Course on Momentum Transfer in Process Engineering
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Lecture 36
Module 8
Pneumatic conveying

Yeah, so we have seen that when the variable flow or sonic velocity or nozzle flow are there, right? And with the compressible gas flow. Now I thought that why cannot we use with some assumption of course and those valid those assumptions are to be valid that why cannot we use this relations for a another engineering application that is called pneumatic conveying. In many cases you have seen that I do not know whether you have any industrial experience or have you seen any industry where conveying is being done, normally that can be through bucket or through some cannons (())(1:17) things like that in different mechanisms are there.

But one such is also pneumatic conveying particularly as you get the example of spray drying so that spray drying that dried material is also conveyed pneumatically, right? So like that many things are conveyed pneumatically, pneumatic conveying means? With the help of the gas that can be air, that can be any other, but generally air is free we do not have to till now we do not have to buy I do not know in future whether you will have to buy or not, but till now it is not to be brought, but someday now as it is maybe couple of decades back people never thought that somebody has to buy water, right?

Now we have to buy drinking everywhere, wherever you go any part of the world you go you have to buy the drinking water and there in the bottles, right? Couple of decades back people did never think like that you have to buy, now that is also in our country you have to buy drinking water in many places in many cities maybe you have to buy water itself, whole water you have to buy. So we do not know whether in future you have to buy air also or not, but as if now it is being free, so air is used as the conveying medium for conveying from one place to the other place.

So if that be true, then cannot be utilizes till now whatever we have learnt, whatever knowledge we have gained with some assumptions that for this applications that pneumatic conveying, right?

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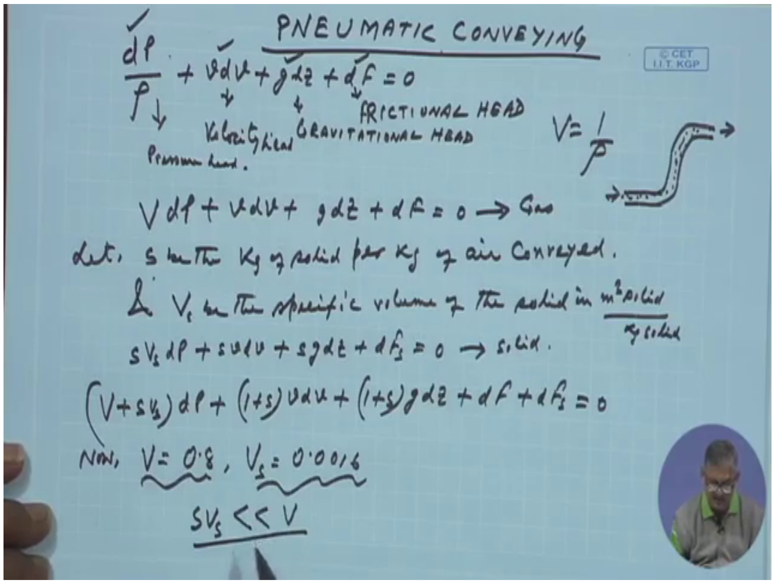

So if you look at, then let us see that in the Bernoulli's equation which we started with is the like it was like this, okay let me write that this is pneumatic conveying so for pneumatic conveying so let me show you a figure.

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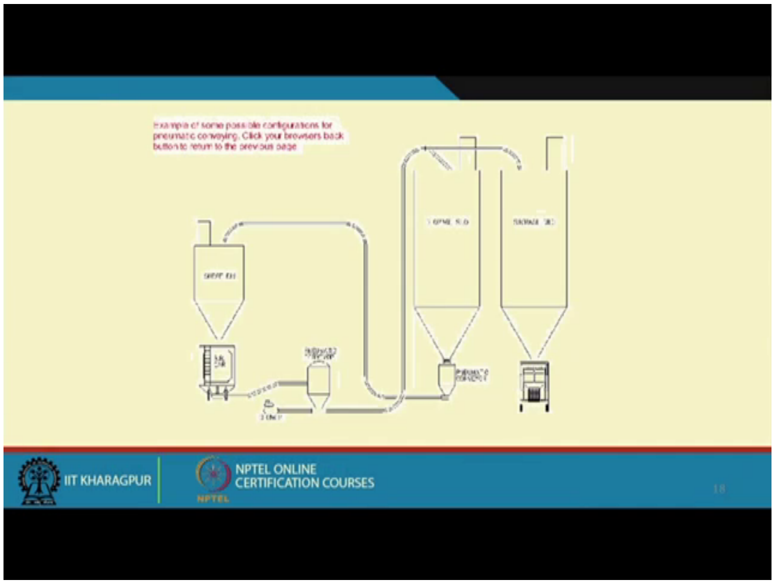

So this is a typical pneumatic conveying, right? This is a typical pneumatic conveying things are conveyed pneumatically and of course you have all other systems, but you are conveying through air pneumatically from one place to the other. So this is a typical example, right?

So if we look at that Bernoulli's equation, so it was dp by rho plus v dv plus g dz, right? Plus df this is equal to 0, right? We said that this is the pressure head, this is the velocity, this is the gravitational head, this is the frictional head, right? If you want you can also write that this is frictional head, this is gravitational head, this is velocity head and this is pressure head, right? So all this put together we got that Bernoulli's equation, right? So this we can rewrite that this to be also we have written earlier this is equivalent to v dp because 1 by rho is equals to 1 by rho, right? So v dp plus v dv plus g dz plus df this is equals to 0, right? Now let us assume that S be the kg of solid of course in pneumatic conveying it is solid which is conveyed, right? It is not normally any liquid which is conveyed pneumatically from one place to the other place.

This is the solid which are being conveyed mostly powders or very tinny small materials they are conveyed pneumatically, right? Whose density is also not so big, then otherwise we have to use lot of force to convey from one place to the other place, for that let us assume S be the kg of solid, right? Per kg of air conveyed, right? And Vs be the specific volume of the solid in meter cube solid per kg of solid, right? And now here we are assuming since it is pneumatically being conveyed, that is from this place to this place it is pneumatically being conveyed, right?

So when it is being pneumatically conveyed along with the air this solid particles are being conveyed along with the air when it is happening like that, so can we assume that the energy equation which is being applied for the gas this is for the gas which is being applied gas can it be also applied for the solid. If we assumed that, then we can say S into Vs dp plus S v dv plus S g dz plus d of fs equals to 0, right? So if it is for the gas this is for the solid, right? So df S this includes all frictional energy and any other energy losses, right? To the solid.

So if we assumed that, then by adding these two we can write, v plus S Vs into dp, right? Plus 1 plus S into v dv plus 1 plus S into g dz plus df plus df S this is equals to 0, right? Now generally v is equals to say 0.8 whereas, Vs equals to 0.0016, so by enlarge so wide, so specific volume of the fluid is much much higher than that of this specific volume of the solid because density of the fluid is much much lower than that of the solid.

So specific volume of the gas or fluid is much much higher than that of the solid, so we can write that S times Vs is this is much much smaller than that of the v, right? If that be true than we can neglect this term that S Vs term.

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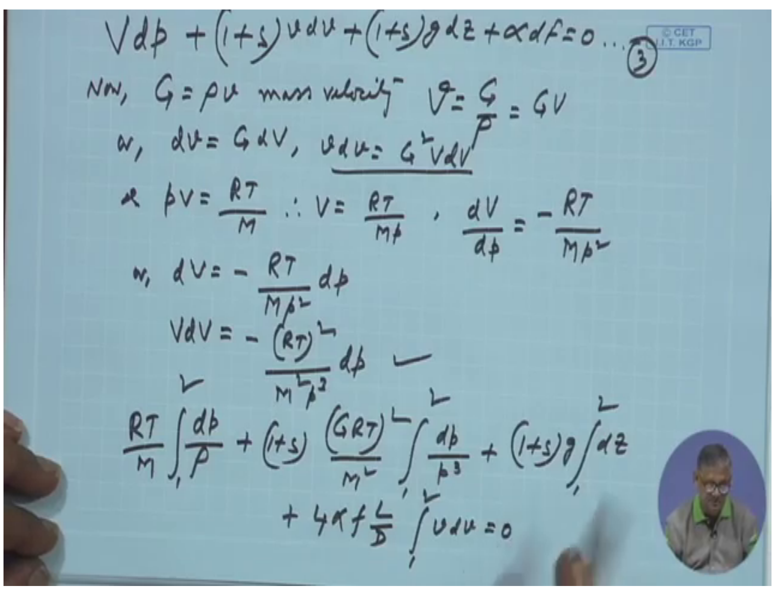

So we can write in that case also one more thing which we would assumed here that this df and df s this put together is some say alpha df alpha is not known alpha is a constant, so this df and df s these two together if we assume to be alpha df, then we can rewrite that equation that v dp because we have neglected S Vs much much smaller being that of v, right? So v dp plus 1 plus S into v dv, right? Plus 1 plus S into g dz plus alpha df this is equal to 0, right?

If that be true, then we can write that say this equation earlier of course we have not given the name of the equations, so if this is gas say for 1 this was for solid it was for solid, say this is for 2 and it is for combination say for 3, right? Now we know that G is equals to rho into v that is the mass velocity, right? This is called mass velocity if G is rho into v that is mass velocity, then we can write that v is equals to G by rho, right? Then we can write v is equals to G by rho is equals to G into v, right? this is small, okay. So G is equals to rho into v that is mass velocity, right? So it is v is equals to G by rho Gv, right? Or we can also write dv this is equals to G dv, right? Or we can also write v dv is equals to G square v dv because this dv we have already seen is G dv, right? And v we have seen is Gv, right? So G and G square and this v is coming this v is coming and dv, right?

So dv v dv is G square v dv, right? Therefore, we can write pV is equals to RT by M not therefore okay we know that pV is equals to RT by M, therefore v is equals to RT by M into p, right? Therefore, here we can write that dv over dp this is equals to minus RT over M p square or dv is equals to minus RT over M p square dp, right? So dv is minus RT by M p square dp, right? Therefore, we can write v dv is equals to minus RT square over M square p cube dp this is by substituting the value of is RT by Mp, right?

So if we substitute v dv, dv value is this with v times RT by Mp square so this becomes square and this was square already so it is cube dp, right? So if we see this, then we can substitute these and rewrite the equation this number 3 as integrating and rewriting that we can write RT by M, right? Between 1 to 2 dp over rho, right? Plus 1 plus S this we can write GRT square divided by M square again 1 to 2 dp over p cube plus 1 plus S times g between 1 to 2 dz plus if we write that df is in terms of frictional loss if we write that, then we can write 4 alpha f L by D, right? Between 1 to 2 again v dv is equals to 0, right?

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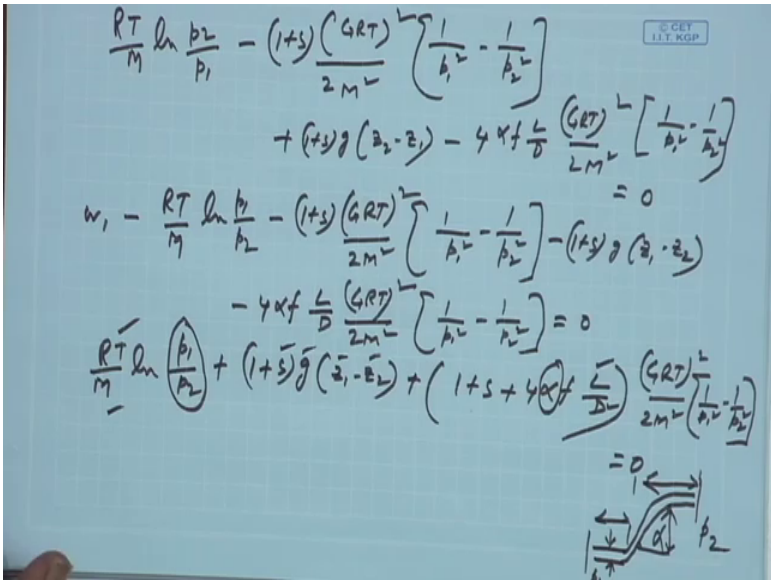

So this on simplification we can write that RT by M ln of p2 by p1 RT by M ln by p2 by p1, right? Minus 1 plus S into GRT square divided by 2 M square times since it is p 1 to 2 so 1 by p1 square minus 1 by p2 square, right? This plus 1 plus S times g into z2 minus z1 minus 4 alpha f L by D is 4 alpha f L by D GRT square by 2 M square this is again we can rewrite that we v dv earlier in place of dp so that can be 1 by p1 square minus 1 by p2 square, right? This is equals to 0.

So we can rewrite that minus RT by M ln of p1 by p2, right? Minus 1 plus S GRT square by 2 M square times 1 by p1 square minus 1 by p2 square we write minus 1 plus S into g into z1 minus z2, right? Minus 4 alpha f L by D GRT square by 2 M square this times 1 (minus) 1 by p1 square minus 1 by p2 square this is equals to 0, right? So we can write by taking all negatives RT by M ln p1 by p2 plus if we take this thing common 1 plus s, 1 plus s was already there, so 1 plus s g into z1 minus z2, right? Plus if we take common, then 1 plus s plus 4 alpha f L by D times GRT square by 2 M square into 1 by p1 square minus 1 by p2 square this is equal to 0, right?

So from here if we know many things we can do the calculations for the either velocity or the pressure as an when it is required, right? As an when it is required we can do we see RT by M R is known temperature at which you are conveying is known molecular weight of the fluid if it is air is known either of the pressures you know either p1 or p2, right? Either inlet pressure or outlet pressure you know that is assumed that you will you should know, right? So everything cannot be from one equation or you can only solve 1 unknown, there is no ambiguity in that, right? So here some of the things normally as an engineer you would like to know that you want to send these match material maybe powder or some granular material, so these match material you want to send from one place to the other.

So what should be the pressure drop? That is one fundamental thing which you want to know because that will dictate major investment from your side, right? In terms of pumps and others motors all these will be dictated by that, so there you would like to know if the inlet pressure is so much, what is the exit pressure? Or the vice versa if the outlet pressure is so much, then what was the original inlet pressure.

So if these is known, then only you can say yes I have come to know and we can find out, right? So here this is known s the quantity of the material being conveyed is known, g from that place is known how much distance you are covering that is known, right? So here one thing which can be generally unknown is that alpha, right? Alpha we had taken that Df plus Df s if you remember we had taken that Df plus Df s to be alpha DM, right? And then subsequently that Df we had substituted with the frictional loss, right? That from the earlier equations where we found out the fanning friction factor, right?

So that we are taking here also that that is the frictional loss, so if we had taken that so this alpha can be either known or unknown, right? The moment this alpha is not known or unknown, then you can play with that if you know the pressure drops in the two places like as we had earlier (()) (25:47) if we know that pressure drop in the two places from here you are conveying to that place. So this place, this place pressures you know p1 and p2, then for a known system you can find out the alpha value, right? For that the length diameter this is the diameter length how much length it has covered like this then from there like this, so how much length it has covered.

So that if it is known how much z if there be at all so this is the z if there z is conveyed how much that is known. So if these parameters are known your G mass velocity is known, R is known temperature is known, so you can and M, M that is the molecular weight of the conveying medium, right? Generally it is air, right? If that is known, then you can play with that okay I know the pressures at the inlet and outlet, let me find out the coefficient alpha the ones alpha of that system is known, then subsequently for a different unknown pressure combination you can find out either p1 or we can find p2, right?

So given p1 or p2 alpha you have already determined for that system and from there by knowing all other parameters like length, like height, like distance, like diameter of the material if all these things are known, then you can also determine the pressure because as I said this kind of process where you are pneumatically conveying from my one place to other place and it is how much energy is required that is your fundamental thing.

Whether that is too much in terms of energy requirement and you need to support with loot of maybe pumps, motors and all accessories. So whether that investment will be suitable or not judge with that how much pressure you will be falling or drop will be there, if that is to be known, then this I thought that this can be a preliminary idea about the pneumatic conveying system, right? Again I am saying that I have thought of this that if the fundamental assumption which we made here is that we want to convey the solid through the fluid.

Now if the fluid can have the equation can we assume the same fluid which is also getting with this material can that material also be brought into this. Obviously some assumptions also we had not assumptions that is the reality that the specific volume of the solid is much much less than that of the fluid or in this case here. So if that be true, then specific volume we separated and we said that this much kg of solid is conveyed per kg of the fluid or say here. So that is of course has to be known, right?

So if this way if we can find out the pressure drop or the coefficient of this friction or whatever you call alpha that if we can determine, then I hope we can guess we can have some idea about the drop in pressure, okay. So next time we will try to really calculate or see the numerals how they are coming up, okay thank you.