Momentum Transfer in Process Engineering
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Module 11
Lecture No 52
Fluidization

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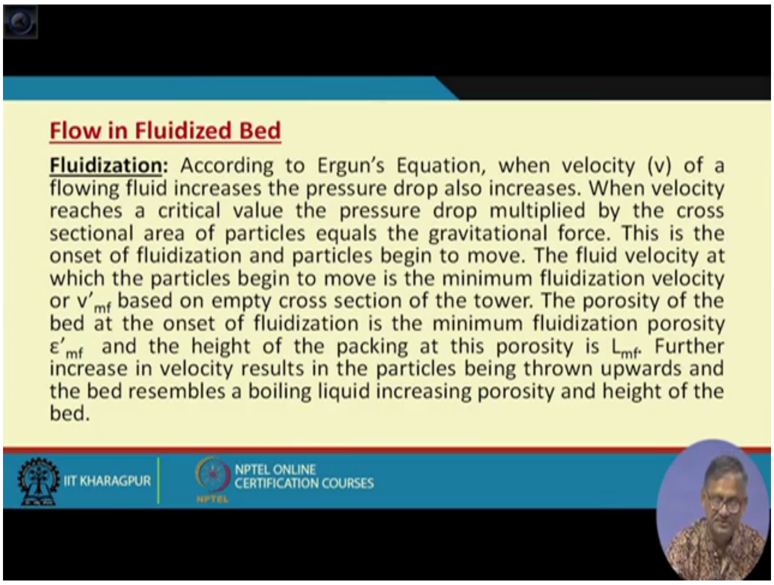

We are done on that bed, now another application of this fluid flow typical in packed bed is called fluidic bed or flow-through fluidized bed. For example, let us go to that 20 yeah so flow-through fluidised bed, now what we understand by that, this is the fundamental thing what we understand by fluidisation of bed, we will come to applications afterwards but before that let us find out let us understand what we mean by fluidisation.

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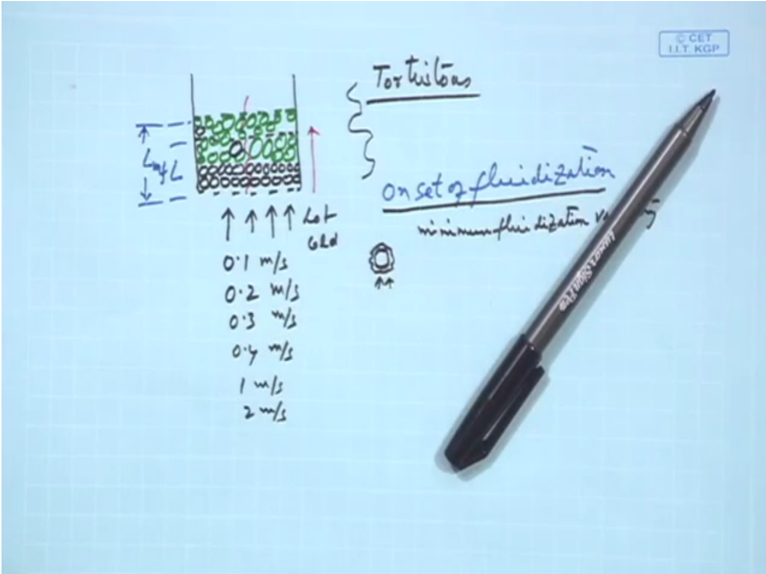

The other day we had said if you remember in packed bed that if suppose you have a container like this and in that containers if it is perforated and if we have full of say peas or similar kind of material, like this is if we assume that it is full up to this. Now say a gas is being passed through this, or a fluid is being passed through this. Now this fluid you can pass at any velocity, say at a very nominal low velocity of 0.1 meter per second, so what will happen?

This will go and there is a term called Tortectors, so tortectors path that tortectors path is nothing but when it is moving like this through the vacant or through the void space between the particles, so we have some void space between the particles, so that void space will be utilised by this gas and when it will go, it will move like this, say gas is passing through this way this way this way, it will pass out and this is called tortectors motion or movement of the fluid.

Had it been no particles, then this gas could have gone through like this step forward but it is not, it has to move through the space available when the velocity flow. Now if we go on increasing say from 01 to 0.2 then 0.3 like that 0.4 like that we are going increasing the velocity, so what will happen after some time these particles will feel that someone is making a thrust from the bottom of this and then they will start moving a little this adjusting this like that, so there will be some velocity when that may be 1 meter per second that may be 2 meter per second that all depends on the gas used and many other factors, the particles many other and packing all.

So at some higher velocity what will happen, these particles they will feel that some thrust is coming from the bottom and they will start gradually little movement in the, so there will be some velocity when these particles will move a little like from here if the particle is getting shifted to this layer, so these particles will be shifted a little like this, like this, like this, like that, like that, so there will be some increase of the length of the original packed bed, originally we had the packed bed length say this 1 as say before the movement of the particle it was say L. Now when this has started, and when the onset of fluidisation we call it be "Onset of fluidisation", so when onset of fluidisation occurs then this height will change to L mf it is called the length of the minimum fluidisation velocity.

So what I mean that these particles they will gradually move from this and all the particles will have a floating like individually they are floating on the gas. Obviously, as we have said that you have to increase the velocity of the fluid, the moment you increase the velocity of the fluid there will be increment of the cost for making that higher velocity. Then if that be, then why do we do? What is the need? The need is that the moment you are doing this, as we said that each particle say this particular particle, it will have if we bring down to this, it will have all around it that gas so the entire surface area of the particle will be exposed to the gas, now this gas could be hot gas, this gas could also be cold gas,.

So either for heating or for cooling if you are using that gas or fluid then heat transfer will be better because the surface area now you got exposed all the entire surface, this is not for a typical one particle, this is for the entire set of the particle, the entire set of the particle which are here, so all the particles they are now exposed to the environment of that gas either hot or cold whatever you are doing, so this improves your heat transfer drastically. There is this addition access up this money which you have invested for creating that higher velocity is compensated or maybe you are getting some profit out of that by increasing the heat transfer there and thereby decreasing the heating or cooling time.

So you are buying the time by increasing the velocity, this set is known as this condition is known as the velocity at which this particle will start just floating on the medium that is the fluid by which you are heating or cooling or through which it is I mean that medium which is passing through this particles, that will be the minimum fluidisation velocity. So minimum of fluidisation velocity is that when your particles have started dancing that is what you can call it to be dancing as if somebody I hope you have seen during your I mean when you were a child some parties or some functions you might have seen that a jet of water is coming out and on the top of it there is a ping-pong or the tennis kind of ball, which is floating on that.

So that you have given the jet of this water and depending on this force which you are applying that particular ball is floating and dancing on that, water particles are gradually hitting on the side and it is dancing like that. So these particles also starts dancing on that involvement and velocity at which this dancing or floating of the particles takes place that is called the onset of fluidisation and the velocity corresponding to that is called minimum fluidisation velocity or minimum velocity for fluidisation,. For example, I have taken this from net or Internet which is available.

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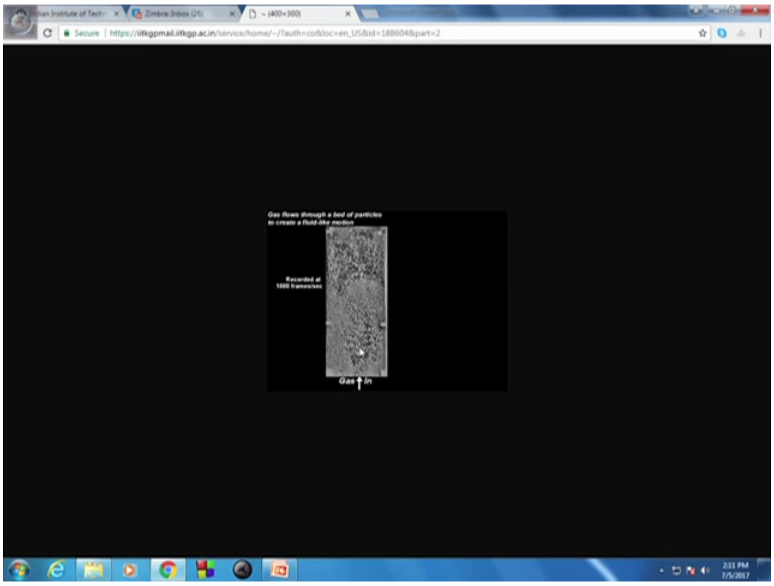

So here if you look at, this is a zip file, it will go (())(12:19) So gas is coming these particles are there, you see when there will be a stay at beginning. So this gas is moving, and gradually it is taking, this one gas only shown one. So if you assume that you are passing all along all through so gas is all coming like that so then what will happen? These particles will start dancing so that the bed and height of the bed is also getting increased, this is the typical example so just to show that yes these particles are gradually I am not saying they are moved away, normally they are not moved away. So that we had told you earlier that pneumatic conveying pneumatic conveying we had said and in that pneumatic conveying you are taking one particle or particles from one place to other place so that is conveying by pneumatic condition or pneumatic flow.

But this is not that, you are not conveying the particles, what particles are doing? They are just dancing on that fluid just floating on the fluid, this is that example of that okay. So this is the bed, originally it was like this and now it has started this all the particles they are moving or floating then the height will be a little increased as we have shown it to be here.

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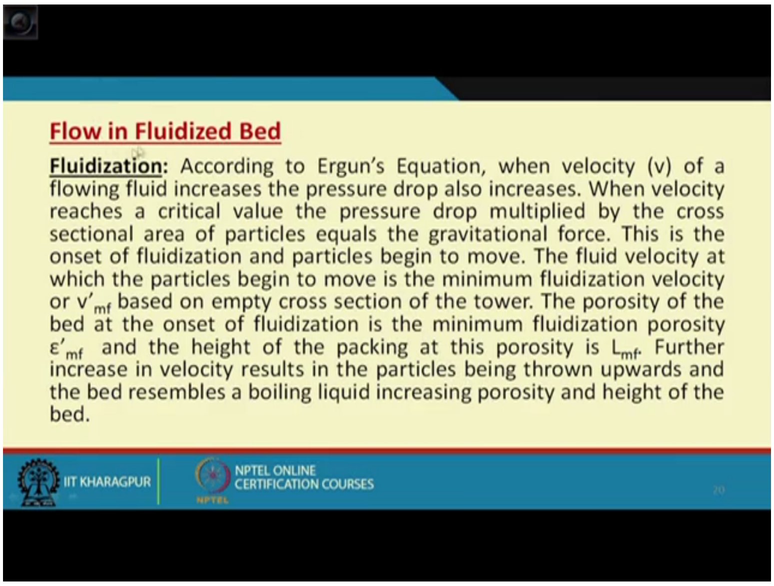

So then let us see that how we have said this, we have said this that flow in fluidised bed that is fluidisation, what is fluidisation? Whatever we have said that is noted down in a language or in a concise way. So what is that, according to Ergun's equation, when velocity v of a flowing fluid increases the pressure drop also increases. You remember Ergun's equation we had said it was Delta p Rho Delta P Rho and then it was Delta P Rho by yeah it was like this.

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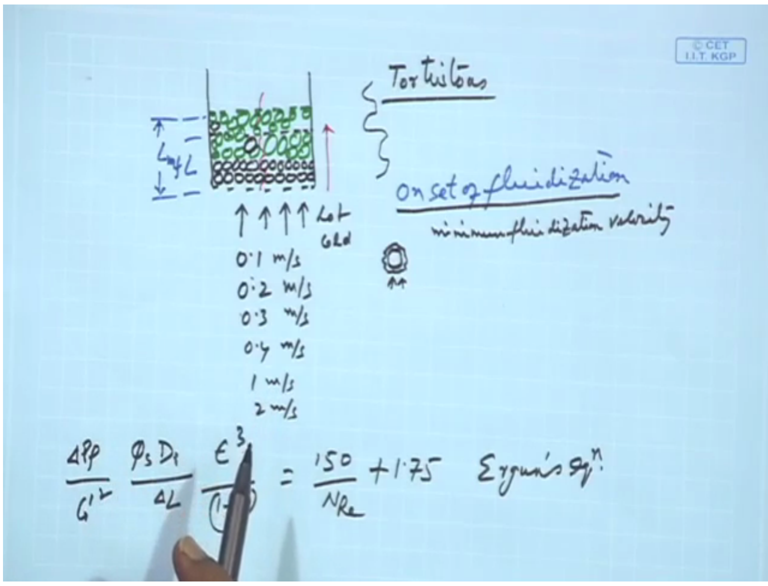

G prime square into Phi s D p by Delta L Epsilon cube by 1 – Epsilon that was 150 by N Re + 1.75, this was Ergun's equation. So Delta P Rho by G prime square into Phi s D p by Delta L Epsilon cube by 1 – Epsilon is equal to 150 by N Re + 1.75 this we said to be the Ergun's equation. So according to this Ergun's equation as the velocity is increasing or the velocity through the particles or packed bed is increasing, the pressure drop also increasing, this is Delta P and in this G prime we have Rho v, Rho v here. So as velocity is increasing, Delta P is also increasing remaining say other things remains same. If that be true then Delta P is increasing this Rho goes there so as this is this being was there so as G prime is increasing, Delta P is also increasing.

So when velocity increases, the pressure drop also increases this is true. So when velocity reaches a critical value pressure drop multiplied by the cross-sectional area of particles that equals the gravitational force. Obviously, that the pressure drop this is the Delta p, this pressure drop must be applied by the cross-sectional area CSA, this must be equals to the gravitational force because gravity is pulling like this and this force is trying to move it. So when the velocity reaching this condition that the velocity is such that the pressure drop multiplied by the cross-sectional area Delta p times CSA is equal to the gravitational force, this condition we call Onset of the fluidisation when Delta p times the cross-sectional area this is equal to the gravitational force.

So when this is applied or when this is applicable this situation arises that situation is known as onset of fluidisation that means any little increase in the velocity will allow the particles to move or to dance or to move inward so it can also be said as dancing as you get the example of that ping-pong ball or table tennis small on the jet of the water many places you might have seen, so that situation that the pressure drop multiplied by this cross-sectional area that should be equal to the pressure force so that situation when the velocity is such that this condition is also good that condition is known as onset of the fluidisation, so we have understood this and this is the onset of the fluidisation and particles begin to move.

The fluid velocity at which the particles begin to move is the minimum the fluid velocity at which the particles begin to move is the minimum fluidisation velocity, so and that is what I said earlier when giving the example that when you are having a 0.1, 0.2, 0.3, 0.4 likewise you are increasing your velocity so in the beginning nothing is happening, after sometime okay there could be some this or that that particles started feeling that okay something is some thrust is coming and then we will attend that velocity, when this situation or this condition that Delta P times sectional area must be equal to the gravitational force when the velocity corresponding to that attends then we call that it is the onset of fluidisation and the particles will start to moving or as we said it is the dancing of the particles.

The velocity at which it is happening is called the minimum velocity of fluidisation or minimum velocity for fluidisation, velocity below that it will not fluidised. Above that obviously it will fluidise and in that case some more particles may slow or may rise or if you go on increasing the velocity, then at certain time this particles may be transferred to some other which was in our case earlier as the pneumatic conveying but we are not going to that extent. So the velocity at which the particles have started dancing or moving is called the minimum fluidisation velocity okay. And the velocity at which the particles begin to move is the minimum fluidisation velocity or V dot mf based on the empty cross-section of the tower.

The porosity of the bed at the onset of fluidisation is known as minimum fluidisation porosity, so as we said when we had initially up to this then there is a porosity and this porosity if it is Epsilon then when the fluidisation has started corresponding to that and the height was L now the new height has become L mf that is the height corresponding to which the fluidisation is occurring that is called the minimum fluidisation height. And this minimum fluidisation height corresponding to that the your void fraction, the void fraction which is there or the gap between the particles that is the void, the gap between the particles which is there that is called Epsilon mf or minimum void fraction when the fluidisation has started.

So the porosity of the bed on the onset of fluidisation is the minimum fluidisation porosity or Epsilon mf Epsilon mf prime because we have denoted that when there was no fluidisation if there is Delta Epsilon if the porosity and corresponding pressure is Delta p corresponding bed height is say L or H whatever you call, say L and when and the velocity is v prime based on the empty cross-section if that be true then when we have started we have obtained that fluidisation that corresponding velocity is V mf prime then corresponding the void is Epsilon mf prime, corresponding length is L mf or height of this is L mf, corresponding pressure is Delta p mf.

So all these parameters are getting changed depending on your fluidisation condition. So when fluidisation condition appeared, that time all the parameters like length or height of the bed or porosity of the bed or velocity in the bed, all these are getting changed and corresponding this we are denoting as mf under minimum fluidisation condition. So we see here that the porosity of the bed at the onset of fluidisation is minimum fluidisation porosity or Epsilon mf prime and the height of the packaging at this porosity is L mf. Now further increase in velocity results in the particles being thrown upwards and the bed resembles a boiling liquid increasing porosity and height of the bed.

As I said obviously if we go on increasing this, then this height will go on increasing like this or then further like this or then further like this or then maybe even further like this. So this will go on increasing and as we said after sometime if still we are going on these particles will start moving and they will be transferred from one place to other place and this is called that this we have said earlier and this condition is called your conveying or pneumatic conveying when you are using air, you call it to be pneumatic conveying as the medium.

So then what you have understood that before the onset of fluidisation, we have a porosity we have a velocity we have a Delta p we have a height of the bed, under that situation as we are increasing the velocity there will be a minimum velocity at which the particles will start moving as if all the particles are floating on the medium that is the fluid which is flowing through that and the particles appears to be like just dancing, this condition is known as minimum fluidisation condition corresponding parameters like height of the bed is L mf, velocity is V mf or V mf prime, void is Epsilon mf prime. So this and your Delta p is Delta p mf, so this way all the parameters will get change, so we will see subsequent process we can find out how much change in the height, what is the velocity, et cetera thank you.