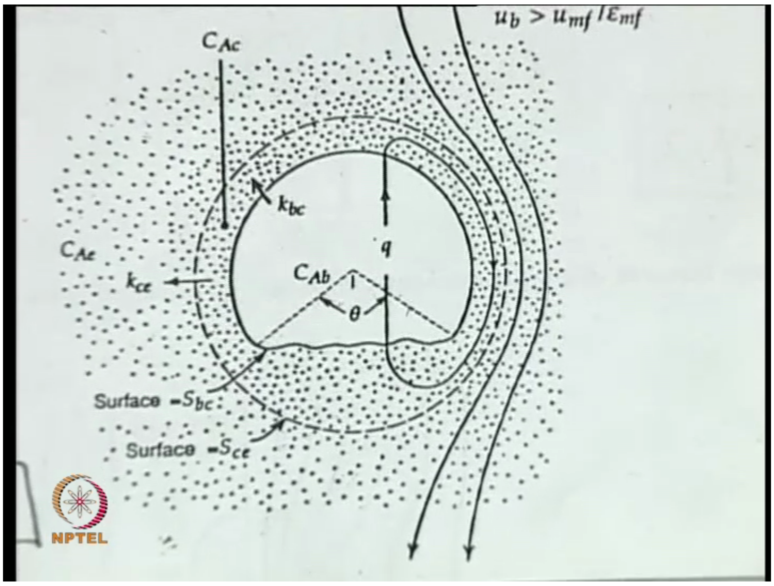


(Refer Slide Time: 40:54)

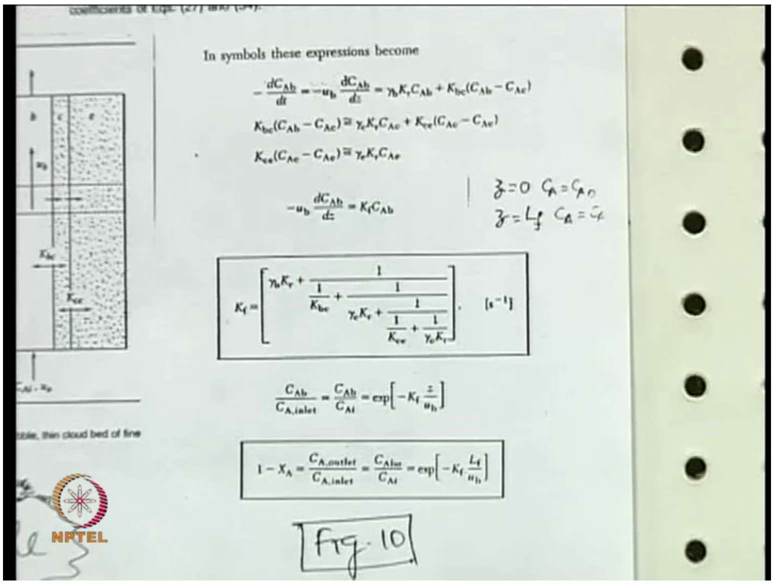


Fluidized bed we are doing but slurry reactor there are just one or two problems.

(Refer Slide Time: 40:56)



(Refer Slide Time: 40:58)



You can do that.

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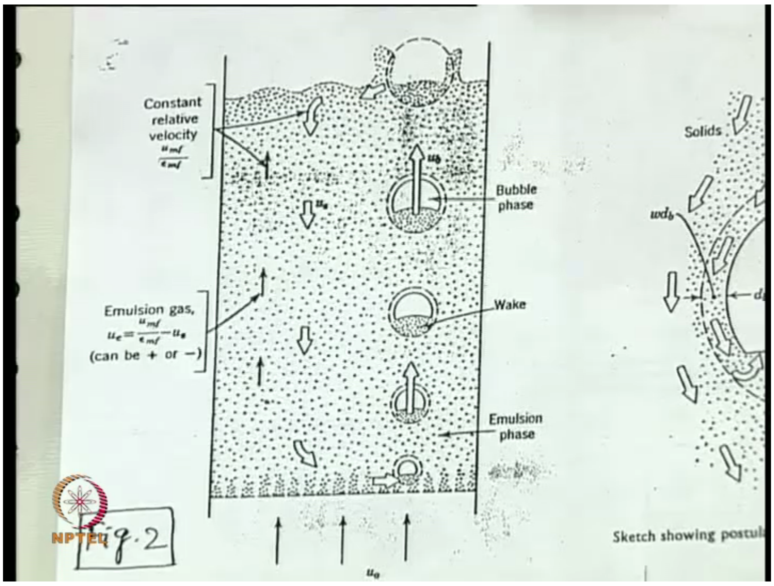
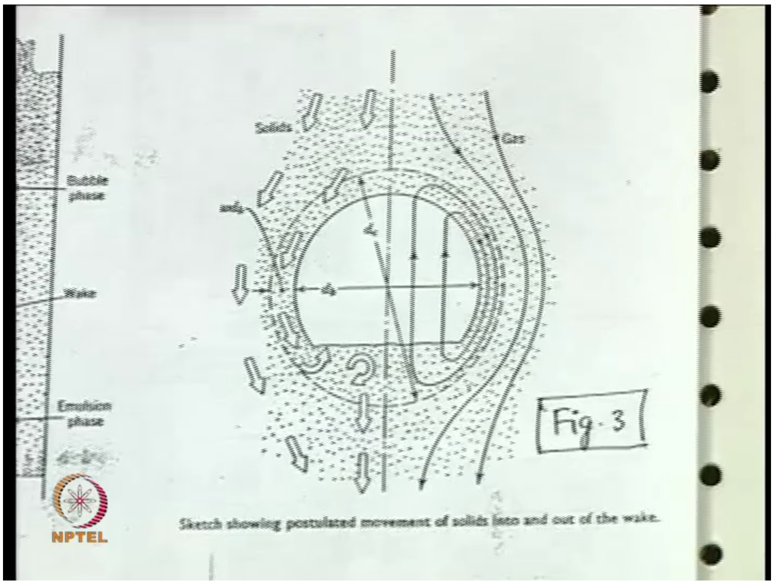


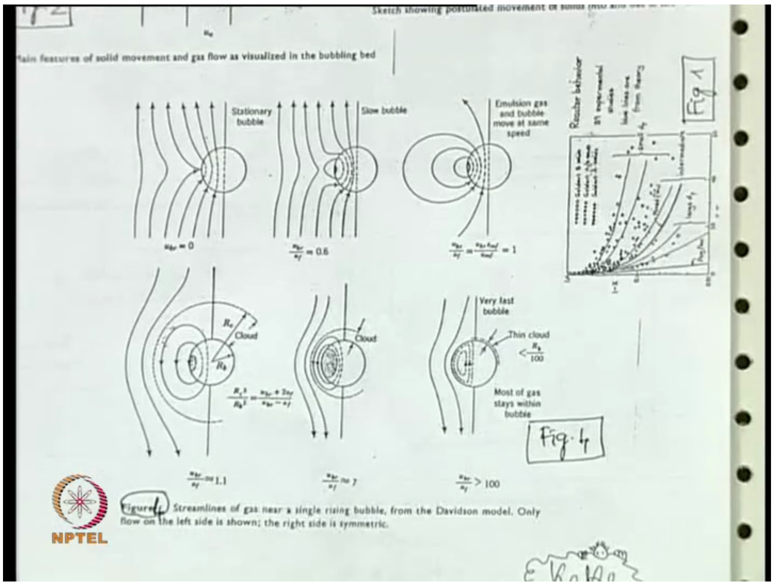
As far as possible whatever I know answers also I have given.

(Refer Slide Time: 41:02)

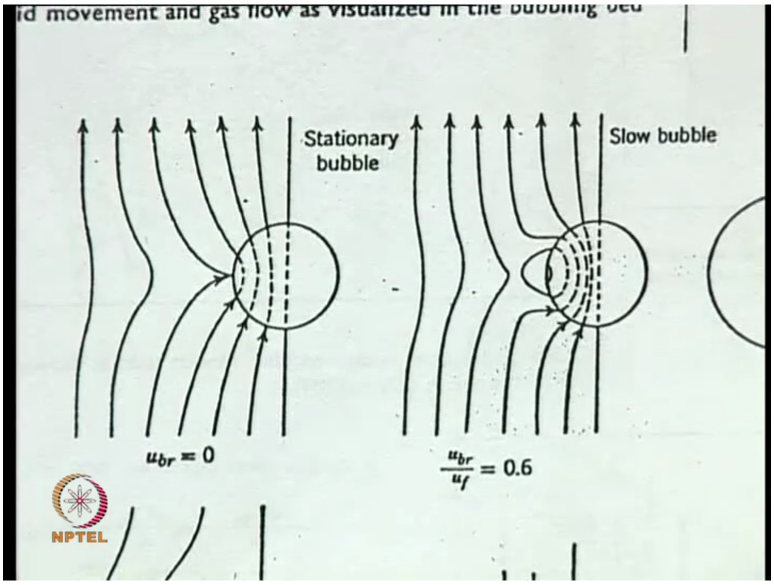


But then just keep it with you and then solve.

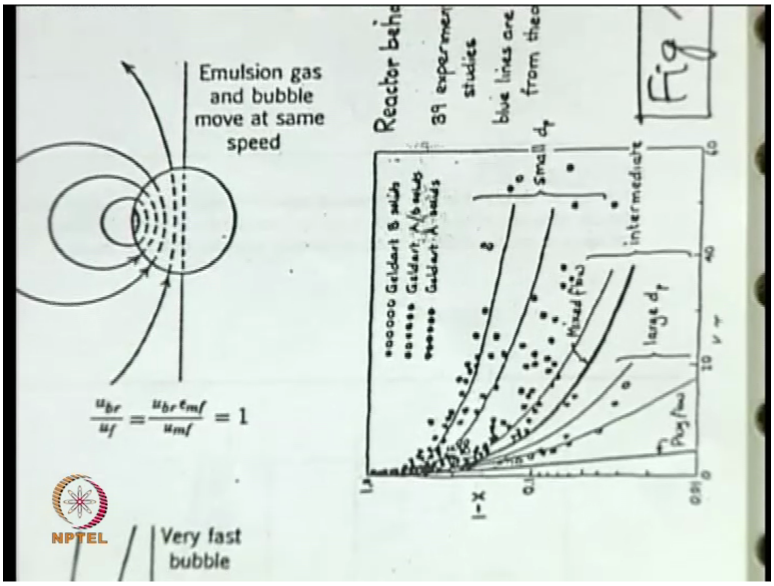
(Refer Slide Time: 41:03)



(Refer Slide Time: 41:04)



(Refer Slide Time: 41:05)



(Refer Slide Time: 41:06)