Chemical Reaction Engineering 2 (Heterogeneous Reactors)

Professor K. Krishnaiah
Department of Chemical Engineering
Indian Institute of Technology, Madras

Lecture 10

Homogeneous reaction model & Design of non-catalytic gas reactors

So in the last few classes we have talked about shrinking core model, right ya shrinking core model is one of the models which we have discussed earlier and the other model is homogeneous model, okay. So here the imagination is that we have a single particle but it is highly porous particle, right so that means gas can easily diffuse through the particle and then the reaction is going on throughout the particle there is no core which you can really identify there.

In the previous shrinking core model there is a clear boundary between the reacted zone and unreacted zone that is why we call that one as shrinking core model because the core which is not reacted is slowly shrinking and finally it disappears but whereas in this model because it is a highly porous model gas can easily diffuse through the pores and at any time if I look into the particle this particle is completely occupied by reactant A with the same concentration, if outside concentration is C A not for example the same concentration is also there throughout the particle and if you ignore the film resistance that is definitely true, right film also is not contributing so we have lot of pores.

So then all the molecules of A can go inside and occupy the occupy the pores and then they simply stay there, right because they stay there and there are reaction conditions so continuously the reaction is going on. So how do we picturize this in our mind first before writing the equations, right.

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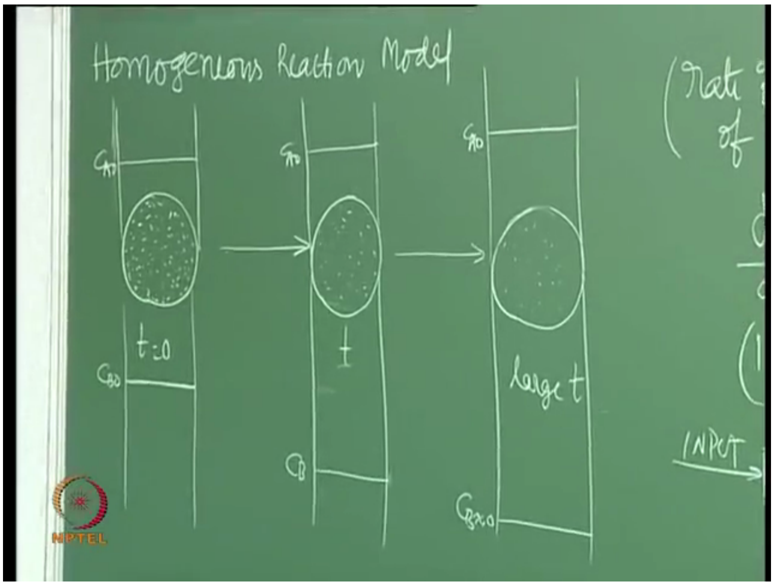

So we have a particle porous particle something like this then we have reactant B here reactant B and after sometime we have the same size particle we are talking about constant size but now this concentration will reduce then after sometime same particle the concentration is almost nil concentration of B I mean only product you will have so with time this is time t equal to 0, sometime t, large t good.

So as usual and we are neglecting film so that we know if it is film control we already know how to develop the equation the same equation can also be used here whether shrinking core model, or homogeneous model, right if only film is controlling so then the same model can be used, right but if it is there is no diffusion here diffusion control here diffusion through ash layer because I have large number of pores large size pores so that the gas can easily enter into the particle and then the reaction is going on throughout the particle, good.

So if I want to plot the profiles here profiles of what profiles of solid, okay how the concentration of B is changing. So here at time t equal to 0 you may have here C B not time t equal to 0 this is throughout same no so that is why horizontal profile throughout okay this is complete particle we are drawing now it is okay ya so then if it is truly homogeneous model this is C B not that means everywhere supposed to be C B not throughout so after sometime t what do you expect?

Ya I mean not 0 here at this point ya you will have something you know here this is C B profile and after sometime it will still go to less and C B will be 0. So that is how the profile decreases, right because number of moles here are more than if I take here number of moles which are spread throughout is less and here number of moles again throughout spread is almost 0 for B because B would have already reacted and the reaction is same reaction what you have been thinking, what is that A gas plus bB solid going to products, okay good.

So now what is ya what kind of profile you get for A? A is the gas so if I draw those profiles here ya ya so A how do you imagine A profile? In all the cases it is because I have sufficient amount of gas diffusing and then staying there, it is reacting continuously and continuously again it is entering because you know that when immediately concentration is less there and you know this gas goes there so continuously it is always it is as if you have immersed this particle in a concentration of C A not you have lots of A there.

So that is why you will have C A not same here if I take that one as C A not, again here C A not, again here C A not with time. So now with this we should be able to imagine what is the rate of reaction for this okay good. How do you do that? In this case I think we know that now the rate should be proportional to concentration of A and concentration of B, okay so earlier case we took you know the concentration of B so large that is why it is not a it is 0 order reaction so it is not directly coming, we are taking only with respect ya with respect to A first order and all that but even here because the rate is proportional to concentration of A and concentration of B, concentration of A is always constant whereas B is changing, right.

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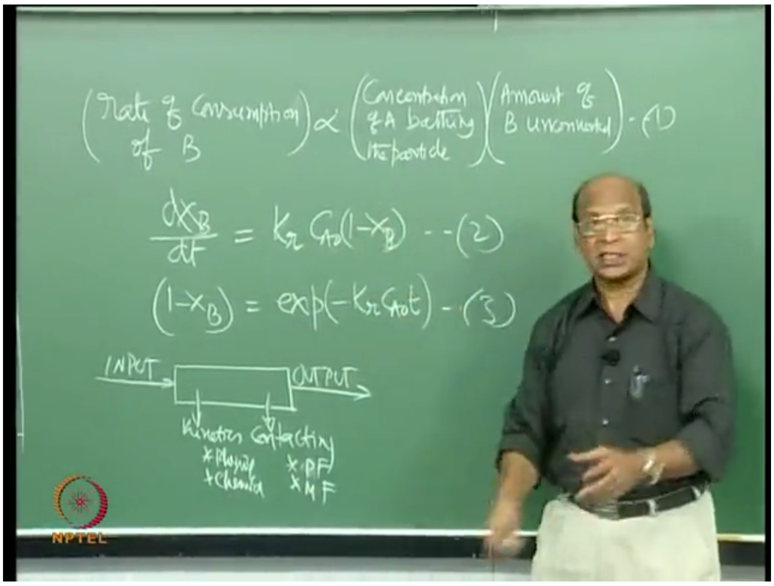

So we can write that as okay here I write rate of consumption of rate of consumption of B is proportional to concentration of of A bathing the particle multiplied by amount of B unconverted, correct now only converted will not participate in the reaction unconverted, good okay. So if I write we can also write this one also in terms of C B or we can also write in terms of X B, X B is the conversion which you are already familiar.

So if I write this one as the change dx B by dt is this proportional to constant I will write something K r reaction rate and C A not which is constant throughout and 1 minus X B so if I take this as equation 1, this will be equation 2 can I integrate this equation? This is very simple no because it is concentration of A and concentration of B left okay ya so 1 minus X B and if you the simplest integration and then the integral expression for this is 1 minus X B equal to exponential of minus K r C A not into t which one same thing here also left side also I have C B not so gets cancel ya same thing this X B also will be there right.

So the definition only I have differentiated this side so you can write the same thing and then you will get cancel, okay good. So this is the simplest equation you see now this equation simplest equation to calculate time and also it is related with X B it is simply like your homogeneous reaction. In homogeneous reaction assuming that this is Pseudo this is almost constant throughout C A not that becomes pseudo first here with respect to A and it is not always true that I should have 1 minus X B I can have in fact X B to the power of 1 minus X B to the power of n, okay.

So what you do with all this is that once you conduct the experiment and if you know initially it is a porous particle and truly homogeneous model may be valid there that you know the physical condition of the particle which you know because you are conducting the experiment, right so once you know that then we have to find that whether it is really first order or second order or whatever order and you should see that the concentration of A throughout the particle is same for long time because without any change in that.

So if you have those conditions then this is the equation I have to try but still I do not know whether it is first order or second order. So then I have to imagine this nth order and then try to plot my X B versus t and then see whether I get a straight line for first order if not square then second order this is called integral method, okay otherwise you know you can take the data like this and then put as X to the power of n again you have to plot log log sheet and then try to find out that is differential method, okay try to find out what is the order and then correspondingly fit it, right and here the imagination is only integer orders may be first order, second order it may not be.

So that is why if you are able to get the data for dx by dt versus X B better thing is differential thing you can use differential technique and then try to find out what will be the order of that particular reaction. So once you are able to fix here here it may be 1.5 correspondingly we have to integrate that and then find out the relationship between X B and then the time.

What is the ultimate aim? In the design I should be able to tell that how many hours if this particular particle or particles must be there in the reactor sorry for complete conversion, okay and for most of these solid particles we wait till complete conversion occurs, okay. So that is what is the ultimate idea and this is one of the simplest models in gas solid non-catalytic reactions simplest because we have taken here first order, good.

So now as per our discussions all the time earlier that we need information for the reactor design this plot again I am just diagram this is input, output, we have here kinetics, here we have contacting, here we have physical, chemical, here we have (MF) no no okay let me write PF and MF, okay this is diagram we have been talking. So now with all this discussion now for non-catalytic reactions we are supposed to be experts in this now that means given any reaction you know how to find out the kinetics, kinetics means how the reaction is taking place with time and what are the quantities or what are the parameters that we have to evaluate.

If it is shrinking core model with three controlling film controlling, ash diffusion controlling and also reaction controlling you have three coefficients there you should know k g and you should know De effective diffusivity and still you should know k s and all three when you are able to evaluate from the experimental data then you should have the relationship between X B and then time for a single particle, right so that is what is the kinetics will tell us.

Now we have to put that information here and because you are already experts of this contacting you know that when you have to take mixed flow, when you have to take plug flow. Now these two have to be combined to finally get the output. Input is given by the (()) (14:21) market survey, right so how many tons of ya particles you want to process or how many tons of gas you want to process if you are interested only in the gas space even in non-catalytic reactions but most of the time non-catalytic reactions we are interested only in solids like because you know combustion, gasification, leaching and extraction of ores leaching is extraction of ores only, okay.

So in all these (react) most of them are metallurgical reactions, okay in process metallurgy they will be touching like this but not thoroughly like us they do not discuss. For example in blast furnace, right so when you have that non-catalytic reaction you should be finally able to design the furnace so that you will have 100 percent conversion of iron ore to that comes from this information kinetics and because you are taking blast furnace then you should be able to visualize in blast furnace whether I have plug flow or mixed flow.

So that is why now the question is the design of we will go to the design I think this is where I stop with respect to kinetic models, right we have done the shrinking core model with three controlling and individual controlling also so we have also done that is copper constant size particle, for changing size particle we have done again one model, right and this is the homogeneous reaction model and this particle is not changing, okay if this is also changing but porous particle what kind of model you use just try to extend what you have learnt till now, is it possible to do or it is not possible for you to do now because we have not done all the models, we have type A, type B, type C, type D, type E and type F okay six models ya we have six type of categories out of this we have done type A, type B and also type D, type B and type A together we have done it and this is type D earlier gasification and all that what you have done so three plus this homogeneous the other things are gas gas gas reaction straight away giving you the solid product that we have not done and some other variations we have not done, good ya.

So if I have for example changing size this is not constant this becomes a little bit smaller, this becomes a little bit smaller, okay is it difficult to handle or what actually do you have that information? Just think I hope question is not confusing you know the first thing generally student say is that Sir question is not clear, okay once more okay ya here we have taken this as a constant size particle size here is not shrinking core because there is no core no you cannot use shrinking core model because it is highly porous model there is no core where is the core throughout the particle reaction is going on, there is no clear boundary between unreacted and reacted zone when you have that boundary only then you will have shrinking core model, okay remember you know when you are taking this Gulab Jamun what do business call Gulab Jamun only Rasgulla ya if it is not properly you will see inside unreacted core some hard material, right ya.

So then you have to now chew it slightly more difficult otherwise it will simply melt in your mouth if it is properly cooked that is shrinking core model, okay even rice also those people are very angry with you and they did not properly cook then outside will be soft, inside will be slightly hard then there is also shrinking core model rice cooking also, okay. So unless there is a clear boundary between cooked and uncooked you cannot have shrinking core model this is porous particle but what I am asking is this is changing with time the size is changing with time do you have any difficulty in handling that?

What is (())(18:19) no I am just asking you to extend your thinking I said do not just sit there as status, there is no film let us not take that film I am only talking about particle becoming smaller and smaller do you have that information? There is no ash layer everything is becoming see again ash layer comes if you have the ya the reacted core separately and then product separately, here product is distributed throughout when the reaction is going on product also is distributed throughout ya it is actually very difficult because no particle is shrinking you know we do not know how many moles have been you know with time ya sorry the size is shrinking.

But generally you can just imagine the question itself may be stupid because what is the reason for shrinking. Why I (())(19:18) we are talking about one particle that is fine ya if I have two different size of particles there distribution of particles each one I can deal with separately that is not a problem that is a design problem, what he is asking is I have taken 1 centimetre particle 5 mm particle both are both are you know homogeneous models, okay.

So then it is not a problem because I will design which takes the longest time and then weight.

Student is questioning: Shrinking core in a porous particle is it similar to the pores of the same size particle (())(19:59) shrinking core in a porous particle is it similar or analogous to a particle of constant size porous particle where in its pores are filled completely.

But in shrinking core the diffusion regime where you have pores is unreacted core is you know is inert core shrinking core model you cannot bring at all here because shrinking core is porous particle.

Student is answering: Shrinking size.

Shrinking size ya shrinking size there is no ash around the particle, okay ya but here we are not saying that I think you know this particle is only decreasing by size but as I told you question itself would have been stupid because what is the reason for shrinking you have to also ask.

Student is questioning: if we have for catalyst we usually know the surface area per unit mass of the particle or the catalyst. In this case if we assume that the size is shrinking uniformly we can calculate the volume and therefore the surface area of the pores which are getting destroyed, area of the porous particle in that case we can actually like he was saying that we can compare it to the deactivated catalyst model, can we do that or is that too difficult as well?

Deactivated catalyst ya where the ya know deactivated catalyst is almost same in fact this similar model is used for deactivated because the deactivation all our catalyst particles are porous particles, okay so that must be homogeneous. So the deactivation goes here in the reverse way here we are converting the reactant into product but there the entire particle is very active in the beginning but during the reaction there is a reason for you know getting it deactivated like for example I have been telling you the example of FCC, FCC catalyst is highly porous particle but one of the side product of FCC you know fluidized fluid catalytic cracking is very fine carbon coke.

So that coke will go and then uniformly try to sit here and there throughout ya. So then the surface area which is actually participating in the reaction is slowly decreasing that also go to exponentially if I assume first order kinetics there in fact the same equation can also be used, okay. So that is why when the particle is shrinking think first of all these particles what is the reason for shrinking?

Ya but here throughout the particle it is happening, right this is homogeneous model ya surface as well as throughout but that is not the reason for particle to reduce in size I am talking about overall particle there is no core, overall particle it is possible only when you have the total molar volume increasing or decreasing I think already I told you this one for calcium carbonate, okay.

When you have calcium carbonate particle becoming calcium oxide and calcium oxide is reacting with sulphur dioxide in the presence of oxygen then you will have calcium sulphate. So calcium sulphate molar you know molecular weight molar density is higher than CaO under those conditions there particle expands, right and if you have a similar reaction where the molar density decreases then particle shrinks, otherwise we do not have any reason for increasing or decreasing, why I am telling all this is even though we simply tell all this student is very happy to copy all this and then keep it wait for the examination but so much discussion can be made so much thinking can go right.

So that is why I try to discuss all this but it was found already most of the time in the models also that whenever you have molar change during reaction are decrease or increase that is not affecting that much the overall model predictions even if I take this, right and then I will assume that is a constant particle, someone else will say that no no it is a little bit changing so he also takes the model and he also develops a model now slightly changing particle or expanding particle, right.

So under those two conditions it was found that the difference is very very less and Carberry already proved that, right. So if you are really able to imagine all this after the class is over when you are preparing for the examination then you will have lots of ideas, okay but if you are treating this only as examination point of view there is no excitement at all you see how much time we have spent on this just to ask you know whether the particle is shrinking or expanding what is happening, Shekhar you are asking something?

Student is questioning: my reaction rate constant is very high I mean my gas does not need not have to go totally inside the particle then the reaction will again happen on the surface itself and because of this the surface and the size of particle will get reduced.

If the reaction is very high?

Student is questioning: k s is very high in that case the reaction will happen on the surface itself the gas will not have time to go inside the particle.

That becomes equivalent to shrinking core model, if the reaction is very fast but here when you derive this automatic assumption is that it is rate controlling, what is rate controlling? Reaction is rate controlling, no reaction I have large pores where the diffusion is very free just going inside, okay. So automatically when you say homogeneous reaction model that is only the reaction control but actually that is also true when you have very very fast reaction even though I have porous particle that behaves as if it is a shrinking core so beautiful things and these two are the basic models ya.

And in reality in reality you will not have completely homogeneous model, okay and that is why actually what happens is you have to draw the profile inside, okay profile inside and now that model is very very complicated which I am not doing here because this takes lot of time the derivation, okay why it takes lot of time because first of all I have to establish the profile inside profile of what? C A and C B both, C A profile because there is diffusion of (()) (27:03) for C B and that is C A so that is why C B cannot uniformly react throughout, right.

So at any point here inside what is the corresponding C A and then C B and then equation is again same, this is not no more constant. So every time I have to find out what is the average conversion throughout the particle, what is the average concentration of A throughout the particle then I have to integrate, okay. So people have already done it people have already done it but we are not doing because I have to do so many things actually we had earlier in IIT Madras separate course called Heterogeneous non-catalytic reaction engineering there we use to discuss all those models but here I have to do (())(27:51) to many things so that is why just giving some information and then beyond that your thinking, okay.

So that is the reason and straight forward if I take that model where I have homogeneous model but still it is not purely homogeneous model porous particle then I think you know atleast it will take 1 or 2 weeks for me to develop all those (())(28:11) it is not that easy, it is very complicated model, okay and but a lot of imagination is required I think in 70's there was one Ven Chinese professor in US I think (())(28:19) he was the starting point for all these models I think ofcourse shrinking core model was already done by Yagi and Kunii long time back but lot of mathematical details of this homogeneous model was given by that Ven okay unfortunately after I complete my P.Hd I wanted to apply to him as (())(28:42) but at that time there is no Emails and there is no fast communication so I wrote the letter and letter came back after may be 2 months later so saying that Ven has died recently I think he was young also may be around 51, 50.

But he has done lot of work you know gasification you take, coal combustion you take some of you may be doing gasification combustion projects everywhere you see his mark because it seems West Virginia is very famous for coals, lot of coal mines are there. So that is why that University was concentrating mainly on that USA West Virginia.

So that is why you know USA has the tradition of doing very good research work depending on the need, here also we have lot of coal Neyveli but we do not have any project in it, we had some project but not for conversion and all that ya because that interaction between industry and academics if you see that old papers 1967 was I do not know whether journal called Industrial Engineering and Chemistry, how many of you know that, only you know you also know Industrial Engineering and Chemistry I think it was there till 80's or so then they changed it to Industrial Engineering Fundamentals, Industrial Engineering Research and Development, Industrial Engineering Product Development three same issue same journal.

Then after 7 or 8 years again they went back to now the current name is Industrial Engineering Industrial Engineering Research it is there now Industrial Engineering Industrial oh my God I also forgot ya Industrial Engineering Research now it is available you are also getting INDCR or something we have research they added but all sections again together. In that journal when it was Industrial Engineering Chemistry this Ven published those paper the original paper is still with me because someone gave me that paper.

Ya so this is what about these models and lots of work is going on even now in these models because this reaction is a very funny reaction non-catalytic reactions are really very beautiful reactions I do not say funny reactions, it is very complicated reactions and calcium oxide to calcium sulphate is one of the very famous reactions just for the sake of environmental pollution, okay calcium sulphate is available plenty on this planet, what is calcium sulphate? Gypsum, gypsum mines are there, okay so that is available we do not have to produce that.

So this reaction is not famous for that particular one but it is famous because when SO 2 coming from Chimneys from power plants for example. So you can remove that SO 2, capture it with the solid and then make it as CSO4 and the CSO4 can be used by someone or I think you have to regenerate and again use that calcium oxide and by regenerating what you get is you are not solving the problem you are again producing (())(31:55), okay but the difference between that SO 2 and this SO 2 this is more concentrated what you are again regenerating.

So that SO 2 can be sent to which industry? Sulphuric acid industry, so that is the reason why it is very famous thing and many power plants and all that have been doing it and the reaction is not that simple I have told you once that calcium sulphate plus not calcium sulphate decomposition is easy calcium sulphate decomposition but calcium oxide reacting with SO 2 in the presence of O2 is not that easy reaction again I am repeating because molar volume is increasing there the pores will block if more the faster the reaction then pore closure is faster.

So that means if I have this is the particle, if the reaction is very fast only this outer layer will be completed you know that will become CSO4 because it is large in means the molar volume is large all the pores are block so SO 2 cannot diffuse inside SO 2 or O2 cannot diffuse inside. So all this one is unreacted calcium oxide so that means you are now producing lot of solid (())(33:12) okay.

So then how do you avoid that you have to know what you have done is your air pollution problem you have made it as a converted into solid pollution problem, right. So that is why people you know in Germany I saw that in Lurgi they used to break this particle and then after breaking simplest way of breaking is to putting water spray water in that during the reaction, calcium oxide reacting with what is highly exothermic reaction calcium hydroxide highly exothermic bubbling actually I have seen with my own hands in our Villages when we are doing you know white washing once in a year you do for that fungal and all that at that time.

So we use to bring the raw calcium hydroxide calcium oxide and then pour water and make it as simple as a small bowl like this and then put that pour water bubbling during bubbling. So that is why ya that reaction and the modelling also is very difficult the reason is that your idea is to predict when the pore is closed because beyond that it is useless. So that is why lot of work wonderful work is there on this I think one Bhatiya from India only but all our people will work only US know not here so this Bhatiya I think he was in US and then he worked there wonderful models they have produced.

And process control people do you know there is a processer called parallel motor (())(34:46) control and all that ya this Bhatiya worked with that parallel motor parallel motor and Bhatiya they have got this papers and at that time the specialization means parallel motor is also specialized in in process control and all that but still they used to work in common chemical engineering problems like this diffusion reaction problems, distillation, absorption all these problems.

So everyone is expert there but here now I think we are experts means we do not know anything else only that part I know absolutely no connection there so that is why when I think in the same building this Benz CEO someone has come from Germany this auditorium you know just below us (())(35:31) auditorium he was giving that lecture and then he was telling even in Benz company also these expertise has come and (())(35:37) there that people say that no no no I am only expert in left back left wheel I do not know anything about all other three wheels that is all backside left wheel only he is expertise, you do anything with other parts, he knows only about that he was also telling that may be (())(35:57) or you know I do not know that but that is what he was telling, he is so serious about our expertise norm.

So I think there are wonderful books also by (())(36:06) and all that in our library on process control and all that, okay anyway good.

So our next job is using all these kinetic models how do we now design the reactor, okay so what kind of reactors we can have like for example the reactor means for example we have reactor design in the form of either plug flow or mixed flow that is all whatever reactor you bring we can convert that into either plug flow or mixed flow ideal reactors, non ideality we will come later that we have to see when non ideality is taken into account ya.

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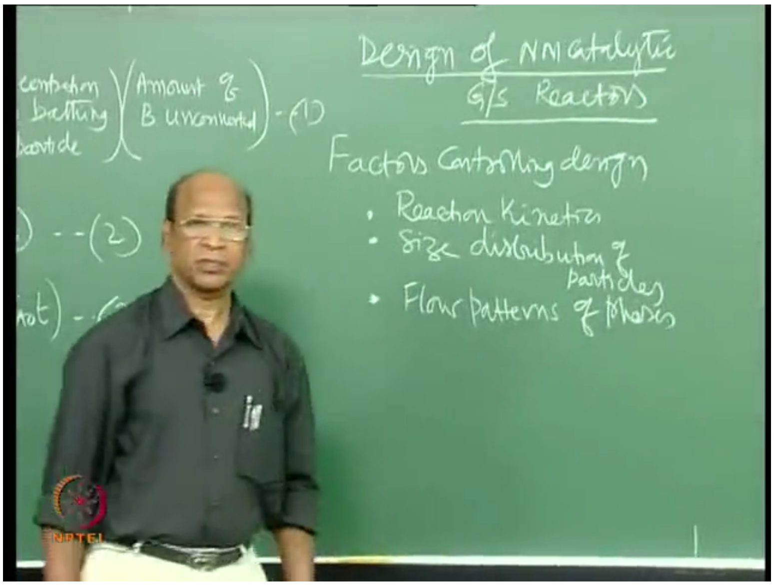

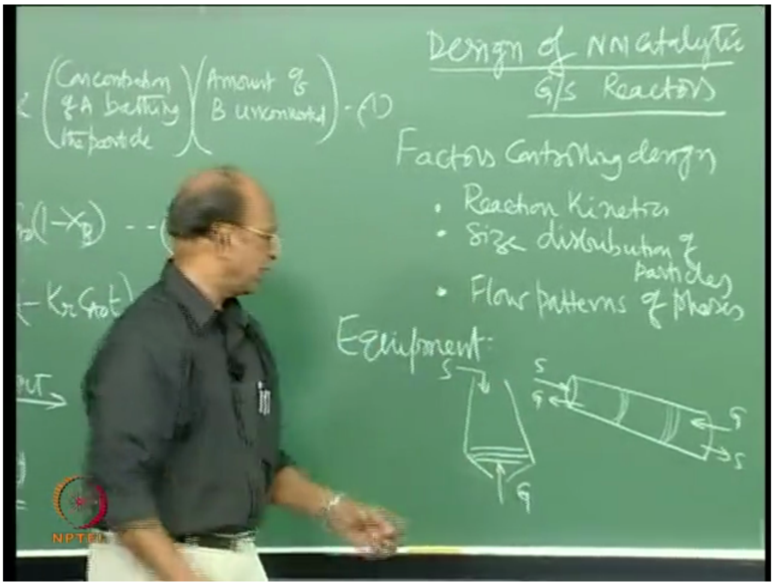

So here we will write design of non-catalytic gas solid reactors ya the factors affecting design may be I think I have to write here factors controlling design 1 we have reaction kinetics, size distribution of particles and number 3 flow patterns of phases these three, do you have information on all these three for the design that means do you know anything about all these parameters, reaction kinetics do you know any information?

Now this point of time to you I am asking (())(38:28) you do not know stupid question ya so you know definitely you have learnt but I think I do not know everyone learnt or not that is why okay. Reaction kinetics we have some information like what you can use either shrinking core model or homogeneous model or very complicated models also which you have not done, okay good that information I say knowing information in any course at the end you should know some information it is not that you are I am asking you to remember the equations but atleast you should know the moment someone asks you okay can you design a non-catalytic reactor then like a reel it has to go yes first kinetics, then what are the models and then contacting what kind of contacting possible, right how the particles move, how the gas move so all this they should reel I mean they move in the mind as if it is a reel continuous reel.

So once you know that information then getting the details, okay kinetics which model is the best either shrinking core or homogeneous, okay in between so you know that information and details you can get from literature I am not asking you to remember all that but anyway definitely in this course you have to remember till exams are over you know those equations I am not allowing you to copy or I am not allowing you to bring the notes and all that so you have to remember that, okay.

So that is why kinetics you know you have some information and flow patterns we have discussed already but still for continuity now I will discuss some more things, okay you know already we have discussed and size distribution of the particles we have not discussed till now because we have only talked about single particles, okay so now what we do is if I have this one is 1 centimetre particle or 5 mm particles and 1 mm particle all three together, okay design is not that difficult when we have that ya average you have to take, okay.

So what is the conversion in the 1 centimetre particle, conversion in 5 mm particle and conversion in 1 mm particle so you have to just average it out weighted average in fact 20 percent may be your 1 centimetre particles, may be another 40 percent may be your 5 mm particles and 40 another 40 may be 1 mm particles. So that is why that also is not difficult for you you can easily handle it, okay good.

So if you are talking about contacting pattern now for non-catalytic reaction generally what kind of reactors used do you have any names in your mind? See non-catalytic reactions can you say first of all what are non-catalytic reactions? Iron ore for example, okay that is one of the easy things to remember so which reactor is used? Blast furnace that is only one nothing else rotary kilns are also used, okay.

What is the difference between blast furnace and rotary kilns when they get the product at the end? Blast furnace you do not remember at all this is high school question is this, high school you should have studied blast furnace you know (())(42:01) so what is the product you get I mean liquid metal or so you know why it is called pig iron I mean I was why it is called pig iron? (())(42:20) pig and high oxygen content?

Student is answering: Carbon content.

Okay even carbon content what is the relation, how do you relate pig with carbon? Tell me ya someone was telling me I do not know whether it is true or not but a (())(42:39) when I ask you what is this pig iron, not now I think may be 15, 18 years back or so. So he was telling me that you know when liquid metal is moving after liquid metal comes out it moves in the channels.

So when it is moving that you know it is highly viscous, so it forms this kind of boundary and then moves this is channel you will have like this and then it is moving, when it is moving it looks as if it seems very fat pig how it walks you are looking from the top this is you know beautiful very smooth surface for the pig, very nicely I have seen pigs also so maybe you would have not seen so beautifully walking and then you know that moves as if it is like this so that is why we call it as pig iron (())(43:24) very nice know I do not whether it is story or may be true also, okay.

So but you get the liquid directly there then you can directly put it in the form of rods or in the form of plates all kinds of things you can do it but whereas here in rotary kiln it is solid, okay you know what is the name of that product called? Not clinker, clinker is put you can also use that kind of thing and wash your body not sponge, you heard of sponge iron know ya why it is called sponge iron? It is not soft like sponge it is porous porous.

So what you get is sponge iron in rotary kiln, not only in rotary kiln fluidized beds can be used fluidized beds also can be used, right. So that is why we have the equipment for example may be it is a blast furnace ya here we have the gas and here we have solid this solid contains iron ore plus you know that slag what they put calcium calcium calcium carbonate ya and also they put coal coke coke coke they put so all three it is a solid solid reaction there, right I mean that coal will become that coke will become CO that CO will be reacting with that, okay ya and ya this is how it looks.

Then you may also have this is rotary kiln may be gas you can send like this, solid like this solid, gas, okay this will be rotating this is too slant in fact you will not have this much slanting ya nice okay this is the one.

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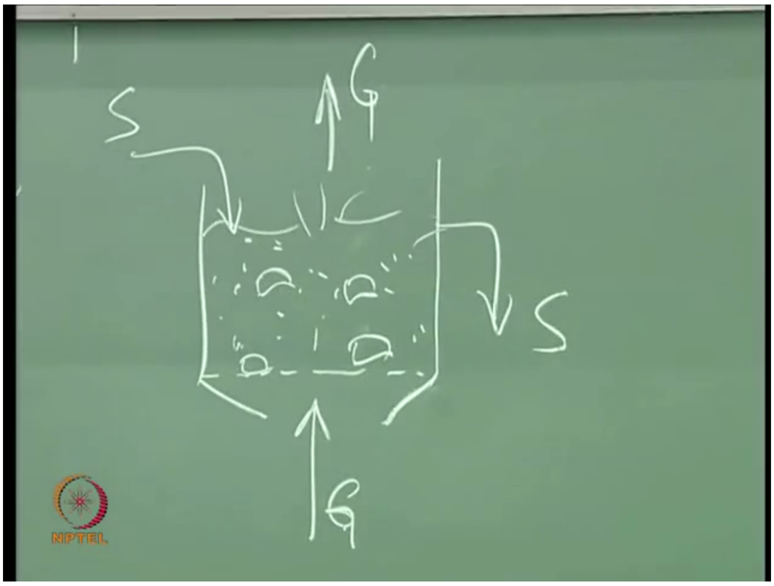

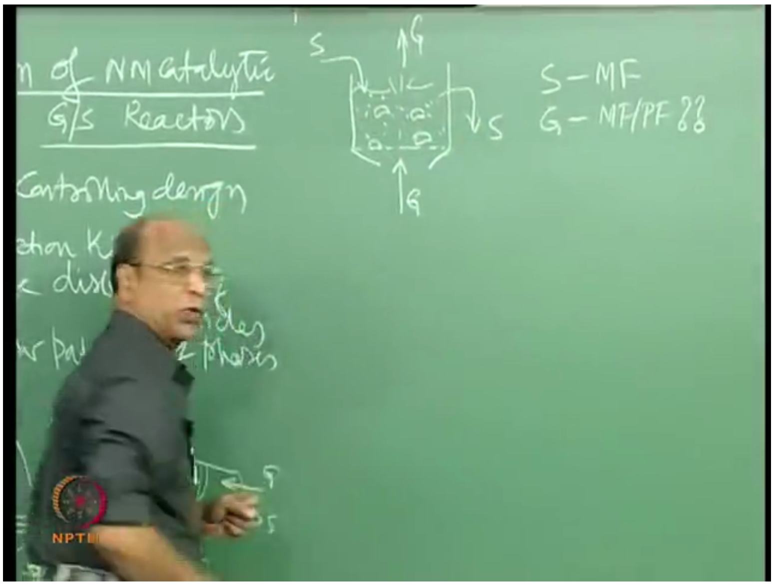

Other reactor also we can use is fluidized bed this is gas, these are the solids we also have what is called bubbles here and solid continuously solid continuously gas goes out, okay and that solid is nothing but your iron ore, okay but only in the blast furnace you will have solids iron ore plus coke and for making that slag I think you add calcium carbonate or calcium oxide you add there in that, okay but here you do not have to add those things it is simply Fe3O4 plus CO 2 or H2 you can this gas can be either H2 hydrogen or CO carbon monoxide I think we have written that know you are looking at me as if you do not know that reaction at all Fe3O4 plus CO or H2, okay (())(47:01) as the product ya so these things.

And this will tell me what kind of contacting patterns I have? Like for example quickly going through in blast furnace there are two phases now okay till the iron becomes molten here only at the bottom here till here almost you will have only solids moving, okay so and gas may be going this they blast the gas that is why I think this is called blast furnace sides also bottom slides and all that, okay ya ofcourse not through liquid iron but slightly above they put it and then it will go.

So how the solids are moving, how the gas is moving? Solids and gas, how means whether it is going as if it is plug flow or as if it is mixed flow and you know the height of blast furnaces normally very tall 5 stored, 6 stored buildings blast furnace heights ya very big very large ya how the solids move are they in plug flow how gas moves is it in plug flow or mixed flow? Imagination I say (())(48:16) which one is mixed flow there are two gas or solid? Solid is mixed flow why even if you say plug flow I will ask why so that is why I think why is a you have to give answer, Sachin just imagination I have a large building and where I am slowly poring that you know solids and then finally I get liquid somewhere down here but ofcourse reaction may be going on through that point ya how the solids are moving?

You can do all this experimentation you can go your home and then take pulses like you know green grams or something and put in a funnel and open the funnel slowly how that moves, plug flow very simple imagination unfortunately that imagination also we are not able to create in your mind I do not know is it our fault or you have totally insulated brain, okay nothing can go in, nothing can come out atleast black holes are better black holes radiation comes out itself but here nothing can go perfect insulator is our mind if you do not want to listen nothing can go correct know really if someone something if you want to avoid 100 percent efficiency only this there is no other system which can be so efficient there, okay.

So that is why simple imagination only it is not at all difficult I think you know I do not know I do not know why you are not able to tell okay gas gas plug flow. So that is why when I have here ya mixed flow (())(50:01) I will tell you why you cannot use mixed flow the reason is definition of mixing itself, okay a particle which is here any instant of time can also come here okay and that particle can also go here, go here, go here, go here, go here anytime is it possible in a blast furnace to have that kind of flow, never and by the way you know what is the size of the particles they use in a blast furnace?

Guess 1 kilometre to any size ya that is very good guess 4 inches 4 inches and that is why they have the palletisation plants okay so they cannot use simply (())(50:50) because during mining they get also lot of powered ore or small particle ore and because it is blast so much gas is going inside I mean blasted inside what will happen if you have fine dust or you know small particles all of them will come out they will be thrown out terminal velocities, okay ya that is where I think when I was handling this B. Tech lab I was asking question tell me 1 use of terminal velocity in industry 4, 5 years no one told ofcourse I only told them later ya because beautifully we derive equations (())(51:26) what should be the one and other (())(51:28) what should be the one terminal velocity and all that.

But I think definitely we do not know where to use, okay but you have not only here in atmosphere terminal velocities how the dust falls on you okay it goes into the air and then there is no sufficient wind to carry out then slowly they attain the terminal velocity and fall on you that is how your cars, your people like me this surface all that will be dust ya so then you have to vibe it out. So I think you know our cars you just leave or your motor bike or your cycle you clearly I mean clean it one day and then wait how many days you will get 1 micron thickness, 2 micron thickness, 4 micron thickness, okay ya.

So I mean these are the examples but otherwise how do you relate what you teach I say, you are not asking anyway but atleast I have to tell no and you are interested whether I give this question also in exam or not that is what only your interest, okay good. So what about this one? Gas is plug flow, this one ya gas is plug flow that is ya gas is plug flow. So I wanted to answer is mixed flow and wrote mixed flow there this neural network also sometimes will not work I say, okay many process control people use neural network with wrong learning sometime, okay good that is the one.

And what about this one solids are continuously fed here this moves slowly do not think that it goes like your other one what is that washing machine is very high but the other one where you sit and go mary go around mary go around, okay mary go around also if you go to centrifugal velocity you will go horizontal you know. So if you make any mistake you will land somewhere okay so it is very easy have you enjoyed that good all of us would have done that recently not when you are kid no that is why only I think as kid only you enjoyed many things I say.

After writing that entrance examination whether it is JEE or whether it is Andhra entrance what is that MCET, KCET, RCET, SCET all you know every state has one CET after that we become I think you know very serious without learning anything because I think you know particularly engineering I think medicine education is thousand times better than engineering education a person who has studied medicine comes out he will know how to treat atleast but we do not know how to even lift a pump, how to carry a pipeline, how to tighten a bolt (()) (54:28) oh my God true simplification I say.

So I will headache but then if you give something you know (())(54:46) tablet to me so then you should understand know you should relate he says that whatever you say and then he listens and then write the things to write that medicine you should know what is the disease that is standard you know basic medicine always ya because you know this is much more difficult veterinary doctors are much more difficult because they cannot ask dog where do you feel so what you have taken today morning.

Student is answering: Sir the dog owner can speak for the dog.

Dog owner but you know how it feels how dog owner tells feeding he can tell, what he fed to that fellow he knows but how it is feeling it is a problem. So that is why I think somehow we are not able to you know do after our degree is over we are not confident to do anything I am not degrading anyone but that is the kind of engineering education what you have that is why one purposely that finishing school you take the degree but afterwards 1 year you work somewhere very seriously in a workshop learn all this and then only your degree will be given, some countries do that that promotional exam at the end but we do not do anything here, okay anyway.

I think I will quickly tell here this one solid is in plug flow, gas is in mixed flow sorry in plug flow both are in plug flow here also, okay ya here ya gas is mixed flow but gas sorry solid is in mixed flow gas we do not know how it flows but simplest assumption is it can be in plug flow.

So then definitely you know why it is mixed flow because in fluidized bed all these particles are held up or floating in gas and then these bubbles are there where they go vigorously up and then break when they are breaking solids can jump up and then again fall so when they are falling they will go anywhere and that is how you will have almost perfect mixing (()) (57:18) also you can do that and then find out it is almost equivalent to plug flow sorry mixed flow, okay.

So that means a particle in the fluidized bed can move anywhere, anytime that is the definition of perfect mixing and that is true in a fluidized bed you see now if I am concentrating on solids assuming that gas is not important for us then I should use here plug flow for solids conversion or solids you know for solids and here also plug flow and here I have mixed flow.

So in the next class we will derive equations for assuming solids in plug flow what are the kind of equations you get for the design design means finding out what is the volume of the reactor, okay that is what we have to do in the next class, okay thank you.