Process Equipment Design
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Lecture - 08
Double Pipe Heat Exchanger-III

Hello everyone. Welcome to the third lecture of week two of Process Equipment Design course and here we are continuing the double pipe heat exchanger, okay. If you remember the lecture one and lecture two of this week, we have already started discussion on double pipe heat exchanger. In lecture one we have discussed detailed steps for design of double pipe heat exchanger.

In lecture two of this week we have seen a detailed example of design of double pipe heat exchanger and that example was taken from R.W. Serth book, okay. So you can find details there also or you can simply go through the example which we have discussed in the last lecture, okay. And in this lecture, we will solve a few problems corresponding to design of double pipe heat exchanger.

So let us discuss example 2 because example 1 we have already discussed in the last lecture. So here I am having example 2.

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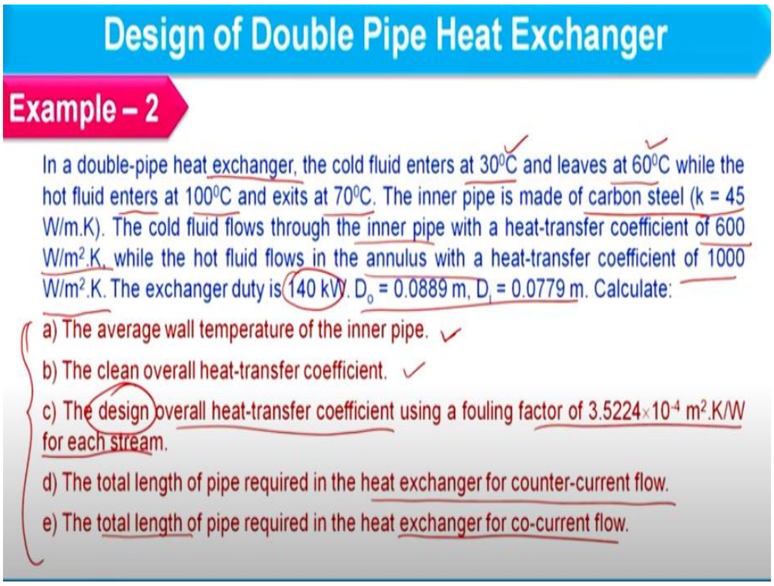

Now in this example, a double pipe heat exchanger is given where cold fluid enters at 30 degrees Celsius and exits at 60 degrees Celsius while the hot fluid enters at 100 degrees Celsius and exits at 70 degrees Celsius. So you know both fluids terminal temperatures are given to us okay. And if you consider the inner pipe, it is made of carbon steel having thermal conductivity as 45 watt, having thermal conductivity as 45 watt per meter Kelvin.

The cold fluid flows through the inner pipe like where I am having temperature from 30 to 60 degree. It is moving in inner pipe with the heat transfer coefficient as 600 watt per meter square Kelvin. So here you already are given heat transfer coefficient value of inner pipe or inner fluid while the hot fluid flows in annulus of a double pipe heat exchanger where heat transfer coefficient is 1000 watt per meter square Kelvin, okay.

Total heat duty of exchanger is 140 kilowatt and here you are given D o and D i as this value. What you have to find out is we have number of things, we have number of parameters which we have to calculate. The first is the average wall temperature of inner pipe, okay. I hope you all remember the expressions etc. And next we have to find out the clean overall heat transfer coefficient.

And further we have to find out overall heat transfer coefficient which I am saying as design overall heat transfer coefficient. It means it includes dirt factor also as fouling factor of 3.5224 into 10 to the power of -4 meter square Kelvin per watt is given for both streams, right. And next you have to find out total length of pipe required in heat exchanger for counter current flow okay.

And similarly, the last parameter is we have to consider the total length of the pipe for co-current flow, okay. So all these parameters we will calculate for double pipe heat exchanger for the given problem. So let us start with part a of this example. So part a says that we have to find out average wall temperature of inner pipe.

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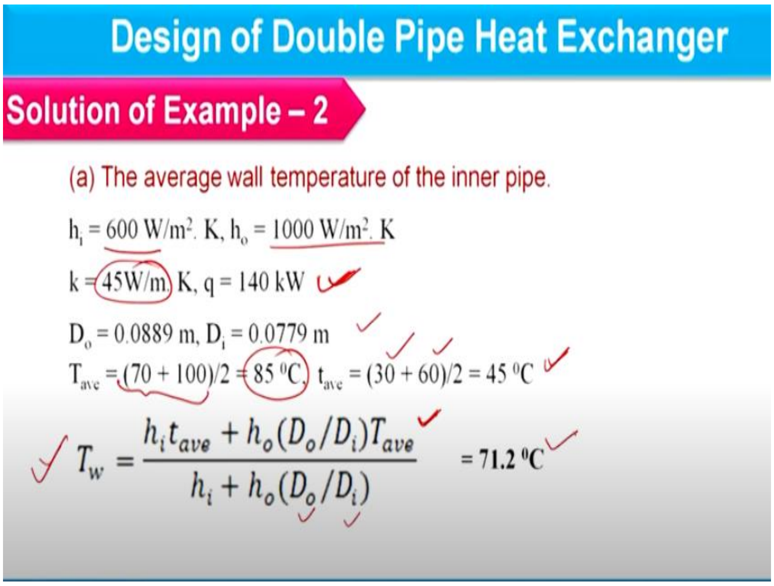

For that you have to find out the heat transfer coefficient at inner layer and heat transfer coefficient at inner pipe or annulus side. So in this problem all these values are given to you as h i is 600 watt per meter square Kelvin and h o is 1000 watt per meter square Kelvin, right. Thermal conductivity of the material is already given to you and total heat duty of the material and total heat duty of the exchanger is known to you that is 140 kilowatt, okay.

D o and D i we can find like this, like D o is 0.0889 meter and D i is 0.0779 meter. So values are already given, so you do not have to use table B 2 or property table because that is not required over here. We can calculate directly the average temperature of hot fluid and cold fluid. So average temperature depends on the terminal temperature and for both fluid you know the terminal temperature.

So the average temperature of hot fluid comes as 85 degrees Celsius and average temperature corresponding to the terminal temperature of cold fluid that is 30 degrees Celsius and 60 degrees Celsius you can find out average temperature of cold fluid as 45 degree Celsius, right. So this is the expression for wall temperature calculation where h i t average plus h naught D o by D i and T and capital T average all these values are known.

All these values are known to you corresponding to, all these values are known to you and further we have to use h i, h naught, D o and D i. So all these values are known to you. You can simply put the value. This is the direct calculation. All values you have to put in this and then you can find out average temperature of wall and it comes as 71.2 degree Celsius, right. So this is first part of example 2.

Now if you remember the last lecture why I am calculating this wall temperature, because it will give me the viscosity correction factor, okay. That may be, that may not be required over here, but this is basically used to calculate the viscosity correction factor. Here one here different parameters you have to calculate, whether they are connected to each other or not, okay. So average wall temperature we can find as 71.2 degree Celsius.

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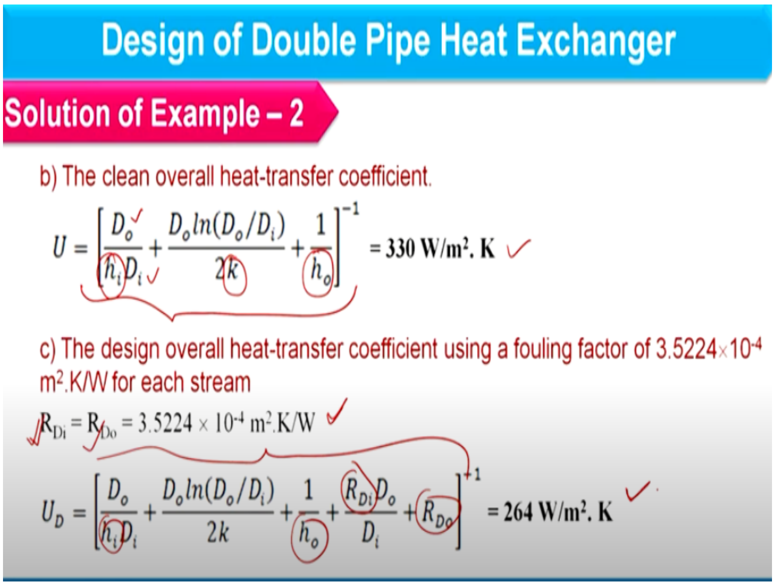

Next parameter we have to calculate is the clean overall heat transfer coefficient. So clean overall heat transfer coefficient it means what? We have to use only three terms, fine? Three terms which includes heat transfer coefficient at inner pipe, heat transfer coefficient in annulus side, and the material of inner tube, right. So here you can simply use this expression of overall heat transfer coefficient at clean condition.

So h i and h naught you have already given, you are already given. And D naught and D i values are known to you and simply you can put thermal conductivity of the material because here material is carbon steel and for that thermal conductivity value is already given. So considering all these values you can find out overall heat transfer coefficient at clean condition which comes out as 330 watt per meter square degree Kelvin.

And next we have to calculate the overall heat transfer coefficient considering fouling factor, okay. And this heat transfer coefficient we consider as design heat transfer coefficient fine, overall heat transfer coefficient sorry. So here you see dirt factor for inner pipe as well, dirt factor for inner fluid as well as the fluid which is moving in annular side are given and that is equal to 3.5224 10 to the power -4 meter square watt, meter square Kelvin per watt, okay.

So considering this value and h i and h o and diameter of both side and thermal conductivity of the material, you can find out overall heat transfer coefficient and if you see in this overall heat transfer coefficient, we are using all five terms, okay where R D i and R D naught are given to me and overall heat transfer coefficient we can find as 2.6. And overall heat transfer coefficient we can find as 264 watt per meter square Kelvin, okay.

So you can consider over here that here if I compare clean overall heat transfer coefficient, we can find that design overall heat transfer coefficient at dirt condition is lesser than that we have obtained at clean condition and the reason is very obvious that dirt factor includes more resistance in the path of transfer of heat and therefore, it reduces overall heat transfer coefficient, fine? So same you can obtain from these calculations also.

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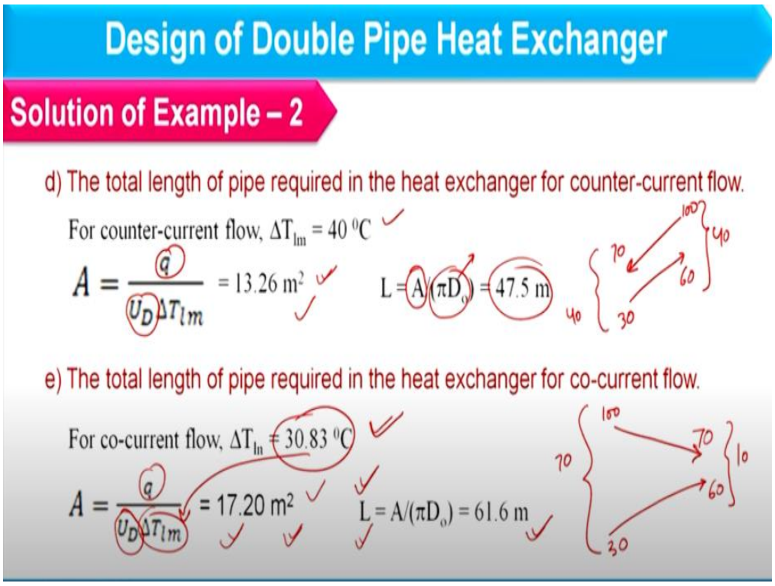

So next we have to find out the counter current flow. So next we have to find out the total length of the pipe which is required in a heat exchanger for counter current flow and that you can simply find out considering heat duty, overall heat transfer coefficient and delta T lm value okay. So delta T lm value will depends on what? It will depend on type of flow.

Otherwise q and U both will remain same. Only we will find the change in mean temperature difference, okay. So if you understand the counter current flow and the co-current flow that so if you understand the counter current flow and co-current flow LMTD value or log mean temperature difference value will change, right.

So here if I am considering counter current flow it is simply this is hot fluid which is moving down because it is reducing its temperature and cold fluid moves up because it is gaining the heat and its temperature will increase, right. So considering both temperatures, if I am considering hot fluid it is moving from 100 to 70 degrees Celsius. And if I am considering cold fluid it is moving from 30 to 60 degrees Celsius.

So if you consider here, we are having temperature difference as 40 degrees Celsius and here I am having the temperature difference again as 40 degree Celsius. So you see here both temperature differences are 40 degrees Celsius. If you compare if you consider LMTD for this right, LMTD is what, delta T 1 minus delta T 2, right. And here both delta Ts are equal.

So what we have to do over here because LMTD in this case becomes 0, right. So what we can do in this case, we can simply consider the arithmetic mean over here as mean temperature difference. So 40 on both sides, so 40 will be your average temperature difference, right. So here you can consider as 40 degrees Celsius mean temperature difference. Q value we have already calculated.

U D you already know, so here we can consider 40 degrees Celsius as mean temperature difference to find out heat transfer area as 13.26 meter square, right. In the similar line we can calculate the, further we can calculate the total length of the heat exchanger which should be divided by heat transfer area by circumference, okay. So which circumference I should consider? I should consider outer circumference, okay.

So that area we have already calculated. D naught you already know. So 47.5 meter square is the total length of heat exchanger we can obtain for counter current flow, okay. And if you have to calculate the number of hairpins, you should know the length of hairpin which is usually one leg of hairpin, right. So twice of that will be the total length and so twice of that will be the total length of hairpin.

And total length of exchanger is given over here, you can simply find out the number of hairpins as we have discussed in last lecture, okay. So now we will consider the last part of this example and that is we have to and in that we have to find out total length of the pipe of heat exchanger when I am considering co-current flow, okay. So what will happen in co-current flow? Both flows will occur in one direction, not in opposite direction.

So I hope you understand the concept of co-current. If I am considering co-current then the start temperature of hot fluid should be 100, right and end temperature is 70 degree Celsius, fine? In the similar line, initial temperature of cold fluid is 30 degree Celsius and final temperature of cold fluid is 60 degree Celsius.

So if you consider here I am having temperature difference as 70 and here I am having temperature difference as 10. So in this case you can simply apply LMTD correction factor for co-current flow and the mean temperature difference considering LMTD you can find as 30.83 degrees Celsius. Here both terminal here both temperature approaches are different, okay. So you can simply apply LMTD which comes as 30.83, okay.

So considering q overall heat transfer coefficient at dirt condition as well as log mean temperature difference which you have just calculated you can find out area as 17.2 meter square, okay. Now when you compare the area of counter current flow and co-current flow, we can have more area requirement in co-current flow and the reason is very simple that mean temperature difference is less in this case.

And therefore, it increases and therefore area of heat exchanger increases, okay. So considering these values we can find out the total length of heat exchanger because obviously, when I am having more area I can find more length of heat exchanger. So as we have discussed in counter current flow we can simply obtain length of heat exchanger as 61.6 meter, right.

So in this way we can find out all parameters which are required to complete example 2. So now we will focus on example 3 for double pipe heat exchanger design.

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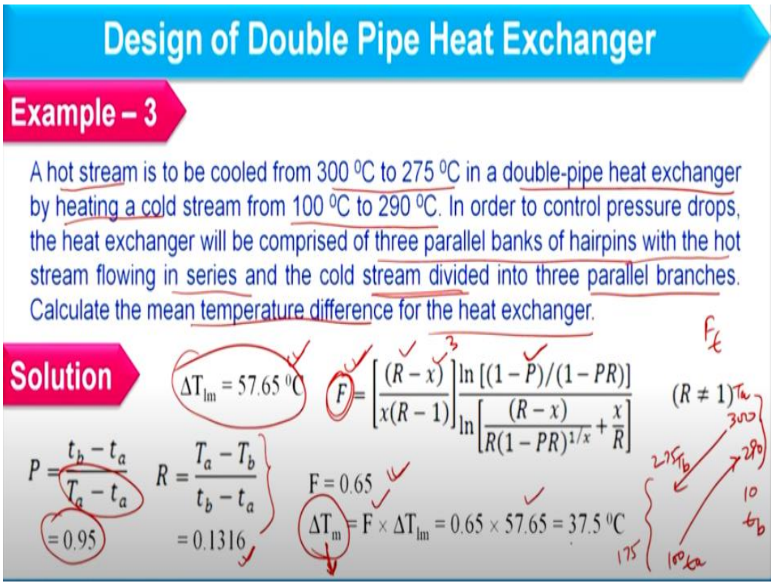

And in this example, a hot stream is to be cooled from 300 to 275 degrees Celsius in a double pipe heat exchanger by heating a cold stream from 100 degrees Celsius to 290, okay. So you can see we have 300 and 275 and 100 and 290. In order to control the pressure drops the heat exchanger will be comprised of three parallel bank of hairpins with the hot stream flowing in series and cold fluid and cold stream divided into three parallel branches okay.

So here we have to control the pressure drop and therefore we have considered parallel configuration instead of series for both fluids, right. So here we have three parallel branches or we can consider that fluid we have divided in three different sections and what we have to find out is the mean temperature difference for the heat exchanger, okay.

Now if you remember the first lecture of this week, where we have discussed design of double pipe heat exchanger, there we have discussed that if flow is parallel right, we have to consider F t correction factor along with LMTD for counter current flow, okay. And the reason is very simple because in this case, we may have counter current as well as co-current, both flow may occur okay.

Both flow may occur simultaneously, right. So we have to consider first LMTD. Then we have to find out F t correction factor and then we can find out true LMTD, okay. So let us start the solution of this problem. Here I am having LMTD for counter current flow. So you can simply understand that hot fluid is moving from let us say 300 to 275 and cold fluid is moving from 100 to 290.

So here I am having temperature difference as 10 and here I am having temperature difference as 175. So considering these two you can simply find out LMTD for counter current flow as 57.65 degrees Celsius. And further to calculate F t correction factor we have to find out P value, R value as well as the number of branches, right. So P value is the thermal effectiveness of an exchanger.

And R is basically the and R is basically division of heat capacities of two fluids, right. This we have already discussed in basic design parameters lectures, so you can refer that. So here if I am considering P, so that should be t b – t a divided by T a – t a, okay. So this capital T a minus small t a is the maximum driving force available in the system.

So if I am considering t b, t a so this is basically t a this is t b and this is T a and this is capital T b. So all values are known to you. You can simply find out P as 0.95. And similarly, you can simply divide the temperature differences of two fluids to find R value, which comes out as 0.31, which comes out as 0.1316. So you can see here R value is not equal to 1. So we have to choose the F t correction factor expression accordingly.

So this is basically the expression. Here I am representing F t as capital F, okay. So that is also so in some books such representation you can also find and in some books F t as it is is given okay. So here if you remember, so here if you see the expression of F t correction factor, we know R, we know x, x will be 3 in this case. P value we can or P value we have already calculated.

So considering all these values, you can find out F t correction factor as 0.65, right. So you can simply calculate log mean temperature difference by multiplication of F t correction factor and LMTD for counter current flow. This is we basically, this we basically call as true LMTD or true mean temperature difference, right. So 0.65 will be multiplied.

So 0.65 will be multiplied by 57.65 and true LMTD or true mean temperature difference we can find out 37.5. So here you can see we can consider the splits of fluid according to the parallel combination we are making and then considering counter current flow you can calculate LMTD and then you can calculate the true LMTD considering F t factor and LMTD for counter currents flow.

So here you can understand the design of double pipe heat exchanger properly. However, detailed example we have already discussed in the last lecture, which is from finding the basic parameters to the final design where feasibility of all parameters have met, okay. So considering all these three examples, you can understand design of double pipe heat exchangers properly, okay.

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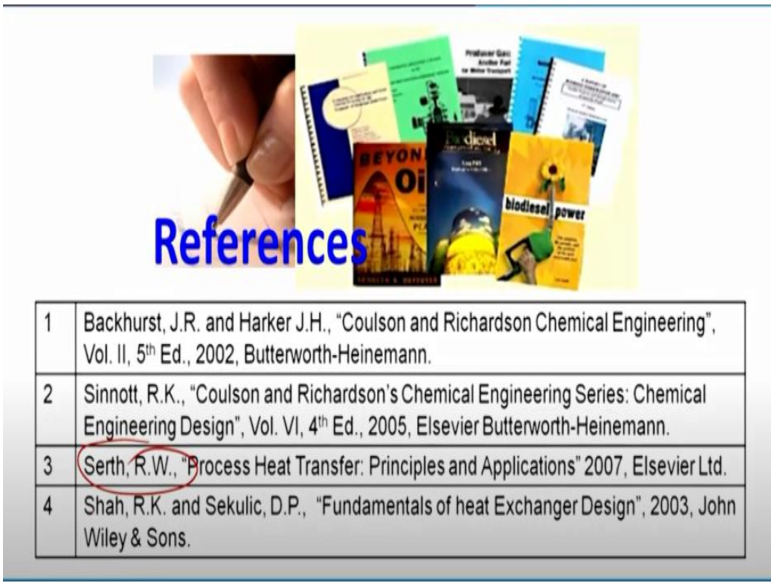

And here I am having the references of the books, okay. So that example which we have discussed in the last lecture, I have taken from this book, so that you can refer okay. And now I am going to summarize the video and this summary corresponds to the double pipe heat exchanger which we have covered in lecture 1, lecture 2 and lecture 3 of week 2, okay. And summary of these videos are

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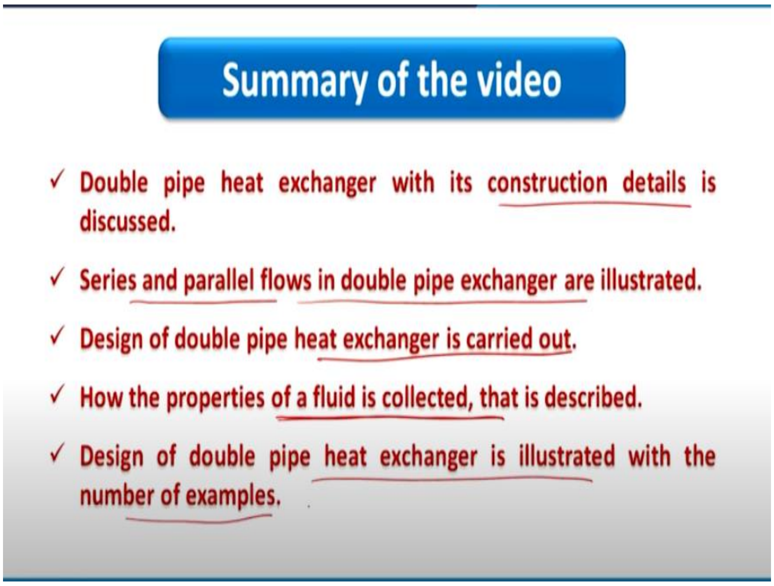

In these videos double pipe heat exchanger with its construction details is discussed in detail, okay. We have discussed series and parallel flows in double pipe heat exchanger. Design of double pipe heat exchanger is carried out where different steps were discussed in detail. Next, we have seen that how the properties of the fluid is corrected. Next we have seen that how the properties of the fluids are collected from given graphs and table.

And usually it is done at average temperature. And finally, design of double pipe heat exchanger is illustrated with number of examples. And here we have considered three different examples to illustrate this design. So that is all for now. Thank you.