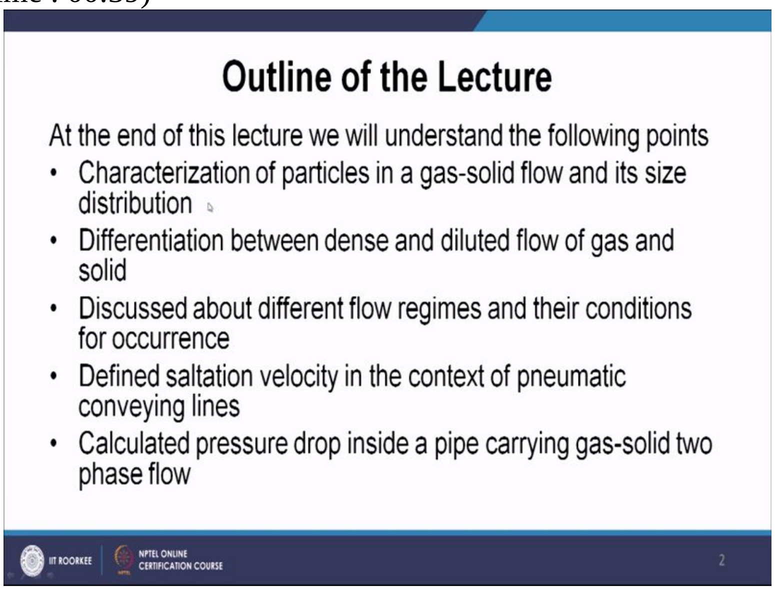
Two Phase Flow and Heat Transfer
Dr. Arup Kumar Das
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture No: 20
Gas-Solid Flow

Hello, welcome to the last lecture Two Phase Flow and Heat Transfer. Today, we will be discussing about gas-solid flow.

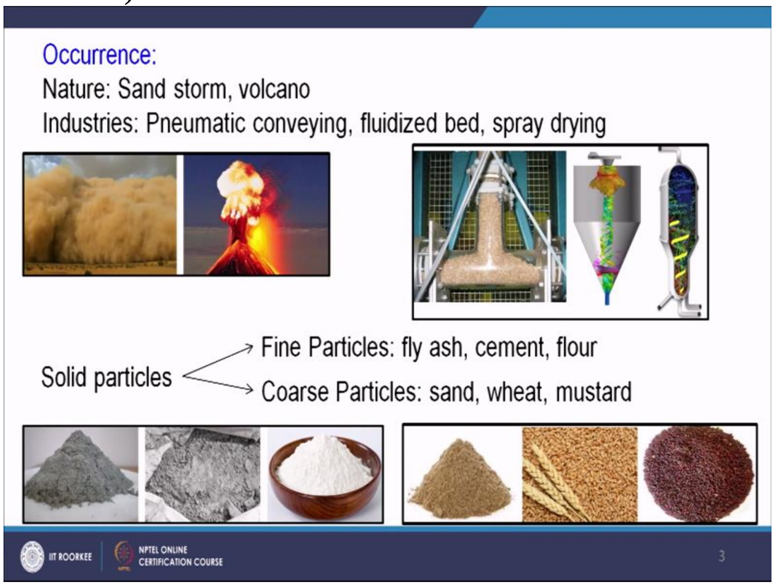
(Refer Slide Time : 00:39)



At the end of this lecture, we will be understanding how to characterize a particle suspended in a gas. We will be finding out what is the differentiation between dense and diluted flow. We will be seeing how different flow regimes can be characterized and what are the necessary conditions for occurring those flow regimes. We will be defining saltation velocity in the context of pneumatic conveying line.

At the end we will be calculating pressure drop inside a pipeline carrying gas-solid 2 phase flow. So we will start with a slide, where we have shown all the occurrences of 2 phase flow okay, gas-solid 2 phase flow in specific. So in nature we can find out in sand storm and volcano, we can see gas-solid 2 phase flow. So here I have given a nice picture of a sand storm in desert. As well as I have given a volcanic eruption picture okay which shows a typical gas-solid 2 phase flow at the top of this volcano. Definitely in industries we are having lots of applications of gas-solid 2 phase flows.

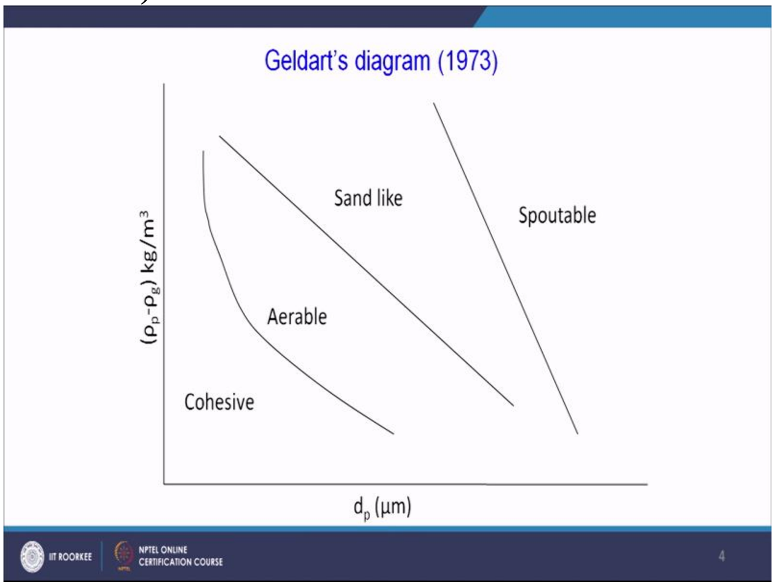
(Refer Slide Time : 1:26)



Some of them are pneumatic conveying, fluidized bed and spray drying okay. So here I have shown some examples experimental and numerical examples where gas-solid flow is occurring in industry. Now there are different types of solid particles which can coexisting gas okay. Depending on the size of the particles we define them as fine particles and coarse particles.

Later on I will tell you how those fine and coarseness can be defined. Just to name few fine particles are fly ash, cement and flour okay. In coarse particles we can categorize sand, wheat mustard, so you can see I have given separate figures for fine particles and coarse particles over here okay.

(Refer Slide Time : 02:53)

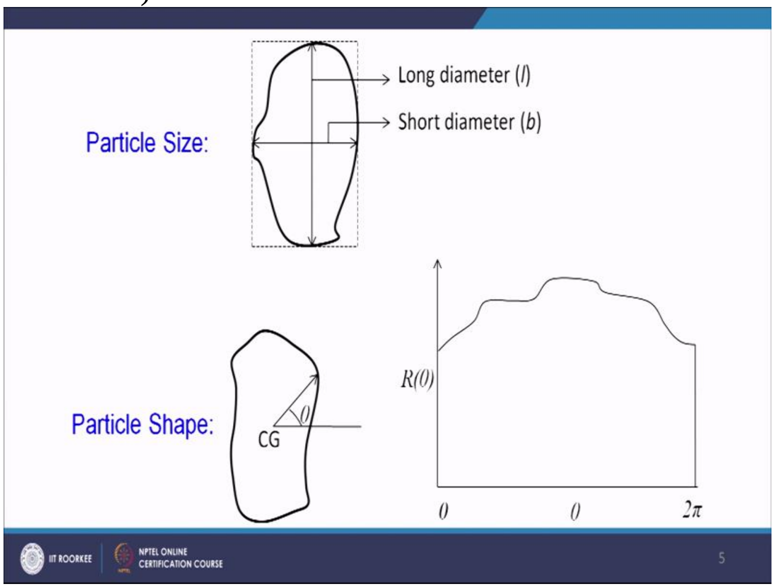


Now how this fine particles and gas mixture can be categorized in case of flow regimes that has been given by Geldart okay . In his 1973 research paper. So this famous graph is actually called Geldarts diagram in which we can find out different flow regimes okay of different particles based on their sizes okay. In abscissa we are having the diameter of the particle dp the scale is chosen as micrometer and in ordinate we are having Rho p Rho g which is a particle density - the gaseous density okay unit is as well kg per meter cube.

So if you see as we increase the diameter okay then we will be finding out at very lower diameter we are having particles in cohesive form. So that means the particles will be actually attracting themselves and forming coagulation. So this is cohesive particles okay. Then with the increase of little bit of diameter or increase of the rho p - Rho g the density difference, you will be finding out those are Aerable that means with the flow of gas those will be actually flying with a gas okay. Then later on you will be finding out if we increase the diameter further we will be finding sand like.

Sand like means those are having some settling tendency also in the air. And at the end we will be having spoutable, spoutable means if you have hopper from there if you drop the particles those will be falling inside the gaseous stream in the by virtue of your gravitational force. So that is called a spoutable nature of the solids okay. So this is a spoutable nature these are applicable for very higher diameter of the particles okay. So based on your diameter and density difference between the particle and the gas these 4 types of particles can be obtained okay starting from Cohesive, Aerable, Sand like and Spoutable.

(Refer Slide Time : 05:07)



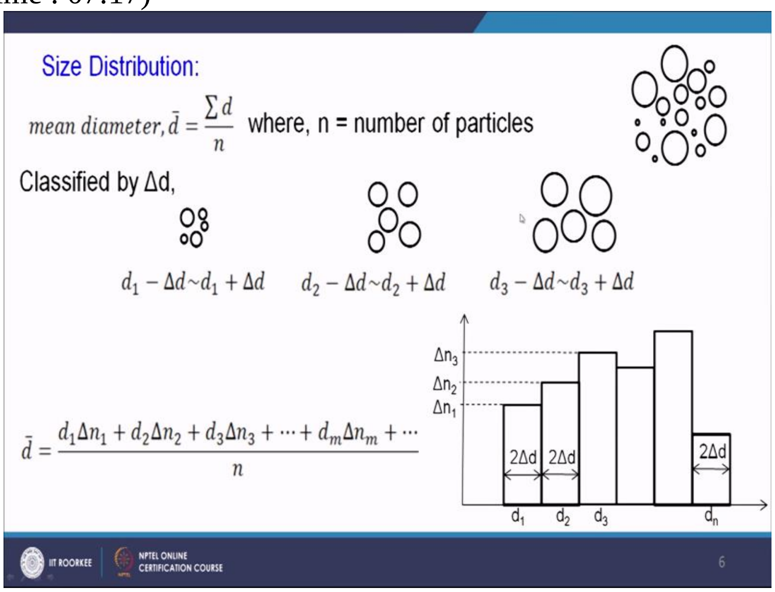
Okay next, let us see as we have talked about dp particle diameter. So definitely we will need to know to characterize the particle okay. So here I have shown you how to characterize the particles, there are different ways one way is characterizing the particle size is what you do you encompass the particle inside a rectangle like this. That means draw one rectangle encompassing the particle inside okay. So if you can draw the rectangle then length of the rectangle is called long diameter l and the breadth is actually called short diameter b okay.

So by knowing l and b you can characterize the particle, irregular particle okay. Another method for characterizing irregular particle is you can start from a line and then you can go azimuthally 2 pi angle over here or rather 360 degree angle over here and at every radial sector you find out what is the distance or what is the radius of the particle starting from the centre of gravity okay. So here I have shown you 1 typical curve, where you can see from zero to 2 pi we are showing over here the variation of theta, where theta is measured from some difference need not to be always horizontal one okay.

And you see in the ordinate we have shown r theta, r theta is nothing but distance of the edge of the particle starting from centre of gravity okay at a particular azimuthally angle theta from the difference. So you can get a typical shape of the particle can be obtained from this r theta versus theta curve okay. So in this way we can characterize the particle size and in this way we can characterize the particle shape okay. Then as we are talking about gas particle or gas-solid flow, we will be finding out particles will not be always homogenous in nature.

You will be finding out particles are having a wide range of shapes and sizes okay. Now to characterize those what we need to do, we need to go for size distribution okay. This little bit of this type of things already we have seen in dispersed flow that means whenever we have seen the bubbly flow situation I have discussed. Let us see it once again. So, let say we are having a cluster of different sizes of the particles like this okay. So starting from very small diameter to very big diameter particles we can observe over here.

(Refer Slide Time : 07:17)



You see all the particles I have shown over here as a spherical mass or let say a circular planar area but eventually you will be finding out all these particles are irregular in nature okay. So always depending on the value of l and b we can convert those into the spherical or equivalent planer circular particles okay. So once we know this particle cluster and their respective diameters what we can do, immediately we can find out mean diameter d bar as summation of d / n okay. So all the particle diameters will be added up and then divided by the number of particles we will be getting the value of the mean diameter right.

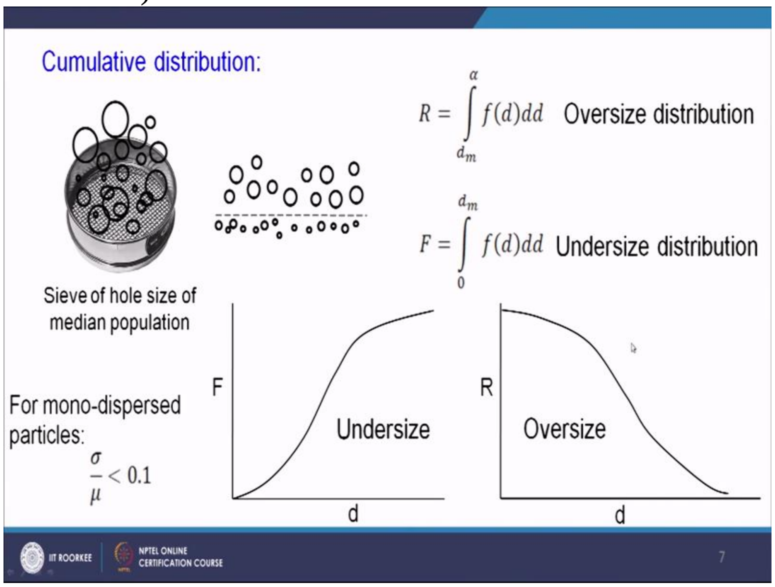
Now, what we can do to get the size distribution? Let us classify okay this particle cluster as a group of a small span of diameters okay. For example let us say here what I have done I have taken a small groups starting from d1 - del d to d1+ del d. So a very small span around d1 I have taken okay. So whatever particles are lying in between this d1 small d and d1 + small d we will be counting those as number of particles in the size distribution. Similarly, we can have another one around d2 and here around d3. So, in your domain size of the particle okay so you are having a wide variety of particle sizes.

So in that if you can discretize in small segments and if you count the numbers then we will be finding out something like this a group of particles smaller particles over here and then progressing on here you will be finding out a group of larger particles okay. So what we can do, we call that we are having n1 number of d1 particles over here, n2 number of you can count the number n2 number of d2 particles and subsequently n3 number of d3 particles. Now if we add then d bar or mean diameter can be written us d1 delta n1 d2 delta n2 continuing so on divided by number of total particle.

So actually this n is nothing but summation of delta n1 + summation of delta n2 and so on okay. So this is another way of finding out you know d okay. Because, if you are having a large number of particles in cluster finding out the average diameter by adding, all those particles individual particles are difficult. So what we do we take an experimental measurement by taking a sieve which, I will be you in the next slides. Different size of sieve we find out and we eliminate a particular range of the size okay and then we can count that how many number of particles are there in that size range okay.

And from there we evaluate the mean diameter like this. In that process what we did not want to do individually all the particles diameter we do not to measure okay. So here I have shown a typical size distribution you can find out for around d1 we are having delta n1, around d2 we are having delta n2 and so on at the last around dn we are having something around delta nn okay. So this type of size distribution one can obtain right. Okay what I was talking to you in the previous slide, you see I have talked about the cumulative distribution.

(Refer Slide Time : 10:39)



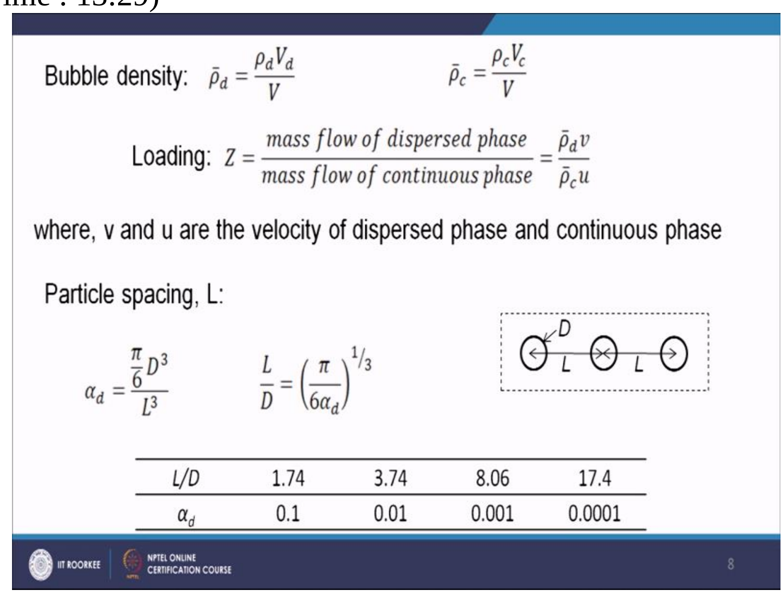
So let us say we are taking a sieve like this okay having a particular size of the sieve and we try to separate out the particle. So you will be finding out that particles bigger than the sieve size will be remaining at the top and particles which are smaller will be going down okay. So in this way what you can do you can sieve out or separate out a size of particles by doing this type of sieving in series that what will be the number of particles in a small subsection around d1 or around d2 something like that okay.

So in that way we can sieve out and you know if in that way if we try to find out what is d bar okay and that then this d bar if we take in such a fashion that d bar we are having the bigger size particles and below this d bar we are having smaller size particles okay. So that we called oversize distribution and undersize distribution. So oversize distribution is that the particles having sizes larger than this you know mean size okay. And the particles having lower size than this mean size will be coming under undersize distribution.

So what we can do we can define R oversize distribution and F as undersize distribution. So aR will be dm which is the median diameter dm to infinity it can go up to infinity. So dm 2 infinity it can go up to infinity so dm 2 infinity and f(d) dd, f(d) dd means how many particles are there of dx size okay. More than dm similarly capital f will be 0 to dm f(d) dd for the lower sizes. Lower sizes can be starting from 0 to the median diameter dm okay. So if you try to plot the f versus d and r versus d at the f defined over here, oversize and undersize distribution, you will be getting a plot like this.

So continuously increasing, so you will be finding out lower size very small number. And here also the higher size also you will be getting very small number okay. Now there is a concept that if you can find out that sigma by Mu of this type of cumulative size distribution, where as sigma is standard deviation and Mu is your mean so sigma by Mu as will be less than 0.1 to consider the particle distribution as mono dispersed particles okay. So if sigma by Mu < 0.1 then we will be calling this one as mono dispersed particles okay. So let us see next.

(Refer Slide Time : 13:29)



So after defining the particles we will be going for the finding out the velocity and you know loading ratio whenever the particle is actually being transported in the coexistent of gas. So let us see we are having let say over here the gas and the solids. So what we will be considering over here so you see rho bar d is = rho d Vd / v okay. Similarly rho bar c = rho c Vc / v okay. So now here you see d symbolizes dispersed phase and c symbolized the continuous phase. So that means in case of gas-solid flow this rho bar d is nothing but your density of the mean density for the dispersed phase that means a solid phase.

And rho bar c is the mean density for the continuous phase that means a gaseous phase okay. Now if we try to find out what is the you know loading ratio okay wet okay, then you will be finding out that is nothing but the ratio between mass flow of dispersed phase divided by the mass flow rate of the continuous phase. So once we try to get the mass flow rate you here we are having the mass flow rate okay. So what we can find out this is nothing but rho d bar small v / rho c bar small u, where v and u are the corresponding velocity of the dispersed phase and continuous phase respectively okay.

So this loading is very, very important parameter capitals Z is very, very important parameter okay. Then let us try to find out that lets say we are having particles like this mono dispersed particles like this. So you are having uniform sizes. So let us say the particle, particle spacing is l okay. So between 2 particles we are having mean spacing as L okay so. How to find out this L okay, now it is also important that if we are having the diameter of the particle let us say that is D.

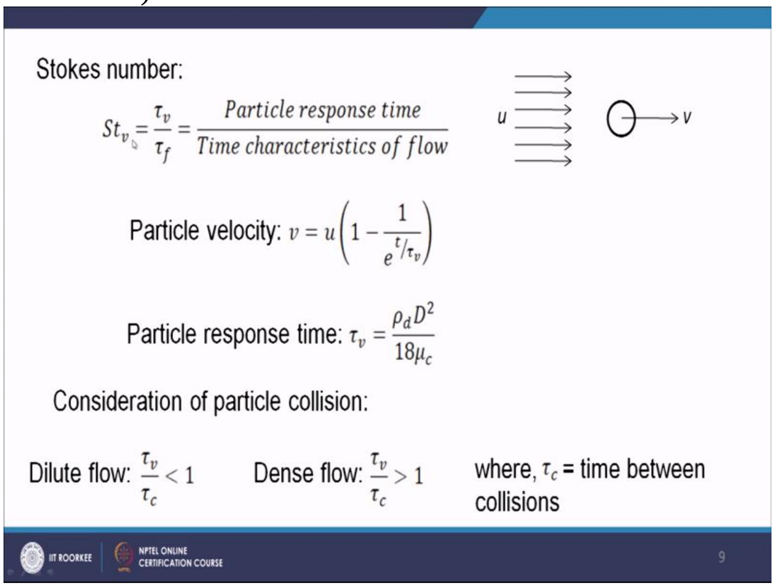
So you will be finding out always this alpha d which is nothing but the void fraction for the dispersed phase can be always correlated with the L and D, what is the length between 2 particles or spacing between 2 particles and whatever at the diameters of the particles okay. So you can find out over here that this alpha d can be characterized as pi / 6 D cube, which is nothing but the volume of this particle having d as diameter. And L cube is actually a rectangular pipe between 2 particles having l as the characteristic length okay.

So this L cube you can say overall size okay of the domain having particle as well as the gas and alpha pi / 6 d cube is actually the volume for the particle, solid particle. So the ratio obviously will be the void fraction for the dispersed phase for the particle okay. So from here I can write down L /D = pi /6 alpha d to the power 1 /3 okay. Now, here you see we can get a chart like this also in literature these kinds of charts are very popular.

Once we know the value of L /D okay. Different values are over here, you can find out what is value of alpha.

So what essentially you need to do, if you are finding out somehow what is the value of alpha d quickly? By referring to this type of chart you can get what is the value of L / D. That means how closely the particles are spaced right. Then let us see another important parameter. Earlier slide I have shown you that this particle velocity v and your carrier phase velocity, your gas velocity u. Those are very, very important parameters okay. Those will be defining the loading z okay. Here you will be tying to finding out what is the relationship between this u and v.

(Refer Slide Time : 17:14)



So here I have shown you a figure, this particle is moving with v velocity by virtue of the carrier phase gas u over here okay. So in this context let me define what is non-dimensional number called Stokes number. So Stokes number is Stv we called as the ratio between particle response time Tau v / the time characteristics of the flow which is Tau f okay. So once we know the value of Tau v and Tau f one can find out, what is the stokes number for the flow okay. Remember this particle response time is very, very important because it will be defining that how frequently that particles are colliding among themselves okay.

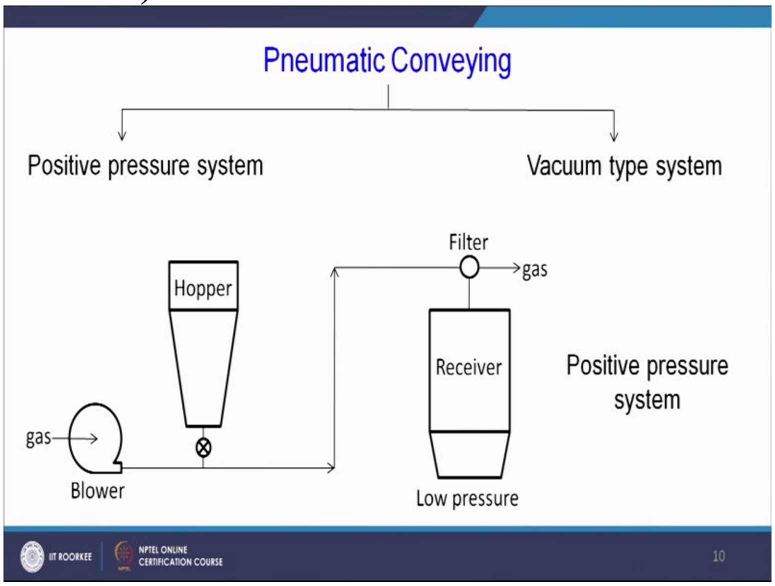
So we can easily find out that particle velocities small v can be related u *1 - 1 /e to the power t /Tau v, where Tau v is nothing but particle response time by the way this is coming from your collision rate. So once you find out, what is collision rate those are dependent on the velocity of the gaseous phase as well as the velocity of particle. So from there if we integrate will be getting this type of equations okay. So what we can do, particle response time we can write down Tau v = rho d D square / 18 Mu c.

So this is coming from your fluid mechanics. So your Tau v which is nothing but your particle response time can be written as rho d D square/18 Mu c okay. Now let us discuss whenever we have talked about mono dispersed flow. So there comes a situation where we are having both the cases that means the particle is closely packed inside the gas or loosely packed. Dependant on that what we have done. We have characterized the gas-solid flow as a dilute flow and dense flow okay.

So whenever Tau v / Tau c < 1, we will be calling that one as dilute flow and whenever will be finding out Tau v /tau c > 1, we will be calling the gas-solid flow as dense flow okay. So already I have shown you what is Tau v and Tau c those are corresponding particles response time and time characteristics of the flow okay. So actually this Tau c is nothing but the time between the collisions okay. So between 2 particles we are having collision. So for that we will be finding out how much time is required okay. So this is very, very important to know the stokes number and your corresponding particle response time okay.

Particle response time we can get from the corresponding physical properties of the gas-solid flow okay and your Tau c one can obtain from what type of flow you are having over here and using this 2, you can find out the relationship between v and u okay.

(Refer Slide Time : 19:43)



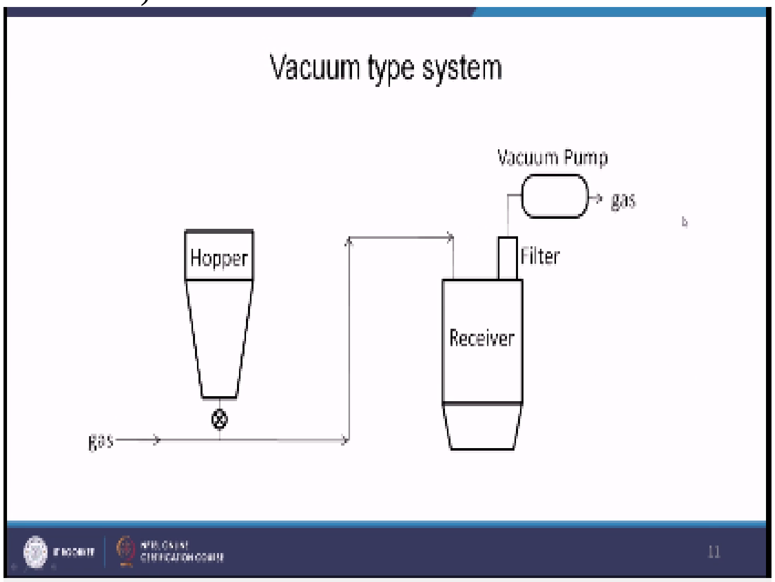
Next let we see, let us show you that what are the different types of gas-solid flow. We see in industry, in industry those gas-solid flows are mainly observed in pneumatic conveying line. So you will be finding out the pneumatic conveying line gas and solid are coexistently flowing with each other.

And you see the pneumatic conveying lines are 2 different types positive pressure system and vacuum pressure system. So here in this slide I have shown you 1 positive pressure system. Let us see the component. So we are having here first hopper. In this hopper we are actually load all the solid particles. Those solid particles can come out through this valve and that can actually come coexistent with the air. So blowing with this blower. So blower is taking air from outside and whenever it is flowing like this due to gravity the solid is falling in the line and that is carrying for whatever in this pipeline.

So after carrying for over here using in this pipeline, which is bend over here. And then after doing it purpose, it can be filtered over here okay. There are various types of filter for separating gas-solid flow, which I am not briefing over here. But what you can do using this filter. You can separate out the particles over here, you can receive over here and you know rest gas you can dump in the atmosphere.

So actually from this hopper we have carried for what the particle in the receiver solid flow. So these actually reduce frictional pressure that’s why you will go for pneumatic conveying lines okay. But important point over here is that you see blower is in the before the hopper section which is called actually a positive pressure okay.

(Refer Slide Time : 21:25)

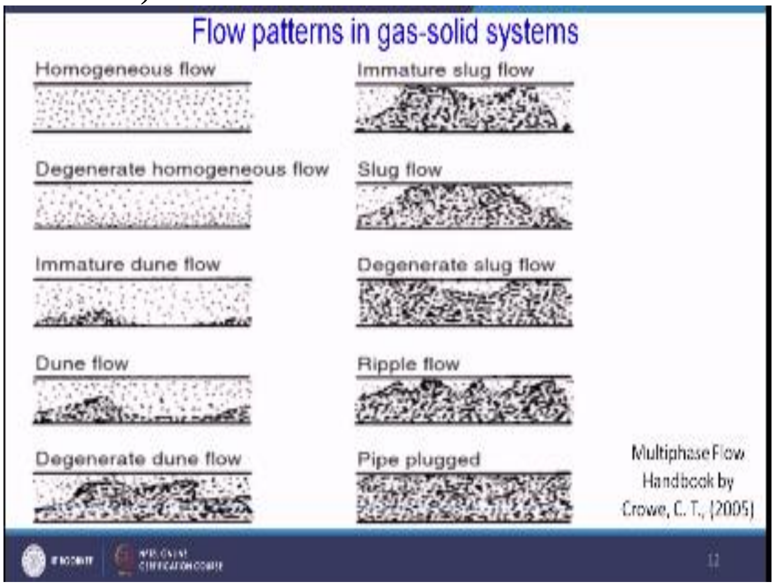


Then next one, let see the vacuum type. In vacuum type, you will find out that though the gas is coming over here and taking the particle from the hopper but it is not actually driven by positive pressure of you know blower in place of that what you have given at the end of the receiver. You have given a vacuum pump which is actually dragging the air from atmosphere through this pipeline okay. And you know at the end of this one receiver will be collecting this particle.

The particles by virtue of way to be falling down and gas through this filtration device it will be actually filter by the vacuum pump. So actually in this system, you will be finding out negative pressure is occurring where as the previous system, you will be finding out a positive pressure is occurring okay. Next let us see what are the different types of flow regimes level in gas-solid flow. So first one is homogenous flow.

So you can find out homogenous mixture of gas and solid over here.

(Refer Slide Time : 22:17)



Then you will be finding out degenerated homogenous flow. You can find out the homogenous flow is actually becoming a heterogeneous one, low towards the lower side lots of particles are being dumped and then immature dune flow somewhere the some shot of dune type you can find out. But that is immature that has not taken its usual shaped.

Then later on with increased of you know your loading ratio, you will be finding out that a proper dune flow. You can see which you seen deserts lots of dunes in that kind of things okay. If you find out the dunes are actually getting higher and higher then you can find out those are actually almost plugging the pipeline and then 2 dunes can merged also among themselves.

So that is called degenerated dune flow. Then this dune actually will be encompassing some amount of bubble over here okay. So you can find out this is separating 1 bubble to another bubble. Look, this is actually bubble, this is actually mixture of gas and solid flow. So here you can find out dune which is almost at the upper wall you actually separating to gas-solid domain region.

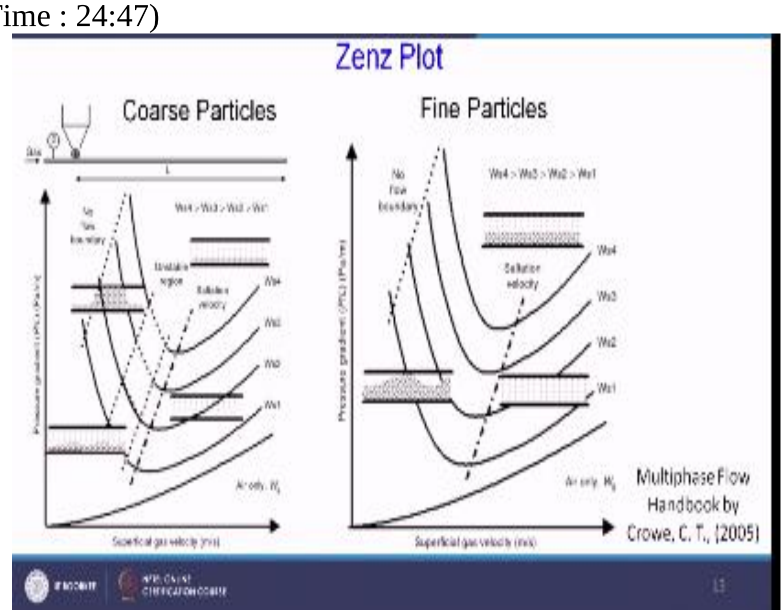
So this you have called a slug flow kind of thing then eventually a proper slug flow. So you see the dune has totally touched the upper wall. So this portion is actually detached from this up steam portion. Then degenerated slug flow if particle loading then you will finding out that small, small air will be entered because this plug flow you will also coming in immature flow.

So the height of the particle position will be increasing the slug flow also and you will find out that a small bubble will be actually getting entrapped in the degenerated slug flow. If you will increase it for that then you will be finding out this upper layer will be forming a ripple kind of thing like this okay. So below that you will be having a very high particle loading issue and above that you are having small ripples okay.

And then at the end you will be finding out the pipe has been plugged with the solid okay. So with increase of particle loading, this was starting from the homogenous 2 pipe plugged. We can find out okay. So this has been taken from book by Crowe, written Crowe okay. Then this is very important depending on you know particle gas velocity and your pressure gradient inside the pipeline.

We can plot that what type of flow velocities or what type of fluid regime will be having inside the pipeline. This is called Zenz plot.

(Refer Slide Time : 24:47)



So you see here I have shown a pipeline okay. So you see here, the hopper is dropping the particle in the gas pipeline. So this is your length l and let say the pressure between the upstream and downstream. We are having p. So p/ l is actually your pressure gradient okay. In Pascal per meter and in up, we saw you are having your superficial gas velocity okay.

So whatever velocity of gas you are having over here that you can see. Now if you start at very high superficial gas velocity then you will be finding out that is having homogenous type of nature over here. And then if you go in the upper side that will be pressure gradient that you can see the pressure gradient increase delta p / l increases then you will be finding out small d position over here okay.

And if you reduce the gas velocity then slowly, slowly you will be finding out that slug type of regime and here you can find out some sort of you know what in the previous slide I have shown over here is immature dune flow or dune flow. So those thing you can see over here at very low gas velocities okay. In case of fine particle, so this is example of coarse particle okay.

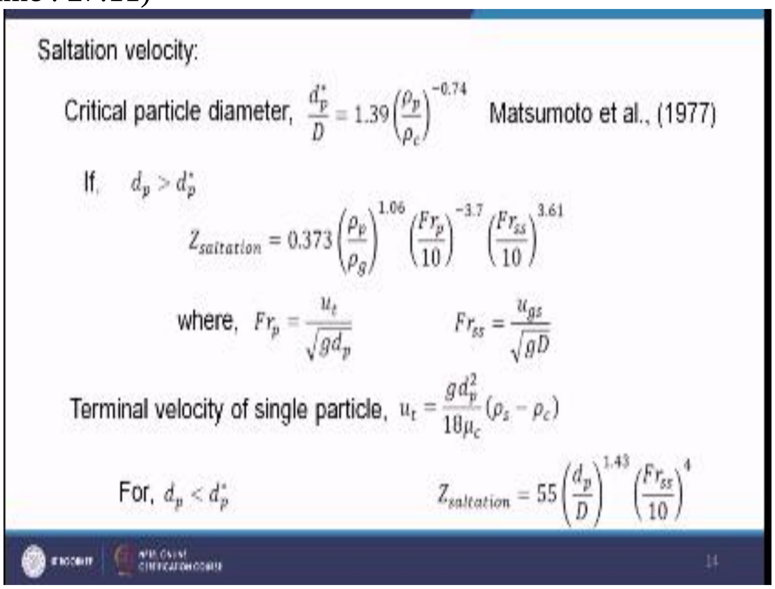
In case of bigger sized particles in case of fine particle, you can find out we are having over here homogenous flow and then once the pressure gradient increases, you will be finding out some sort of stratified flow kind of things. So at the lower layer we are having the solids and upper layer you are having once again dilute gas flow mixture, gas-solid mixture.

And if you reduce the velocity, you can find out that somewhere you are having that slug flow kind of thing whatever you have seen in case of coarse particles also. In these 2 plots, Zenz plots we are also having air only pressure gradient, pressure drop okay for different velocity. If you consider only air is flowing, so this is the pressure drop but you can find out for different loading issues w.

So you can find out what will be the pressure drops over here and along with the different flow regimes okay. In this curves you can also shown one line which is called saltation velocity. The saltation velocity is very important. After this velocity the gas and solid will be in homogenous mixture below and above this sorry, velocity lower than this.

We were always finding out that there will be some kind of deposition at a pipeline okay. So let us see what is saltation velocity. So in case of saltation, velocity very important thing is to find out. First the critical particle diameter.

(Refer Slide Time : 27:11)

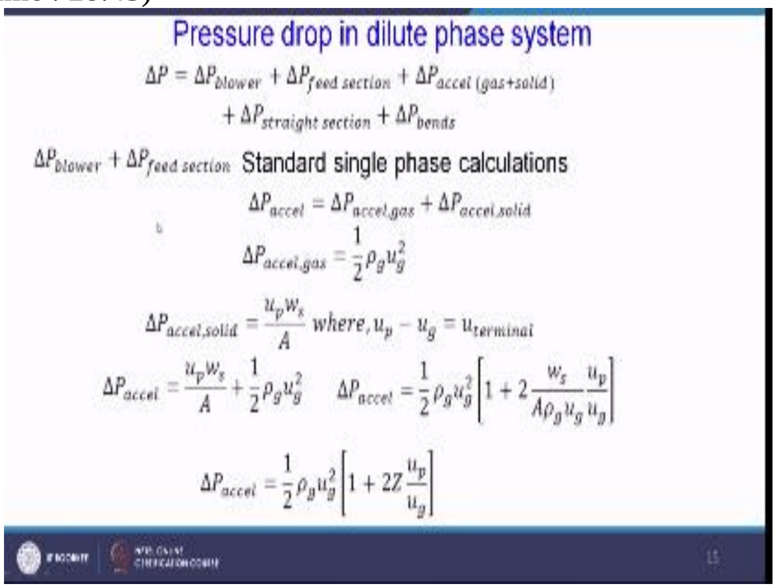


So this has been given by Matsumoto. He has proposed that critical particle diameter dp * can be found out that dp* = 1.39 capital D * rho p rho c to the power – 0. 74. Already we know what is rho p and rho c and capital D, the pipe diameter. So you can find out dp*. If dp *, if your particle diameter dp is higher than dp * that means you are having coarse particle then you can find out the saltation velocity in this fashion.

Where it is the function of the Froude number for the particle and Froude number for the gas. In this fashion Froude number can be found out ut / root over of gdp ugs / root over gd okay. So terminal velocity ut of already you have shown what happen for a single particle. It will be similar for a bubble terminal velocity whatever you have shown the dispersed phase lecture.

Now if dp your particle diameter is less than this critical particle diameter dp * then saltation velocity can be found out in this fashion and here you see Frp is absent Frp is not shown over here. So it is only dependent on Frss which is the ugs / root over gd okay. So in this way you can find out the saltation velocity and find out after which velocity you will be having homogenous flow okay.

(Refer Slide Time : 28:43)



Then let us try to find out what does the pressure drop in a dilute pipe value phase system okay. So pressure drop delta p will be actually dependent on the component whatever I have shown you delta p will be delta p blower + delta p feed section. Wherever feedings will be the hopper then you will be having delta p acceleration due to gas and solid + inside the pipeline you will be having acceleration pressure drop.

Then we are having delta p state section okay. And finally if you are having in bend that I have shown in the pipeline. We are having lots of bends for that also will be having some pressure drop okay. Now delta p blower and delta p feed system that is actually carrying single phase gas.

So pressure drop in those section can be found out using single phase consideration, which already I have shown you how to find out using Reynolds number and finding out friction factor although those things. So you can carry of those calculations and find out the delta p blower and delta p fixation. I will be discussing over here what have about this delta p acceleration first.

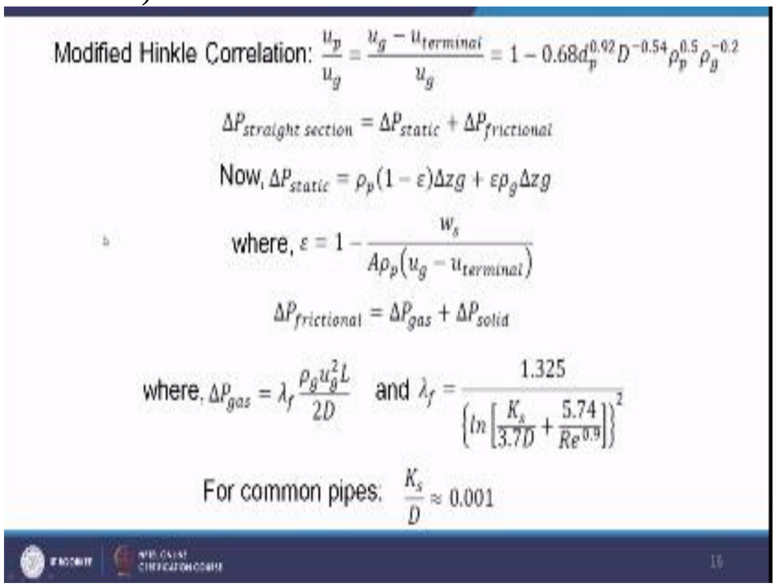
So, here you see delta p acceleration it will be causing due to 2 factors. First one is gas and then second one is solid. So you see delta p acceleration total I have written p acceleration for gas + delta p acceleration for solid. So for gas it is very easy delta p acceleration for gas will be ½ rho g ug square okay.

And for solid, you will be writing down this one as up ws / A, where up - ug is actually u terminal velocity for the particles. Once you know the terminal particle size, you can find out terminal velocity. And you know ug is always known to you, what is the gas velocity you can find out from a blower data also.

So from there you can find out what is up you can put it over here to give the delta p acceleration for the solid. Once we add these 2 using this equation that means this gas and solid acceleration, we will be getting delta p acceleration comes out to be 1/2 rho g ug square 1 + 2* ws / a rho g ug *up/ ug. This can be this, the right-hand side the ratio between all these terms can be written as z up /ug. Okay, so z is nothing but ws by a rho g ug okay.

So finally we get that acceleration pressure drop is nothing but ½ rho g ug square easy to find up into 1 + 2z* up /ug, how to find out just now I have described from terminal velocity it will be coming and you have to find out the z, which is nothing but your loading okay. For finding out your up and ug there is another correlation which is called Modified and Hinkle correlation. So this correlation also helps sometime.

(Refer Slide Time : 31:16)

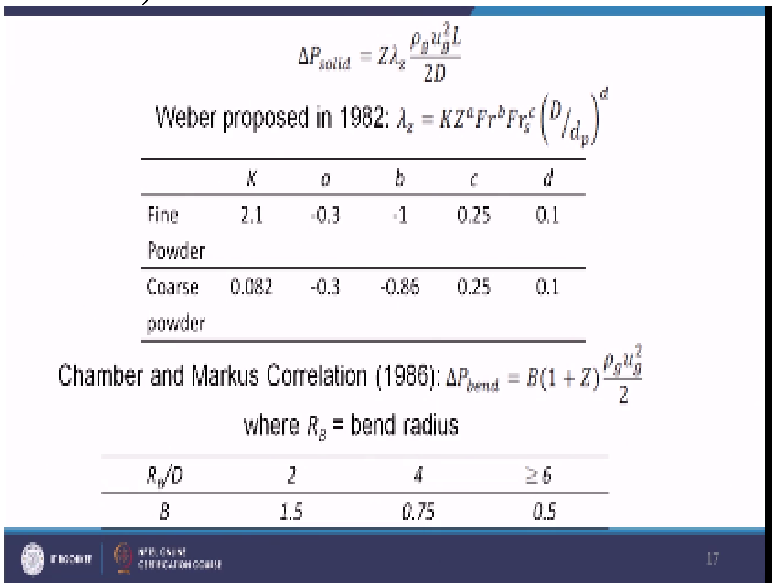


So up /ug is written as 1 - 0 .68 dp power 0.92 capital d to the power – 0.54 rho p to the power .5 rho g to the power – 0.2. So this Hinkle correlation can also be used if you don’t want to find out the terminal velocity. Okay then for the state section we know that for the state section we are having the static pressure head that means the gravitational pressure head as well as we will be having the frictional pressure head.

So already we have discussed that how to find out static pressure here that will be rho p into 1 - epsilon * delta z g, where delta z is the gravitational high epsilon find as 1 - ws /a rho p * ug - u terminal okay. And a frictional part can be written as frictional part can be written as over here delta p gas + delta p solid.

So delta p gas will be actually lambda f * rho g ug square l / 2d okay, where lambda f can be written as 1.325 / ln of Ks /3.7 d + 5.74 by Re to the power 0.9 whole square okay. Here Ks / d for the common pipe it will be something around .001. So all these things are given by a Modified, Hinkle equations. So next part is how to find out the delta p solid.

(Refer Slide Time : 32:44)

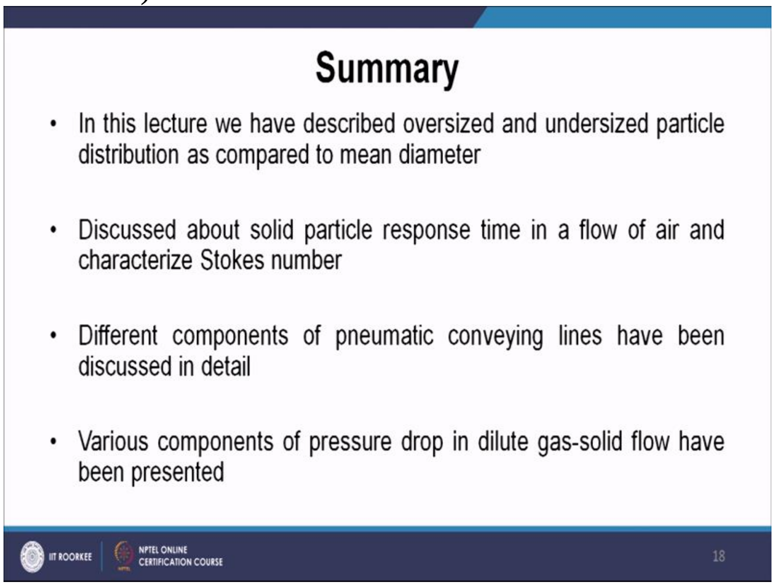


For delta p solid you see this will be z, which is your loading multiplied by lambda z rho g ug square l /2d. Here only unknown is lambda z that Weber has been given on 1982, some correlation using lambda z. So he has told that lambda z can be found out that KZ to the power a Fr to the power b Frs to the power c * D/ dp to the power d okay. Here lots of empirical constants are necessary. First thing is you see we are we need to go for a, b, c and d. So those constants are given like this K is also there so k, a, b, c, d for fine and coarse particle is how to find out Weber has proposed obvious.

So once you know what parameter you need to follow whether it is fine or coarse. We can find out what is lambda g putting the value of lambda g over here we can find out the solid pressure drop okay solid frictional pressure drop. Okay, so rest part is nothing but your bend pressure drop in the equation I have shown you only part is bend pressure drop state section already we have considered acceleration already we have considered. For the bend ah Markus and Chamber they have given correlation in 1986 they said delt p bend is actually B (1 + z) rho g ug square / 2 okay.

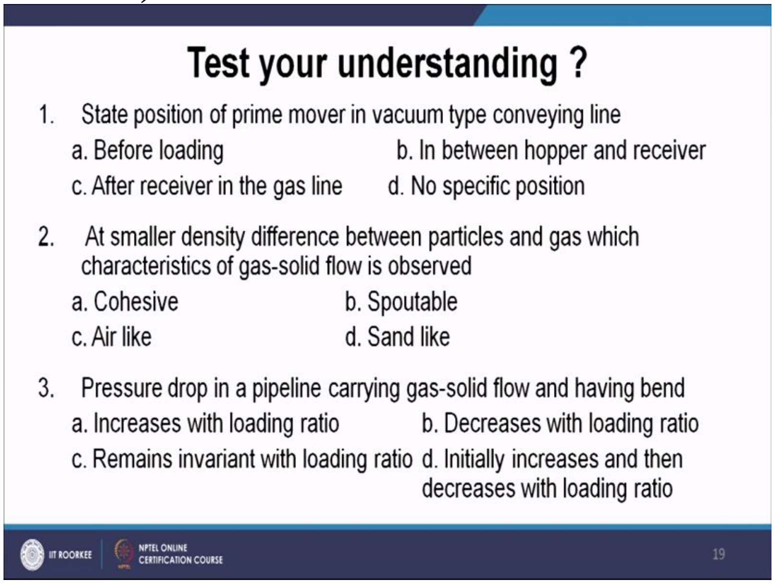
Where RB is the bend radius okay. If id RB / D = 2 then B will be 1.5, if RB/D = 4, it will be .75 B = .75 and if RB / D is more than 6 then always take B is equal to 0.5. So this is Chamber and Markus they have consider for the bends okay. So here I have shown you how to calculate the pressure drop for a pipeline in (()) (34:29) system okay. So with this let us summarize lecture. So in this we have described oversized and undersized particle distribution and compared it with mean diameter. We have discussed about solid particle response time in a flow of air and characterized it with Stokes number.

(Refer Slide Time : 34:36)



Different components of pneumatic conveying line we have discussed in this issue, we have talked about your positive and vacuum type. And various components of pressure drop in dilute gas-solid flow we have presented over here. So let us test your understanding you are having 3 questions over here. State position of prime mover in vacuum type conveying line. Remember this is vacuum type conveying line we are having 2 types.

(Refer Slide Time : 35:04)



So this is vacuum type second type. So 4 options are there, before loading in between hopper and receiver, after receiver in the gas line and third 1 no specific position okay. So the correct answer is obviously part c. We have shown after the receiver in the gas line will give the vacuum convey. Second question at smaller density difference between particles and gas which characteristics of gas-solid flow is observed. At very smaller density okay between the gas and particle so rho p - rho g is very small.

So you will be finding out you are having 4 options cohesive, spoutable, air like and sand like. So these are answer you can find out from Geldarts diagram. So obviously the correct answer is cohesive one. Because that lower density difference we can finding allows cohesive. Third question pressure drop in a pipeline carrying gas-solid flow and having bend.

We are having 4 options. Increases with loading ratio, decreases with loading ratio, remains invariant with loading ratio and finally last one initially increases and then decreases with loading ratio okay. So pressure drop will be always having bend. So that will be coming from Markus and Chamber correlation. So correct answer is first one, increases with loading ratio. Here I end my lecture as well as the course. Wish you best of luck for the final examination. Thank you.