Bulk Material Transport and Handling System

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Lecture - 16
Exercise with Basic Design Calculations

So, welcome back to our discussions. We started discussing about the design of pneumatic and hydraulic conveying and in that we have introduced you the basic principles. Now, today let us do a little bit of exercise so that you can take up some of the design problems by yourself.

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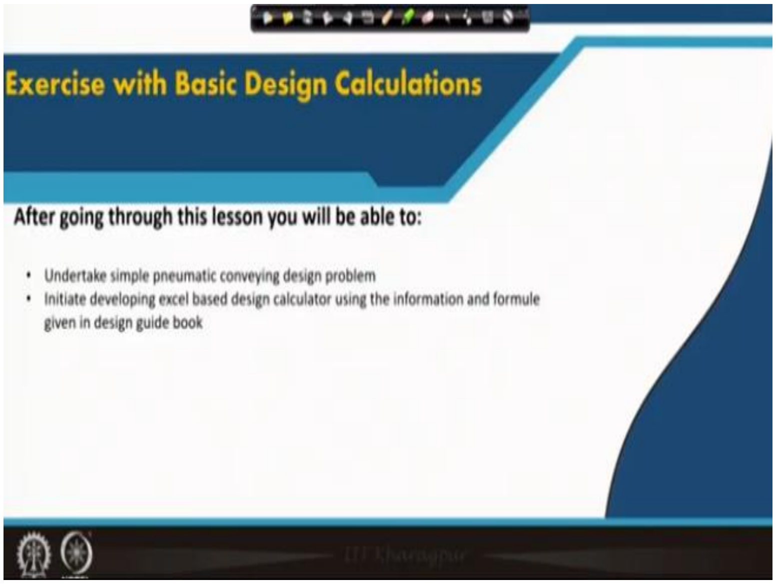

So, we will undertake very simple pneumatic conveying design problem today and I hope that at the end of the class you can decide to initiate some developing excel based design calculator, taking all the formula and the guidance from the design guide book you develop your own calculating package, that is excel based calculator for doing this exercise.

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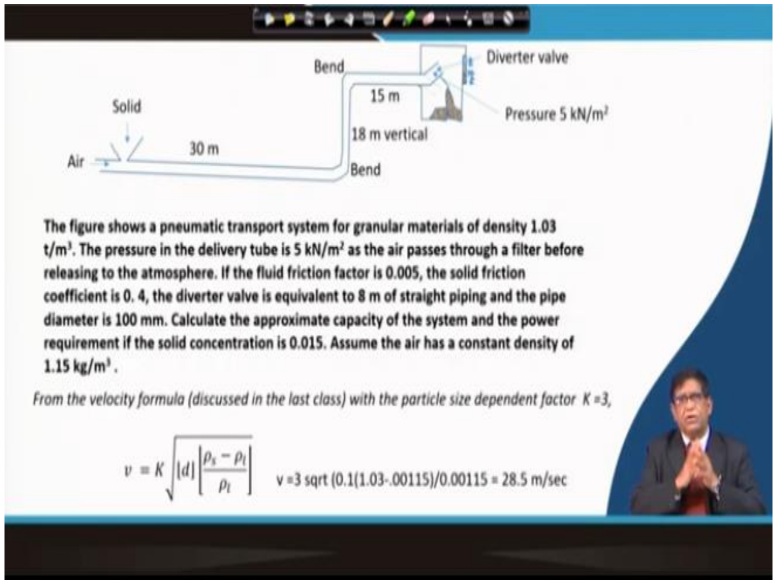

So, in that we have discussed that in your pneumatic conveying, our main objective is that how much throughput will be achieving and for that how the components will be fixed. That means we need to know what will be the diameter of the pipeline? Will have to know that, what will be the compressors or a blower or a fan what should be its capacity? How much motor power will have to be used? All these things, so how much will be the pressure drop?

And in that we have discussed that different flow resin that means, whether it will be a dense flow or it will be a dilute phase flow. And you have seen that in a dilute phase flow, when is your velocity is more, the particles they are distributed, but then we know that in different type of materials depending on the size of the particles that velocity will have to be selected. So, that the particle to particle collisions do not give them a deterioration of its characteristics.

At the same time, we will have to also see that the frictional resistances with the particle and the pipe, the pipe do not get much wear, so there are lot of issues need to be handled. So, let us say how these type of problems are the basic calculations are carried out. In the diagram here, you can see that we have got a system in which we are making the air to go, the pressurized air is flowing over here in this.

And there we are having a diverter valve by which you can load it wherever you want and in inside these ones, we are storing the material and there is a straight that is your horizontal path, there is a vertical path and then again in a horizontal path. We have seen here that; two bands are there and then we will have to introduce our solid. So, that solid introduction you know either by venturi type or by rotary feeder type, we will have to put it over here.

Now, when you will be seeing that, this problem let us define a problem in this way, here is a pneumatic transportation system for granular materials of density is given 1.03 ton per meter cube and the pressure in the delivery tube, it is there 5 kilo newton per meter square specified, as the air passes through a filter before releasing to the atmosphere here. And the fluid friction factor is given and the solid friction coefficient is also given that.

How that exactly fluid will be having friction with the pipe? That solid material will be having friction in the pipe. The diverter valve is equivalent to 8 meter of straight line path that is this will be offering certain resistances and it will be that there will be a certain pressure will have to be applied for it. So, that it works over there and that is equivalent to as if, this length of the horizontal pipe is increased by 8 meter that is an assumption made over here.

And the pipe diameter is also given, so what you want to calculate the approximate capacity of the system? How much exactly will be the throughput capacity if you are using it? And then the power equivalent requirement if the concentration is given. So, you need to assume that air density in this one we have assumed it at say 1.15. So, a problem has been defined, now we have already discussed in the previous class this velocity formula, where this K one factor is there to be selected for different type of particle sizes.

So, for our granular material let us take this as tree. Now, by directly substituting this value given in the problem in the formula, we can get that velocity with which it will be moving, we are getting 20.5 meter per second.

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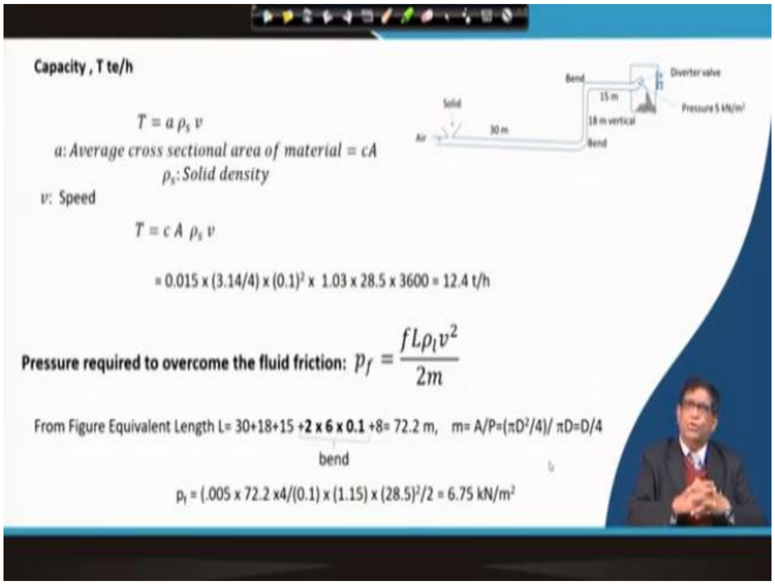

This velocity will be used in the calculation of the capacity. And the capacity is what as you have seen in conveyor belt problem also, whenever you are taking carrying a bulk material in a continuous mode, that area of cross sections of the material on that conveyor belt you remember that, whether it is a straight belt or it is a trough belt, how the materials were there. Similarly, in this when your weather in hydraulic also you have seen that inside the pipe in the fluid, how much material is exactly.

Because, when it is moving in the total cross sections, how much is the material cross-sections. If that, is a material cross section is taken a, and that if you know that your concentration, that is, it is concentration is known speed is known. Then, you can find out if the solid density is not known. You can see that this is meter square, ton per meter cube and then meter per second or that per hour if you say, then you can get it as a tone per hour capacity is coming.

So, this cross-sectional area you can calculate it is, it can be experimentally determined or you just if you know that concentration how much material on the volume of that tool total pipe in that volume of that air, in that how much material you have introduced from there, that also you can find out what is the concentration. If you know the; concentration and the area of cross section of the pipe, because diameter is known.

So, you know that area and you can calculate this stone as in ton per hour, very simple calculations. Then comes your, the how much pressure required for overcoming different frictions. Now, first is that air which is going at through this pipe, at that time how much pressure will be required given by your Darcy's law, we discussed in our previous class. So, when you put the parameters over here this L is the length which will have to be taken for your this paths.

Now, as we said that as because there is a diverter valve and that 8 meter extra length is there. But also, there are two bends. Now these bends depending on the type of pipe, depending on the radius of curvatures you will have to take it. Here, we have taken but for this two, we calculated that 10% of that 6 meter equivalent length we have considered for this and that additional amount of that, additional length we have taken care of.

So, that whatever the pressure drop is there it is accounted for. So, now you can put all the values given and you can find out this drop is coming 6.75 kilo newton per meter square. So, this is the way you will be calculating out the pressure required for the fluid.

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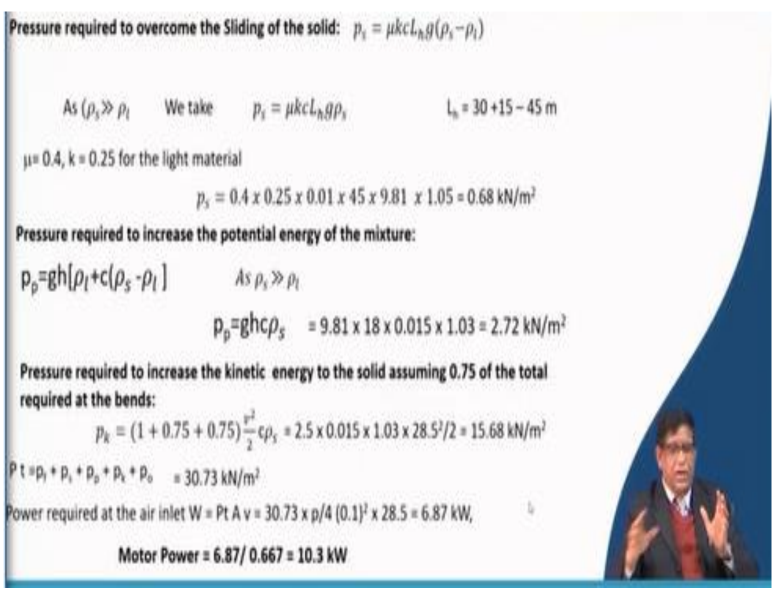

Next comes that your pressure required to overcome the sliding of the solid, because the solid will be dragged through the pipe in that, our this formula also we have discussed earlier, it will be depending on your coefficient of friction and then your mainly that equivalent length and also with the density differences of that solid and liquid. So, if you go on putting these values you can find out that frictional loss it is coming this one.

So, like that you need to calculate the pressure drop for increasing the potential energy of the mixture. Next component is because now this it has been raised, it has been that when an energy that work is being done on the material, that your liquid and your fluid mixture, here air and the solid, this potential energy because how much it has raised for on that you are getting it and you can calculate this is just your gh, then concentrations and the entire density.

When you make this, we are getting that, total how much is the pressure drop that is the pressure will have to be created. Similarly, because it is a moving at that time, that is exactly it will be proportional to the square of the velocities half, this constant of proportionality you can calculate it out and as the given formula, we have given it earlier, we calculate this also and then you can find out the total pressure drop.

And once you know that total pressure drop, then you can calculate the power required or that power which is being operating there, this is the total pressure area of cross sections into velocity. Now, but the motor power will be as if we take the efficiency of the system, motor and the compressor is 0.667 you can get it as this is the power.

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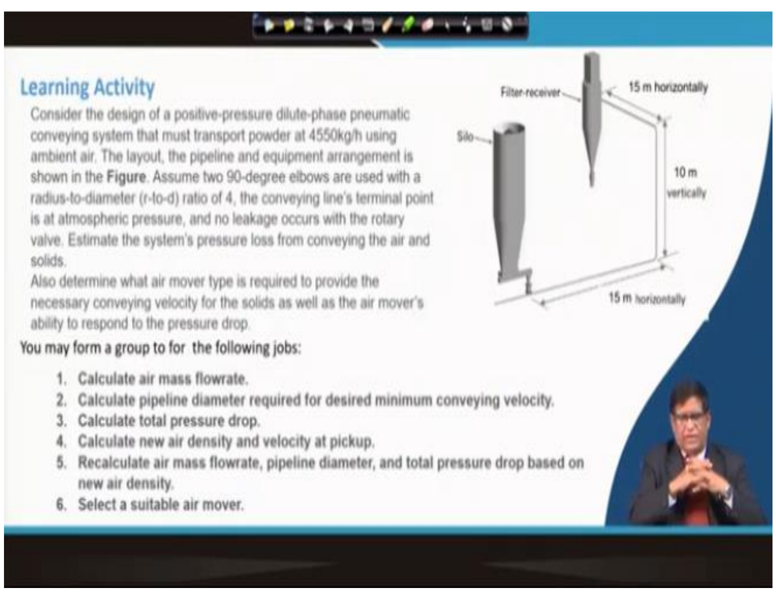

So, this is a simple way we can do a calculation, but now you will have to take this learning activity. We can make different type of combinations of a problem. You can make your own problem like here you have got a silo; from there this is going through this 15 meter horizontal path, 10 meter vertical path, then another 5 meter horizontal path. And here it is a filter receiver and here is the silo you will be feeding it over here.

Now, in such a simple system you may define that is your, what is the tonnage rate. So, here we are telling we want to transfer material at a 4550 kilogram per hour a system. Now, here we will be using air, now here that is your, what is the diameter of the pipe and then your this radius, their ratios because of manufacturing purposes, these ratios will have to be maintained. Again, you can refer to the design guide book.

They will be telling for a particular system, for particular diameter; how much exactly a bend you can do? Because, if you make a very sharp bend and that is at that time, there will be more pressure loss and there could be a soaking over there, if the particle get released and put over there. Then it may plug the flow and that is why we will have to while designing you must be very careful about that considering the bends.

Then, we need to calculate in all these things to design or to prescribed air mover, which can be a blower, which can be a fan, which can be an exhaust fan, which can be a different type of what type of your fan, compressors or blower you use. That will be depending on what is the total pressure loss. So, to get this type of problem you will follow these steps, that is calculates the mass flow rate.

That is total how much exactly the fluid is moving and how much of your; that solid will be moving. After you know that, then you will have to determine the pipe diameter that is what type of pipe diameter will be there. In the previous problem we have seen that pipe diameter and all are prescribed. If it is not prescribed, you know only the your throughput capacity, this is your because you want to deliver, you want to serve some industry that they require this much.

And then you will have to calculate whole pressure drop, then what happens? Whenever, you will be supplying this air and then, that new air density and velocity at the pickup, because there in a particular volume you will have to make this air flow, the air get compressed. So, that is why at that place the density will be having a change under that pressure. So, this will be having an impact on how your other feeders will be working.

So, that is what you will have to remember to find out what will be the new density after the basic calculations. And then recalculate the flow rate. In any designing exercise, these iterations will be going on, till you get the optimum solution. So, you will be doing one, you find out with that and then you see whether your; the flow rate is coming or not, you again then change another parameter and you find out and ultimately you select that which is optimum. So, this is that designing with iteration.

Nowadays, by if you are using through a programming or you can do using by even in an excel sheet, you can very quickly do whole exercise repeating it over there and then you can come out with the solution, so that is exercise you will be doing. Then, after doing these calculations you find out exactly, what is the total pressure coming and then what will be that exactly total work load, that is at how much at what pressure, how much volume will have to be, volume of your mixture will have to be sent at what velocity.

That these three parameters only will be deciding that what type of, that is your mover, that is air mover that to your fluid will that compressed air or your another gas, whatever the media you need to do so that calculation. So, I think it is clear that you have now an approach for doing the designing.

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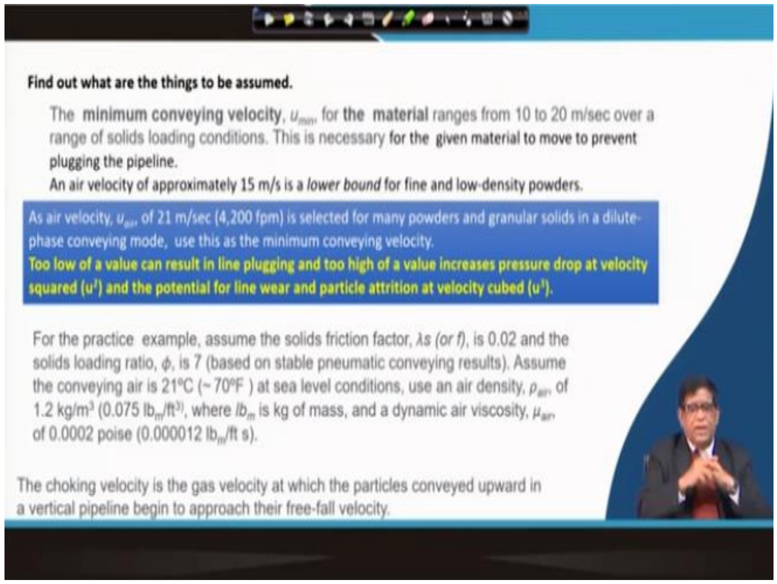

So, this problem if you want to take, the first thing to find out what things to be assumed, because certain when the designing exercise start, at that time you take certain preliminary assumptions. From that assumption, you will start calculating and then again you will be refining your assumptions or you will be redefining and recalculating the things, so that you get your optimal solution.

Now, what first thing is that a minimum conveying velocity, that is your air velocity and for the material that could be you can take 10 to 20 meter per second, over a range of different solid loading conditions. Because if that you will have to again consult the design book for a particular material which is there, what type of range of velocity will be useful for that. And this is exactly as the velocity has got its direct impact on the flow pattern.

Whether it will be your dense flow, your plug flow, whether it is a that is your saltation flow, whether it is having a dune flow, all this different type of flow has got a relationship with the density last class you have seen those graphs. Now, the air velocity in this case, it may be approximately 15 meter per second that is a lower bound for fine and low density powders. So, we have in our assumptions, we have not taken exactly what powder, what material.

If you are transporting through this a very fine that your carbon dust or carbon particles or your coal particles or you are sending flyers, depending on that will have to decide this velocity. Now, air velocity of about 21 meter per second is selected here for doing this exercise, because it works for most of the granular solids and for a dilute phase conveying mode. Because, dilute phase conveying mode you remember that, which will be having almost uniform distributions.

And then that flowing all that, without having any plug or without having any saltations, it will start moving. And, if you make a very low value of this velocity, then what will happen? That material will start depositing at exactly that settling velocity if it comes, then there will be dragging over there and there will be the problem with the pipe, those issues are another, so we have selected like this.

Now, the friction factor that is again from the design guide books, you will have to find for that particular material and the type of pipeline we have used, what will be the friction factor? So, here it could be your 0.02 and the solid loading factor which is again an important that we were if we defined it, that is that your; the bus concentrations and that air mass their ratio as a solid loading factor and for that, we take as a 7 as a value for the stable purposes.

And then we need to know in as we said earlier also that in a pneumatic conveying, if the temperature variation is very high, because of then this your universal gas equation pv by t will be coming, but we are neglecting t and considering it is a constant temperature, here we are taking as a 21 degree centigrade, you can take any other things also. Now, we will have to while considering if the design, whether you are going to design in for lay or it is going to be design it for your on the this near the sea level.

There the pressures and all will be having a different relationship, so you need to be careful about designing that. And then we know that overall, what is that your air density? Because the density of air at the high altitudes will be less and density of air in a near sea level, we can take it as a 1.2 or 1.15 like that thing is there. And then the dynamic air viscosity this value, we are taking as 0.0002 poise.

So, you need to know that the soaking velocity, so sometimes in a pipe the material will get choked, if the particle moves very slowly and it will be depositing that velocity will need to be considered for at a particular situation.

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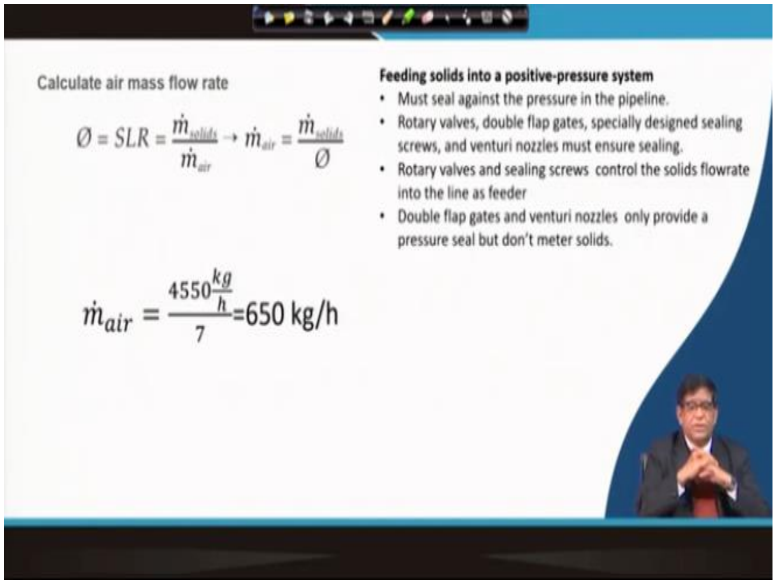

Now, as you know that is your solid loading ratio, it is your what is that mass of the solid and the mass of the air in a particular flow their ratio and that solid racing ratio, we have taken as a 7, so that means in that pipeline first when we have said that, we want to transfer that is your take 4550 kg per hour. And then in that hour that air, that mass of the air that how they will be flowing, it can be determined from this ratio and it is 650 kg of air per hour will have to move along with that material.

Then, only you will be achieving this capacity. Now, there are few things you need to be very careful in a pneumatic conveying system design, your wherever this is say your loading and feeding at that time, it should be totally air sail, that is because it will be at a high pressure in the pipe, if any leak is there, then the whole air will go out that pressure will drop and the velocity will drop and then your material will start depositing.

So, that is very important at wherever the feeder will be there at that point, it should be proper sealing of the system from the outside will have to be there.

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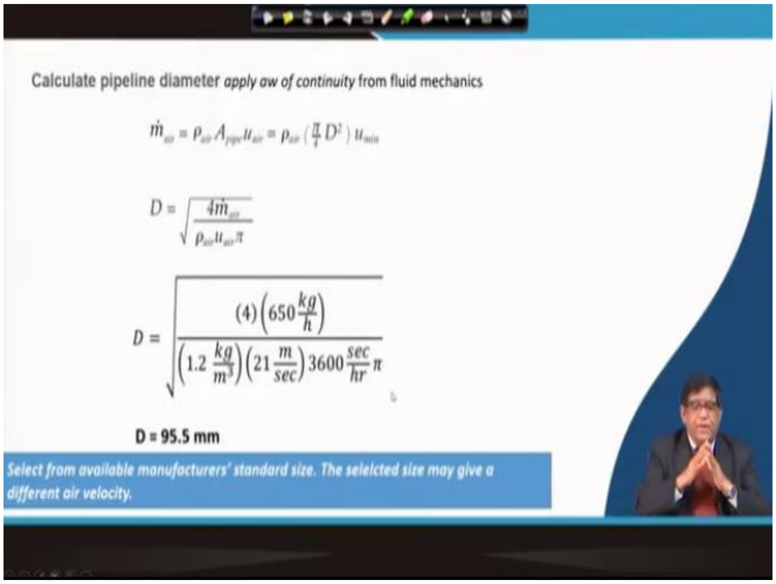

So, the pipeline diameter, how much diameter will be there? The diameter calculations will be on the basis of what is that flow rate, you know that your mass flow rate, and we know the density and you know the density of the air and then we can easily find out that is the diameter of the pipe. So, after you can do this calculation over here and you can find in the given conditions, I calculated it as a 95.5 millimetre you can check it doing it.

So, now one thing is there, when you find a diameter you, please consult the guidebook that, what are the manufacturers are providing. If you give an odd value that which is not available in the market, then you cannot procure it over there. So, at this stage itself you should be referring to the available diameter, which is exactly commercially available.

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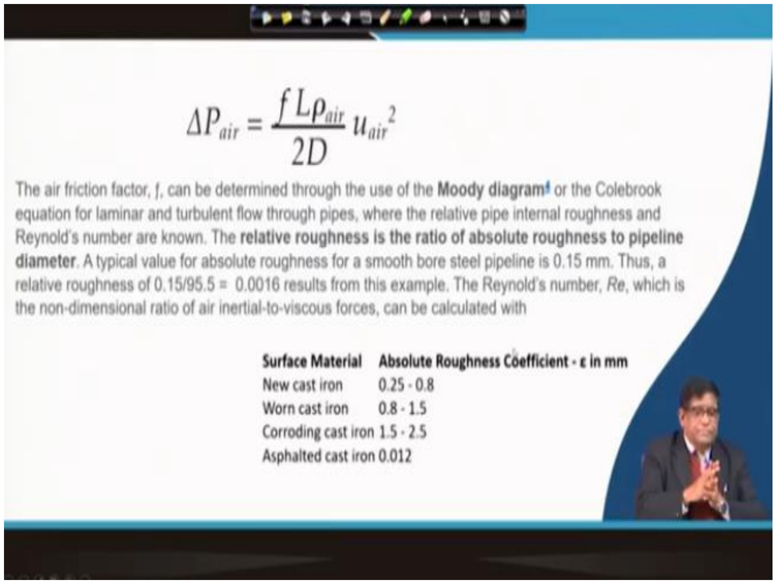

Now, then you need to find out that, what will be the pressure loss? That is as you know that because of the air as just like in the previous calculations, we have to do it by using the Darcy's equations. And this pressure loss we can calculate here now this roughness coefficients that your friction coefficients, this will have to be again selected for the material and for that calculation in a fluid mechanics you might have studied about the moody diagram.

And then how it is related with your Reynolds number those exactly calculus, taking up the proper that your frictional coefficients will have to be done from there.

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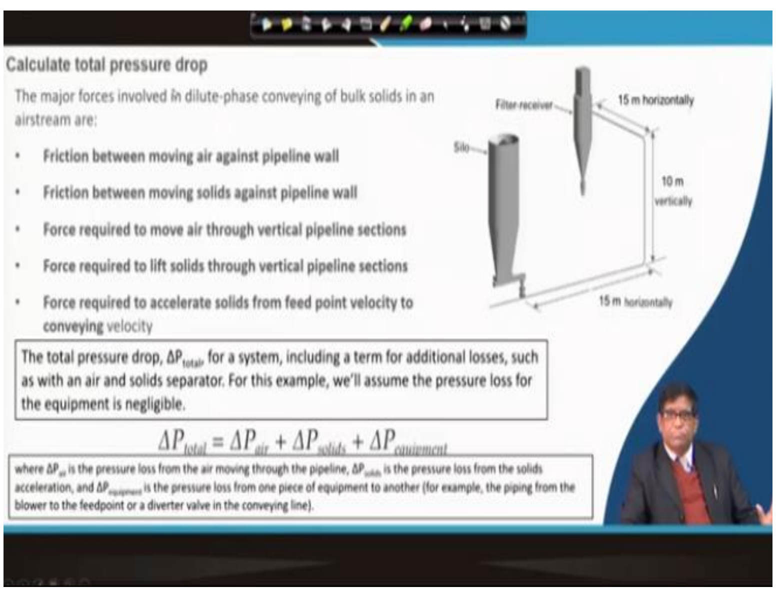

So, now this exactly that pressure drop, the total pressure drop will be where the friction between the moving air against the pipe wall, friction between the moving of the solids against the pipe wall, then force required to move the air through the vertical pipeline, force required to lift solids through the vertical pipeline and force required to accelerate the solids from the feed point to the conveying velocity, that acceleration mass also will have to be there.

So, once you know then the total pressure that will have to be introduced over there that is for the air, for the solid and for the equipment. This once you find out then only you can do. So, this is very important what you need to do in a systematically after getting the problem, you draw a schematic diagram and then you identify, what are the components or what are the work to be done on the fluid or the mass and then you calculate it one by one.

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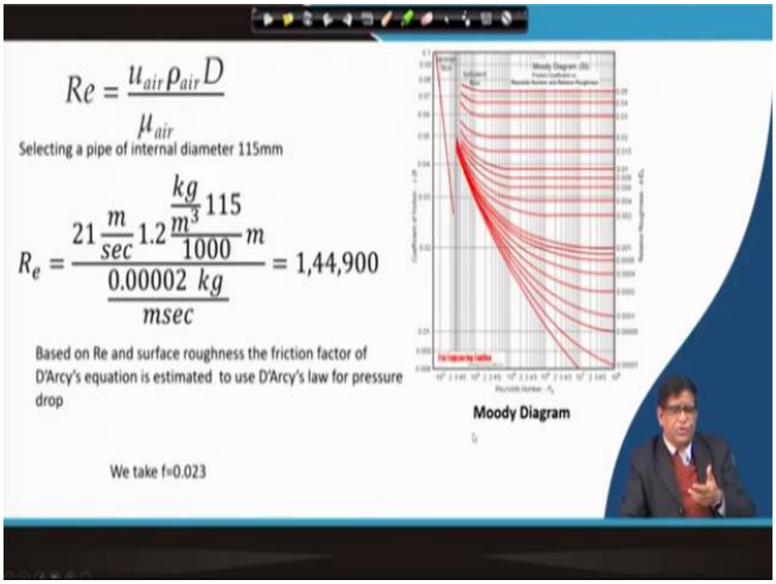

For that, as I said from you can you will be using Moody's diagram, for determining the Reynolds numbers, so that you can find out what is the coefficient of friction is coming. Many times, it is exactly if you are working for a known systems, coefficient of frictions are known, you can do it otherwise, these are available in the design books you will have to use from there.

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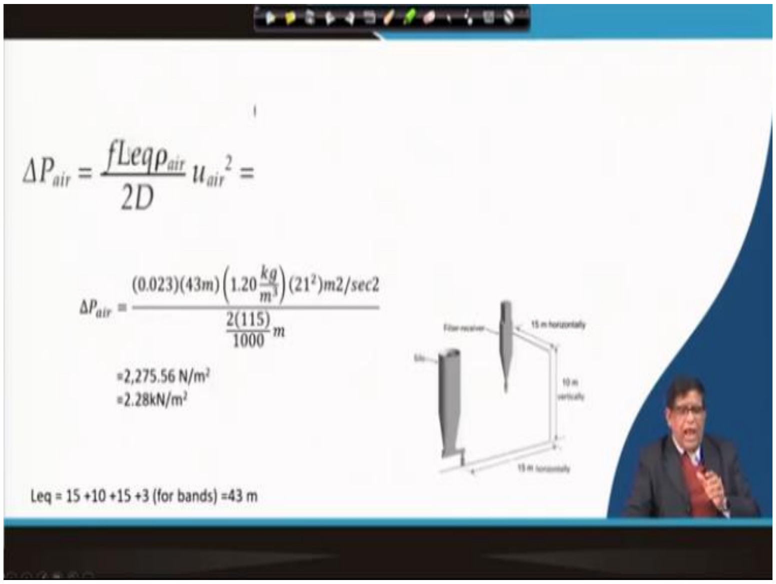

So, once you have got that value f and then this equivalent distance length. Here also just like in the previous one, we will have to take this that for the your curves some additional length will have to be taken, so that is why we have taken a 3 meter that additional length is giving here that equivalent length. And then your density of the air and then the velocity of the air, we have calculated it and with that velocity square, we can find out by what will be the pressure drop or the pressure will have to be introduced over there.

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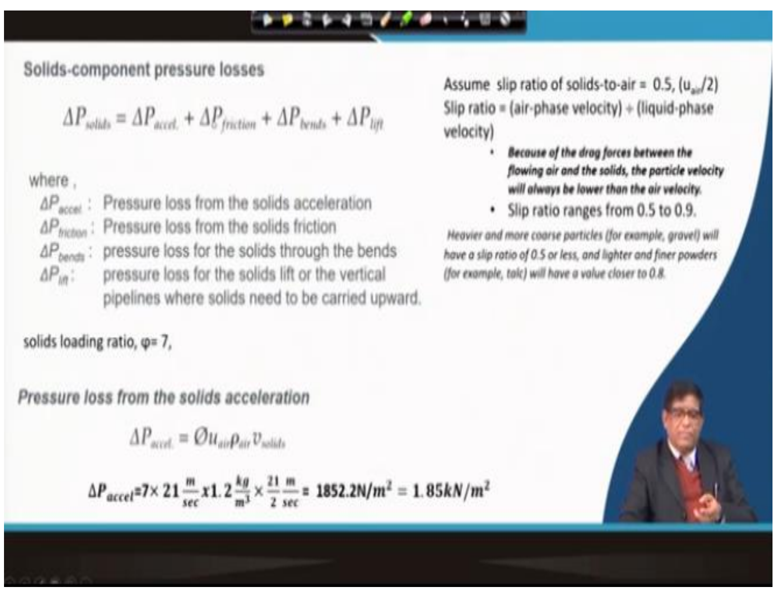

Similarly, for the solids pressure is basically that photo accelerated to overcome the frictions and to overcome the bands and overcome the lift. So, this also one by one you will have to calculate it out. And that as we have taken the solid factor as a 7, that is a solid loading factor SLR is our 7 and on that basis, you can take this acceleration, this formula given you can easily derive it, if it is not given and then you put the values, we have done the calculations over here. Just for your understanding you will have to do it yourself.

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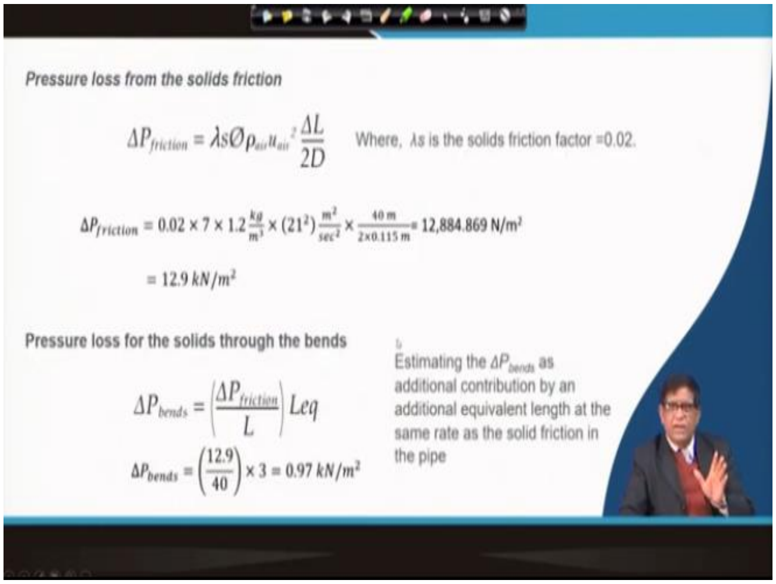

Now, the pressure loss from the solid frictions is again same formula only here that you will have to use this formula of getting this value, because this frictional force you can see here, this pressure coming about your 12.9 Pascal. When you are getting 12.9 Pascal compared to all other pressure, this solid friction is the highest component. So, need to be careful about and you see how much it is.

So, down for the bends, we will be taking just uniformly distributed or for the 3 meter, because we have got this 12.9 as a friction for the total your 40 meter, so if the 3 meter additional length of your bends, that will be giving you another. So, this will be another contribution to that pressure.

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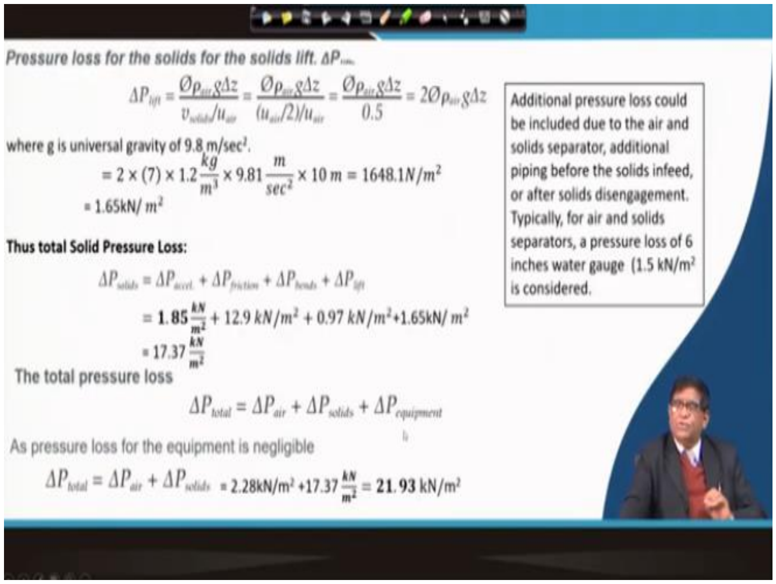

Similarly, that for the solids and that for the lift section, for the lift sections how much Pascal additional pressure is coming? It is coming as you see 1.65 kilo newton per meter square. So, like that your total pressure loss all the things your acceleration and all everything taken care of coming as a twenty. Now, this is the very important calculations to determine this pressure. So, now here we are having about your 22 Pascal; 22 Pascal, total force is coming.

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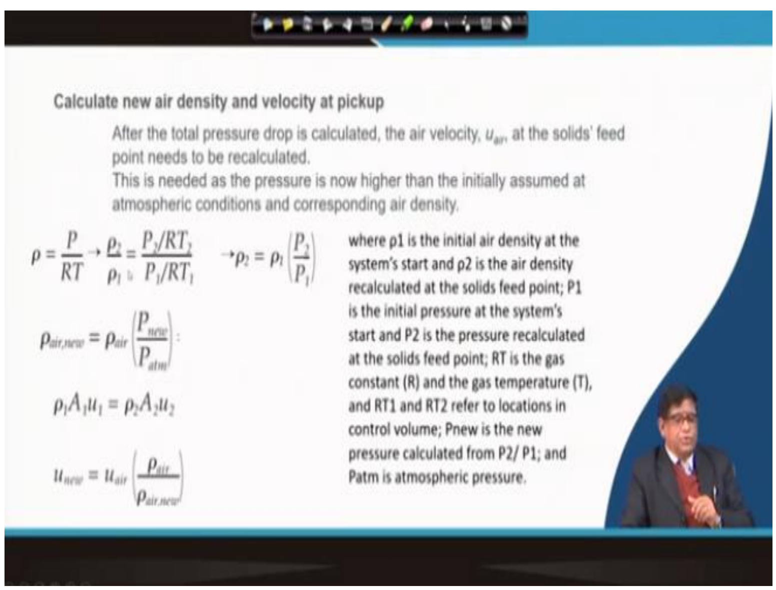

Then, what will be the new density of the air at the peak up? Because, now we know that this much pressure is on the air, so that means the density has now increased. Now that, new density of air on that basis of that, what velocity it is getting with just only pressure ratios you can calculate it out.

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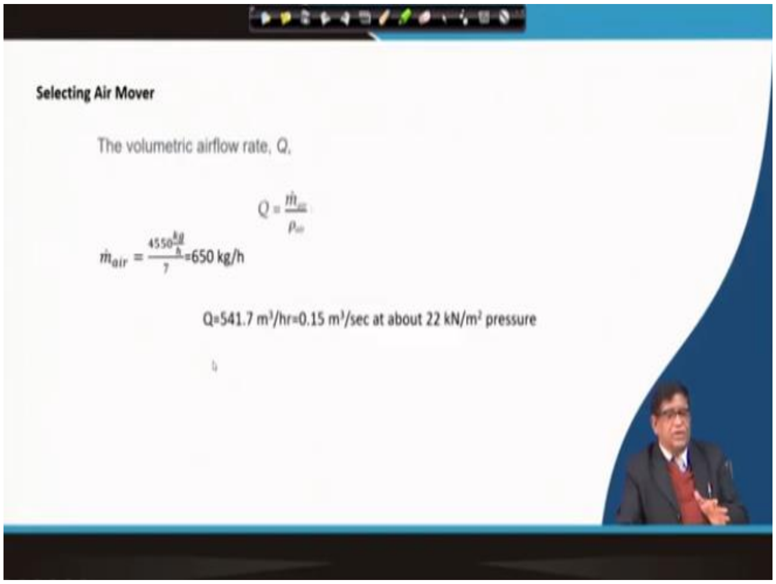

Once you do this calculation, you will have to calculate that what is the volume of air required? Because, you know that your flow rate was that was 650 kg of air was to be introduced and that air, now with the new density you have calculated and with that you can find out that your total amount of air, how much? That is about at about 22 kilo newton or that 22 Pascal, your 0.15 meter cube of air will have to given.

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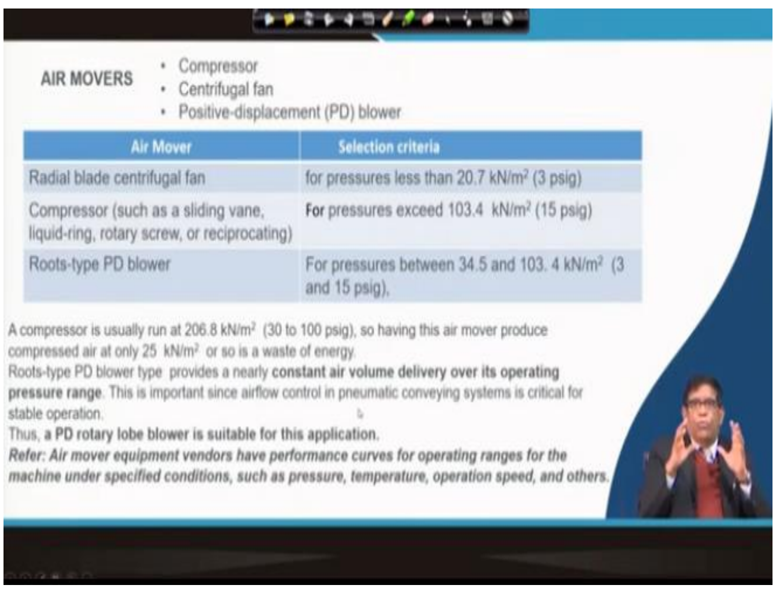

So, now you have got what is the total workload for that your air mover? Now therefore, in any pneumatic system you can have that air mover of three types, either is a compressor type, it is a centrifugal fan or it can be a positive displacement blower, that whatever you use there are certain criteria. For, if your pressure is less than 20 Pascal, that is about 21, 22 Pascal, you can use the radial blade centrifugal fan. The normal centrifugal fan can force the air to the system.

That is why this type of thing will be used for a low pressure work. So, for example in your dust collecting system, if you are working in a coal handling plant or a raw material handling section of a steel plant, where the materials are going in a conveyor belt, lot of dust will be generated, some dust collector is there from the dust collector or from that your electrostatic precipitator, the dust will have to going through a pipeline.

In that you can have that your low pressure area, it may work. But where pressure exceeds say about 100, it go 100 and 130 at that time you will have to a different type of compressors are there, that will have to be selected. And for a medium size say between 35 to 103, that is your 35 to 105 Pascal you can have roots type positive displacement lower. So, if this is there as a preliminary design calculations and design things here will be prescribing, let us to take this blower.

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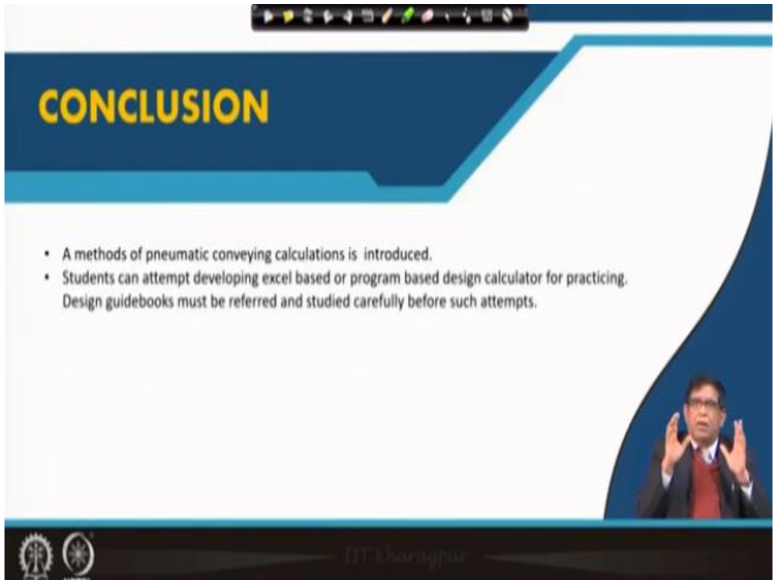

Now, once you have done that, after that you will have to check the design guide book, recalculate, reiterate because, now we have taken a particular design, that is particular blower a particular pressure. Under that, whether you are achieving that target that is your; this selected system with that diameter will it be giving you the flow rate or not. Once you have selected that and then you prescribe, after that will be coming your how you will be doing the manufacturing drawing.

That means, once you have just found that one, but to erect it in the site there will be more things will have to be done, how will design the layout and all those things comes in the detail exactly when you will do an applications in the field. But for this here, I think you have now learned that solid transportations in a two phase mode by hydraulic transport or pneumatic transport, they have got lot of applications in different field, different machines you have seen.

I think, in a civil engineering you might have seen number of slurry pipelines, number of cement slurry they are just put into the while constructing building and all through machines, they are taking over their short distance slurry transports are there. In almost every industry there is a this type of bulk material transported, either in the hydraulic mode or in the pneumatic mode. As for environmental purposes; this dust collecting systems are almost in every plants there.

Other than that, mass flow in your mineral industry and food industry are there. So, these things you will have to study and then try to see the references I have given and prepare to make a some excel based calculations, then only you will be able to exactly develop your expertise as a bulk handling engineer. Thank you very much.