Course on Momentum Transfer in Process Engineering
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Lecture 56
Module 12
Problem and solution

Okay, so we have done pipe flow and flow through annulus and many others so in that let us do also some problem because we said that if you do and if you can solve problems then you are definitely grasping the subject more. So to do that let us also try some problems to be solved, mind it that this problems you can also find out in many books many many sources and as many problem solutions you will do, it will not only give you that application of the subject, application of the topics, application of the equations but also it will help you to understand different values different values I mean that it is unlikely that I give the one good example that we if we have in both the hands, one had a copper rod and another hand one wooden stick.

And both if we put in say oven and a within very short period of time, we get in the hand where we have copper rod that will be very much heated up we cannot hold it, whereas the other one wooden one we know that it will be some more time required lot of time required by that time you can no more hold it. This is then known fact, true the reason also you know true, but the values what is a value of the conductivity of copper or that of the wooden stick or wood if you are not coming across.

Then that the difference between you and another person who is not of your field or who is not basically from science if he says then it you will feel that he is also saying the similar thing I am also saying the similar thing the difference, the differences will be you will not be able to explain the reasoning with scientific background, scientific details. So for that detailing you may need to know the required values, right? And this you can gather you can capture as many problems you solve so much you can do, right?

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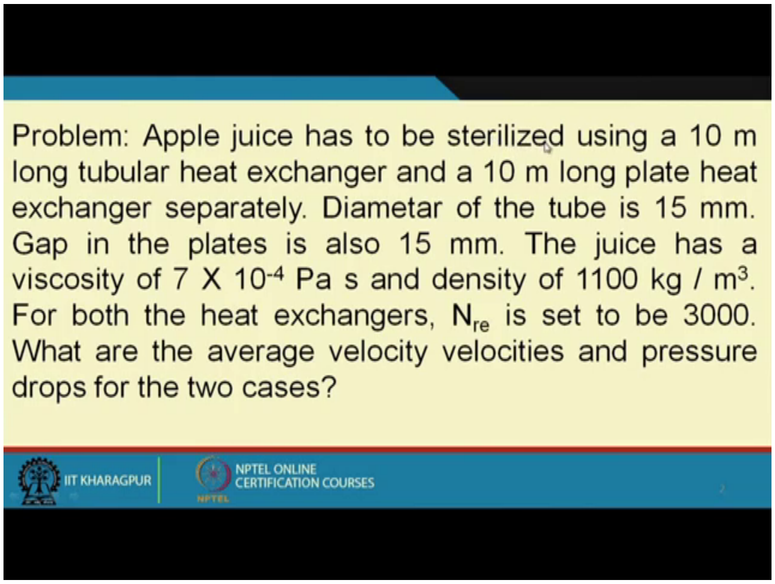

This you keep in mind and solve as many problems wherever from you get it and solve it, right? For example here if we look at that apple juice has to be sterilized using a 10 meter long tubular heat exchanger and a 10 meter long plate heat exchanger separately. Diameter of the tube is 15 millimeter gap in the plates is also 15 millimeter. The juice has a viscosity of 7 into 10 to the power minus 4 Pascal second and density of 1100 kg per meter cube. For both the heat exchangers Reynolds number Nre is set to be 3000 you can take it 2000, you can take it 1500 this is just for an example. What are the average velocities and pressure drops for the two cases, right?

So we reread the problem once again, apple juice has to be sterilized using a 10 meter long tubular heat exchanger and a 10 meter long plate heat exchanger separately. Diameter of the tube is 15 millimeter. Gap in the plates is also 15 millimeter. The juice has a viscosity of 7 into 10 to the power minus 4 Pascal second and density of 1100 kg per meter cube. For both the heat exchangers Reynolds number Nre is set to be 3000. What are the average velocities and pressure drops for the two cases, right?

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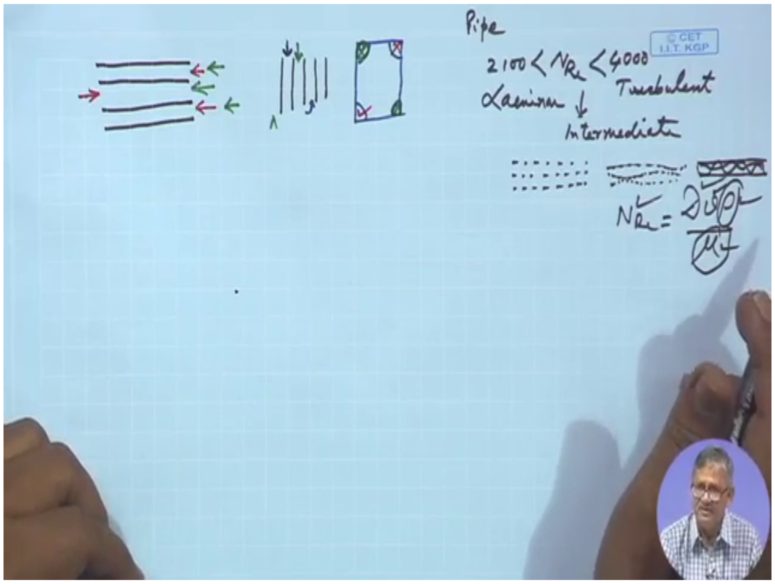

So it is a simple problem as far as you are concerned by this time we have come to know the details of it and you can solve it, but you see the tubular heat exchanger what it is, that means tube in tube. So one tube is here and another tube is there so one fluid is flowing, one fluid is say flowing through this and another fluid is through that this is called counter current. Of course when you come across with it in heat transfer you will see that counter current is more effective then co-current had it been like this, this is also moving this way and this is also moving this is the annular and this fluid is also moving this way then it would have been parallel, right? So parallel is less effective than counter current, okay. So whatever dimensions has been given that we have seen and we have been here it is not the heat transfer problem, it is the problem of fluid flow, right?

So one fluid is of our interest that is the juice which is flowing and not the heating or cooling, so heat exchanger does either heating or cooling that is exchange of heat, right? So if it is hot, then you can cool it, if it is cold then you can heat it. So depending on what you are doing accordingly it will be, right? The other one is a plate heat exchanger as it is said, right? So in the plate heat exchangers there are plates like this several plates are there, right? I am drawing a little apart the reason being so that you can make it out, right?

So in that case also, so one fluid if it is going this way, another fluid maybe coming out this way, right? So this acts as this plate acts as the heat exchanger plate, right? So let us put this one, so this will go this way and this again will come this way this will again go this way like that, right? So this will go this way and then again come back, right? And again maybe going out from there it will enter this way, right?

So that depends on and in each plate there are if you look at in each plate there are if this is the view of the plate there are four holes like this, right? Out of which depending on the flow of the fluid maybe one maybe for one fluid say this is for one fluid and maybe this is for another fluid. These two plates are normally then closed, but these two are open. So like that depending on which one is open, which one is closed the flow becomes either parallel or counter current that is as far as heat transfer is concerned we are not in this subject, what we need? We have to find out whatever has been said that what is the velocity and what is the pressure drop, right?

So we would like to find out that velocity and pressure drop. Now you remember that this is simply nothing but a fluid flow problem I think yeah this is for this, okay this is nothing but a food fluid flow problem and in that we have been asked that what is the pressure drop and what is the velocity, that we have to find out. So for that here we have not we have been given a Reynolds number of say rough 3000, we know that for pipe flow, flow through pipe that Reynolds number is less that 2100 Nre less than 42 or 4000 roughly it is said 4000, right?

So that means beyond this number less than this, this is laminar, this is turbulent and in this region it is intermediate means neither laminar or turbulent. If you remember we had said that laminar flow means this is the flow, this is the flow, this is the flow so it is all these are not interchanging interacting with the other layer if these are each layer of the fluid, right? If it is intermediate means it will be going like this some may come and exchange with like this so there could be some exchange some laminar, so that will be.

Whereas if it is turbulent, then it will be a totally mix so all the fluid inside is mixing, right? So that means depending on the and who will dictate this laminar or turbulent, this Reynolds number Nre, right? If Nre is less than 2100, then for pipe flow it is laminar if it is more than 4000 it is turbulent intermediate is between that, right? So what is Nre? Nre is Dv rho by mu all are fluid property rho is the fluid property, mu is the fluid property, velocity is the fluid not property that has to be found out and D is the diameter of the pipe, right?

So if that means this property values of the fluid for a given D the property values of the fluid can also dictate either on the Reynolds number or on the velocity or vice versa, right? If it is high velocity Reynolds number will be high, if it is low velocity Reynolds number will be low or vice versa for a given D if the property values are changing that is why I said that moving the values are also very much effective and in most of the cases are required also, right? Okay.

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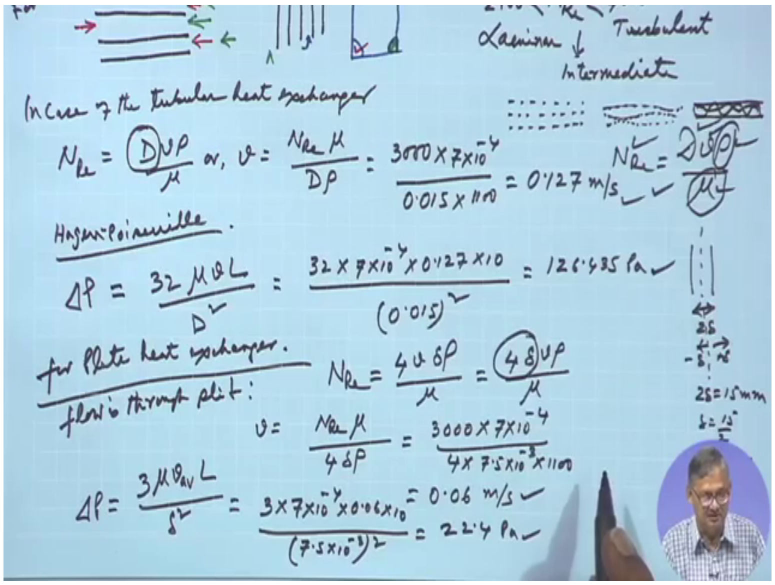

Now let us come to the problem solution, right? Solution is what, in case of the tubular heat exchanger so in case of the tubular heat exchanger the flow of the juice is a flow through the pipe, right? So Nre is Dv rho by mu or v is Nre into mu over D and rho, right? Now the values are given the values are given as Nre given as 3000 mu given is 7 into 10 to the power minus 4 Pascal second and D is given 15 millimeter if I remember 0.015 and density of the fluid was given 1100, right? So from that if we do the calculation then we can see that 3000 into 7 into 10 to the power minus 4 so much divided by 0.015 is equal to this divided by 1100 is equal to 0.127.

So the velocity through the tubular heat exchanger is 0.127 meter per second, right? So if we have found out, then pressure drop we can also find out from the Hagen Poiseuille's equation, what is Hagen Poiseuille's equation? So from the Hagen Poiseuille's equation we can also find out what is the pressure drop, so if you remember Hagen Poiseuille equation we have derived developed, so delta P is equals to 32 mu v L by D square, right? So delta P is 32 mu v L by D square, so in this case delta P become equal to 32 into mu is 7 10 to the power minus 4, right? v we have found out just now 0.127, right? And we have been said that it is 10 meter.

So if it is so, then D was 0.015 square, right? So if you see what is the value coming, value is coming 0.127 times 7 times 10 to the power minus 4, right? So this into 10 into 32 is equal to so much divided by 0.015 square, so that is 126.435 so delta P is 126.435 Pascal, right? So the pressure drop is not so high because velocity is also not so high maybe and whatever the property values have been given you just with the same all of the dimensions all of the things it change the property values and see how it is affecting and you will see that the property values have great influence on both the velocity and the pressure drop, right?

The same thing you do for water it will altogether different, okay. So now let us do the other one this is for the tubular heat exchanger. So for the plate heat exchanger here it is it was a pipe but in this case the plates are very close and we can assume it that this is that was for here let us write for tubular heat exchanger, flow is through a pipe. Whereas for plate heat exchanger the flow is through a slit, so we have to remember the relation of Nre for the slit flow, right? And if we remember that for the slit flow Nre a was equal to 4 v del rho by mu or it should have been 4 del v rho by mu D was substituted this D was substituted by the 4 del, right? So and if you remember if we had taken this as slit we had taken this as 2 del, right? If this was the axis, right? This was 2 del 1 half plus del and another half minus del, right? This was our consideration if you remember, right?

So that is why it is coming and this was equivalent diameter or equivalent to that this slit what is the equivalent diameter that we can find out it is to 4 del we had also found out there. So it is 4 del v rho by mu all other things remaining same, then v becomes equals to Nre into mu over 4 del rho so Nre we have said to be 3000, mu we had said 7 10 to the power minus 4, 4 del now 2 del we have said to be if we remember that it was 15, right? So 15 millimeter apart. So that means 1 del 2 del is 15 mm so del is 15 by 2 that is 7.5 mm, right?

So we can write 4 into 7.5 into 10 to the power minus 3 into 1100, right? And then let us see what it comes? It comes to be 3000 into 7 into 10 to the power minus 4 is equal to so much divided by 4 divided by 7.5 divided by 10 to the power minus 3 divided by 1100 is equal to 0.06 meter per second. This tells that we have a this thing much much less velocity much much lower than that in the tubular heat exchanger. So the velocity in the for the same now let us look into the delta P.

So the delta P is equals to from the flow through slit if we see the expression this was 3 mu v of course average L by del square, right? So 3 into mu 7 10 to the power minus 4, right? To v average we just have found out 0.06 (divide) into L, right? L was same as 10, right? And del 7.5, so 7.5 10 to the power minus 3 square, right? Let us look how much it comes, 3 into 7 into 10 to the power minus 4 into 0.06 into 10 is equal to so much divided by 7.5 into 10 x to the power minus 3 x to the power 3 plus minus this square, so is equal to 22.4 Pascal.

So here the pressure drop was also high, here the pressure drop is also low, here the velocity was also high, here velocity is low, pressure drop is also low. So that gives us idea that whenever we are doing such kind of thing we have to be also knowing this value gives us idea that in tubular heat exchanger the pressure drop and the velocities are high, whereas in the similar way because we maintained the dimensions more or less very very close same fluid, right? But in the plate heat exchanger the velocity as well the pressure drops are much lower than that of the tubular heat exchanger.

You will see if you find out the percentage it will be almost 30, 40 even 50 percent lower than that of the tubular heat exchanger then in plate heat exchanger. So that is why solving problem gives you some idea not only on the values, but also on the subject like here you got idea about the both tubular and plate heat exchanger out of which who is giving how much velocity and how much pressure drop. So when you go to the industry obviously pressure drop will be of very very fundamental thing because in the higher the pressure drop more will be your expenses, right? So that has to be encountered so this way you can get idea about the values, right? So do some problems, thank you.