IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

Lecture41

LECTURE 41 : PROBLEMS AND SOLUTION OF FLUIDIZATION

Good evening, my dear boys and girls, students, and friends. We have discussed how fluidization occurs, right? And we have also presented that the Ergun's equation can be fitted in such a way. So, this is the fluidized beds continuity class that Ergun's equation can be fitted in such a way that it can be used for the minimum fluidization equation, right?

So, we found out how Ergun's equation can be used to determine the fluidization, okay? Now, we started with this problem, but the problem was not completely done because the time was over. So, quickly, I am going through the problem again: solid particles having a size of 0.127 millimeters, a shape factor of phi s of 0.9, and a density of 1100 kg per meter cube are to be fluidized using air at 2 atmospheres absolute and 30 degrees centigrade, with a voidage at minimum fluidizing condition of 0.4. The sectional area of the empty bed is 0.3 meters square, and the bed contains 300 kg of solid. Calculate the minimum height of the fluidized bed.

The pressure drop at minimum fluidizing conditions and the minimum velocity for fluidization, of course, given the condition is viscosity is 1.8 into 10 to the power of minus 5 Pascal seconds, and the molecular weight is 29, okay? So, we have found out that the minimum height of fluidization is 1.52. We have only equated here, assuming that if there would have been no void, then it would have been only solid. Then L_0 A_0 into 1 minus epsilon is L_{mf} A_0 into 1 minus epsilon. Since $epsilon_0$ is 0, then L_0 A_0 by A_0 into 1 minus $epsilon_{mf}$ is the L_{mf}, right. So, by substituting A_0, A_0 goes out. So, L_0 by 1 minus $epsilon_{mf}$. So, there we have found out the volume from the weight and density of the solid to be 0.273 meter cube. L_0 we have found out by volume divided by sectional area, that is, 0.273 by 0.3 is 0.91 meter. Therefore, L_{mf} we have found out from 0.91 by 1 minus 0.04, that is 1.52 meter.

Now, if delta P is the pressure drop. Then delta P can be written as Lmf into 1 minus $epsilon_{mf}$ into rho_P minus rho into g, right. Here, what is not known? It is not known what is the rho? So, rho we can find out from the relation P M by R T.

P given 2 into 101325, M is 29, R is 8314, actually it is said 8.314 into 10 to the power three. We are making 8314 directly into T said to be 303 Kelvin. Therefore, rho is 2.33 kg per meter cube. So, we can find out delta P, that is L_{mf}, 1.52 into 1 minus $epsilon_{mf}$, that is 1 minus 0.4. Into rho_p minus rho is given, 1100 minus 2.33 into g as 9.81.

So, it is 9.82 kilo Pascal delta p. Since p_1 is given, therefore, we can find out p_2, p_2 is 212,470. That was given in Pascal, and $P_{average}$ is 207,560 Pascal. Obviously, P_1 minus delta P is P_2. P_1 we have found out to be 2 atmospheres, that is 2 into 101,325. Right, whereas, it is now 212,470 Pascal, right, ok.

P_1 we can say yes, P_2 is more than P_1 with delta P, right. So, $P_{average}$ we have found out is 207,560 Pascal. Therefore, $rho_{average}$ we can find out at $P_{average}$ into M by RT, that is 207,560 into 29 by 8,314 into 303 is equal to 2.389 kg per meter cube. Now, using the Ergun's equation, 1.75 by phis cube into 1 minus $epsilon_{mf}$ whole square by $epsilon_{mf}$ cube into N_{Re} square plus 150 by phis cube into 1 minus $epsilon_{mf}$ whole square. by $epsilon_{mf}$ cube N_{Re} minus D_p cube into rho by mu square into rho_p minus rho into g is equal to 0.

In this equation, other than N_{Re}, all are known. So, we substitute, it is 1.75 N_{Re} square plus 150 N_{Re} minus D_p cube rho by mu square into rho_p minus rho into g into phi_s into $epsilon_{mf}$ whole cube by 1 minus $epsilon_{mf}$ whole square. that is equal to 0, or we can write 1.75 N_{Re} square plus 150 N_{Re} minus all the values that is 0.127 into 10 to the power minus 3 whole square. into 2.389 into 1,100 minus 2.389 into 9.81 into 0.9 into 0.4 whole cube over 1.8. into 1 minus 0.4 whole square.

This is equal to 0 because we have taken that on one side. Therefore, we can write 1.75 NRe square plus 150 N_{Re}, and this on simplification comes to minus 21.07. Therefore, using the Sridhar Acharya formula, minus b plus minus b square minus 4 a c by 2 a. So, it is a quadratic equation where a is 1.75, and b is 150. And, c is minus 21.07. So, we can write N_{Re} as minus 150 plus minus N_{Re} minus 150 whole square, then the minus will go off.

b square minus 4 a c. So, minus and this minus c becomes 4 into 1.75 into 21.07 divided by 2 into 1.75. So, it is 0.14. Obviously, with 1 plus or 1 minus, it will be quite different. You check whether it is with plus or minus taken divided by 2 into 1.75. So, it is 0.14. So, N_{Re} is known now as 0.14.

Therefore, v_{mf} prime from its definition is N_{Re} into mu into 1 minus epsilon_{mf} by D_p rho into phi_s is equal to 0.14 into 1.8 into 10 to the power minus five into 1 minus 0.4 by 0.127 into 10 to the power minus 3 into 2.389 into 0.9. So, it is 5.537 into 10 to the power minus 3 meter per second is the velocity. You see how small it is, 5.537 into 10 to the power minus 3 meter per second. That means it is 0.005 meter per second, right, or 0.006, roughly, meter per second.

So, similarly, if we do another problem of a different nature, then it becomes clearer that particles having a size of 0.2 millimeter, a shape factor of 0.85, and a density of 1150 kg per meter cube. are to be fluidized using air at 25 degrees centigrade and 202.65 kilo Pascal absolute pressure. The void fraction at minimum fluidizing condition is 0.45. The bed diameter is 0.5 meter, and the bed contains 400 kg of solids. Then calculate the minimum fluidization height, the pressure drop at minimum fluidization, and the minimum fluidization velocity, given mu is 1.3 into 10 to the power minus 5 Pascal second and M is 29, more or less similar, a little different, right. So, we can do it. The only thing you have to understand is what is given and what is to be done, right. So, given is that the particle size is 0.2 millimeter, the shape factor is 0.85, the density is 1150 kg per meter cube, and they are to be fluidized using air at 25 degrees centigrade and 202.65 kilo Pascal. absolute pressure.

The void fraction at minimum fluidizing condition is 0.45, the bed diameter is 0.5 meter, and the bed contains 400 kg of solids. Then calculate the minimum fluidization height, number 1, number 2, the pressure drop at minimum fluidization, And number 3, the minimum fluidization velocity. Obviously, the given condition is that the viscosity is 1.3 into 10 to the power minus 5 Pascal second and M is equal to 29. Obviously, like the previous one, here also we can write that if the bed were of 0 porosity, that is, of a single piece, the bed volume would have been 400 by 1150, that is, 0.347826, that is, 0.35 meter cube.

It is absolutely true that, had there been no porosity, like, if it had been a solid, with no porosity, then its volume would be that total volume. So, that is what we have found out: that, had there been no porosity, then the volume of the bed would have been 400 by 1150, which is 0.35 meter cube. Now, if L_o is the height at this condition, then L_o or L_0 is equal to 0.35 divided by the area, which is pi by 4 into 0.5 squared.

So, that becomes equal to 1.783 meters. That is L_0. Then, L_{mf} is nothing but L_0 divided by 1 minus epsilon_{mf}. So, L0 is 1.783, and L_{mf} is then 1.783 divided by 1 minus 0.45, which is 5.55. So, that means it is 3.24.

Since L_{mf} is found out, then delta P can also be found out very easily, as we have seen earlier. That delta P is equal to Lmf multiplied by 1 minus epsilon_{mf}, multiplied by rho_P minus rho, multiplied by g, right. So, what is not given here? Lmf, we have found out; epsilon_{mf} is given; rhop is given; rho is not known; and g is known.

Then we again find out rho. As P M by RT is equal to 202650 into 29 divided by 8314 into 298 is equal to 2.37 kg per meter cube, that is the rho. Therefore, delta P we can find out easily. L_{mf} is known, epsilon_{mf} is known, rho_P and rho are known, g is known. So, 3.24 into 1 minus 0.45 into 1150 minus 2.37 into 9.81.

So, this is equal to 2006.2 Pascal. 2 0 0 6 . 2 Pascal, right. So, if we divide with 1 0 1 3 2 5, then we get so much atmosphere, right. Now, here one thing I would like also to highlight, that, yeah, we are doing problem solution, we are doing derivation, etc. What is the application?

Here, application in our department, we have all kinds of instruments using fluidization techniques. For fluidized bed, it can be used as heating or it can be used as cooling. What is the move? Or purpose of doing fluidization, that first we understand. The moment we are fluidizing, ok, let me also give some idea here.

The moment we are fluidizing, say this is the container, and this we have. So, they are like this; we are sending some pressurized gas. So, under minimum fluidization conditions, next corresponding to this, this is starting may not be dancing, but the whatever porosity was there in this case. The porosity here has increased or decreased. Here it was more compact.

So, when fluidization started, that means they are more free; that means fluid velocity, that is, that means epsilon, that is. Void fraction that increases, right. The moment it is done, that means the area of contact is getting more; earlier it was like this. So, the area of contact at some point would have been disturbed. Now, it has become free.

So, it is having all sizes everywhere possible for the transfer of heat. Basically, this is done for. Extending the surface area or expanding the surface area available, right. So, that the heat transfer becomes easier, right. So, the pressure drop which we have found out here, what I was saying is the purpose is that.

The area of heat transfer or area of action. It can be heat transfer; it can be many other things. So, the area of action is increased; that is the motto, that is the objective of fluidization, right? So, if it is for drying, You can use a fluidized bed dryer; there are plenty available, right?

You can use it for freezing; there are plenty of fluidized bed freezers available, where you can use temperatures much lower than 0 degrees, much lower than minus 18 degrees, whatever you want, you can achieve. In our laboratory, we have a freeze dryer, or rather a fluidized bed dryer; we have a fluidized bed heater or drying equipment. So, hot air is used as the medium in one, and cold air is used as the medium in the other. So, hot air or cold air is either heated separately or cooled separately and then passed through the bed, right? So, what is the reaction?

Reaction means that, in this case, for heating and cooling, we are increasing the surface area, and thereby the heat transfer is increased, right? Obviously, delta P may be required; the more the velocity, the better the heat transfer, the more the pressure drop, right? So, this you have to keep in mind, and now we have seen that delta P is 20062.2 Pascal, right.

P_2 we can find out it is 182587.8, and the average P can be 192618.9. This is simple arithmetic or mathematics. So, $rho_{average}$ is 2.25 kg per meter cube. Therefore, delta P is 0064.3, and $P_{average}$ is 20.064 kilo Pascal. No, delta P is 20064.3 Pascal, that is 20.064 kilo Pascal. From here again, using the equation similar to the Ergun's equation, we get D_p cube rho by mu square into rho_p minus rho into g into phi_s into $epsilon_{mf}$ by 1 minus $epsilon_{mf}$ phi_s into $epsilon_{mf}$ cube by 1 minus $epsilon_{mf}$ square.

So, by substituting the values, 0.2 into 10 to the power minus 3 into 0.85 into 0.45 whole cube into 2.25 into 1150 minus 2.25 into 9.81 by 1.3 into 10 to the power minus 5 whole square into 1 minus 0.45 whole square. is equal to 221.85. Therefore, 1.75 N_{Re} square plus 150 N_{Re} minus 221.85 is equal to 0. Therefore, N_{Re} again using the Sridhar Acharya method we find out minus b plus minus b square minus 4 ac by twice a. So, it is 1.45. Therefore, from the relation v_{mf} prime is N_{Re} into mu into 1 minus $epsilon_{mf}$ by D_p into rho into phi_s, it is 1.45 into 1.3 into 10 to the power minus 5 into 1 point into 1 minus 0.45 by 0.2 into 10 to the power minus 3 into 2.25 into 0.85 is 0.027 meter per second, ok. So, with this, we have come to the end of the class, this class. So, we thank you for listening to the class. Thank you very much.