Heat Exchangers: Fundamentals and Design Analysis
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Lecture – 29
Plate fin heat exchanger: Numerical

You are welcome to this lecture, we were talking about the Plate fin type heat exchangers. Now, today in this lecture we will try to solve some numerical problem where we will try to estimate the heat transfer or the heat transfer taking place it is basically simulation problem. We will try to solve, where we will try to estimate what is the amount of heat getting transferred in the plate fin type heat exchanger.

So now, we will look into the details of this plate fin type heat exchanger where we will find that all the heat exchanger dimensions or the details will be given with some inlet parameters. And accordingly we will be trying to solve what is the exact temperature of the fluid streams. And also we will try to estimate what is the amount of heat getting transferred.

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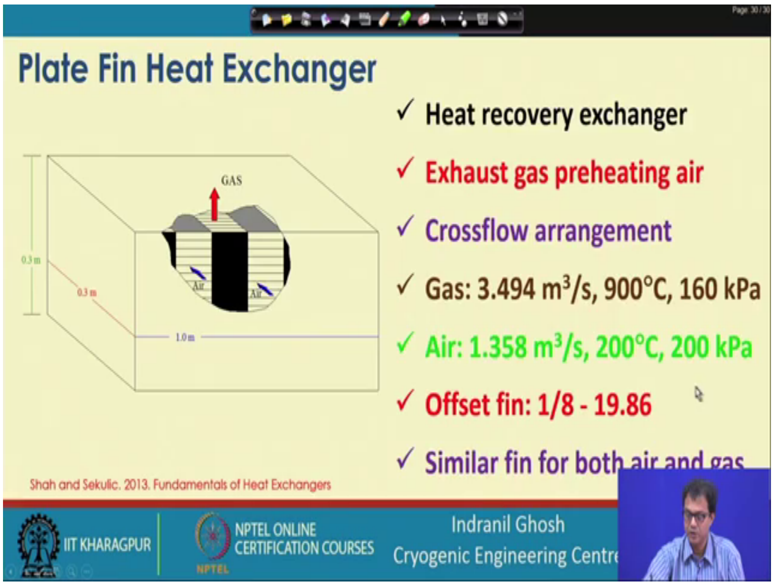

So, it now look into the details of this heat exchanger configuration, this has been taken from the book by Shah and Sekulic, the Fundamentals of Heat Exchangers. And as the Fundamentals of Heat Exchanger Design, particularly I am sorry this is Fundamentals of

Heat Exchanger Design. So, in this problem what has been told is the overall dimension of the heat exchanger has been given.

So, before doing that one, let us look into the other parameters that has been already been told. Say, here this is basically heat recovery exchanger where the gas and air will be exchanging heat. So, the exhaust gas is preheating the air. So, as we can understand that the exhaust gas is pre heating the air means, the gas is getting cooled and the air is getting heated up.

So, this is the hot stream so, this stream is the hot stream, and this air is basically cold stream. So, we have a 2 stream exchanger and as you can understand from the configuration, that this is basically nothing but a cross flow type heat exchanger. So, these fluid stream are there in a cross flow arrangement. Then what has been given as the gas flow rate you can see that the gas flow rate is given and it is volumetric flow rate, it is not the kg in terms of kg per meter cube or kg per second it is in meter cube per second. And also its entry temperature is given it is entering at 900 degree centigrade at a pressure of 160 kPa kilo Pascal.

So, the air details are like this; its flow rate is 1.358-meter cube per second it is the volumetric flow rate entering at a temperature of 200 degree centigrade at a 200 kilo Pascal, its inlet pressure. So, what we need to look at is now the geometry. This is an offset strip fin, this is the specification where you will find it this has been taken from the Kays AL London, The Compact Heat Exchanger book. And this is an offset strip fin with 1 by 8 it was the nomenclature given in Kays AL London and 19.86.

So, this 1 by 8 stands for basically we will look into that part, what it stands or whether it is the lands length of the fin height or the fins. And this is of course, the fins facing number of fins per inch. So, when we have these knowledge about the offset strip fin or the fin, this offset strip fin will all the details will be it is expected to be known; that means, we will be able to find out its fin height, fins spacing, then what is the fluid flow area and etcetera. So, then we have another information given to this is that, the similar fin, the same fin rather are used both in; I mean for both gas side as well in the air side both air and gas side will have; the same offset strip fin 1 by 8 19.86.

So these are the things those are known, along with that the fin height, sorry the heat exchanger height, then width and the length of the exchanger has already been told. So now, if we look at this geometry we will find that this is gas flow area, I mean, this is how the gas is flowing on this side, the air is flowing on this side. So, what is the frontal area for the air? The air frontal area is this much is the air frontal area. So, the air is coming from this end and this is: what is the frontal area that is 1 meter by 0.3 meter. Now, if we look at the gas side, what we will find, what is the frontal area? We know that this is the frontal area, I mean, the gas is coming from this side. So, it faces this is what is that surface area on for the gas. And what is that dimension ah? We already know this dimension is 1 meter and this dimension is also 0.3 meter.

So, here in this case we have both the frontal area similar to each other. So, we have this information the overall dimension of the heat exchanger is given, the fin details are given, the volumetric flow rate, and the inlet temperature and the pressure of the heat exchanger is given, and it has been told that or it has been the construction of the heat exchanger; that means, it is a cross flow type heat exchanger, that is also given. So now, you can look what we have to estimate is the exit temperature, I mean, we have been told that the gas is entering at say 900-degree centigrade at a pressure of say 160 kilo Pascal. And this air is entering at a temperature of say 200 degree centigrade. And it is pressure has already been told as 200 kPa. So now, what we need to find out is the exit temperature of the air, and what is the exit temperature of the gas.

So, when we know the exit temperature of each gas, we would be able to find out the capacity or the rating or the of this heat exchanger, how much is the heat load of this particular exchanger. So, looking at this problem, now it is not difficult for you because of your I mean previous knowledge, we have already talked about it. That this is basically rating problem or this is nothing but heat exchangers performance problem.

So, rating or heat exchanger performance evaluation or simulation; where whichever name we tell it or we call it as simulation. So, we have been told about the geometry of the exchanger. We have been told about the inlet conditions of the 2 fluid streams. And all the heat exchanger specifications are known. We know about the fin details. We know about the flow arrangement, we know the overall dimensions of the heat exchanger, we know this is the length is 1 meter 0.3 meter.

So, basically it boils down to a simulation problem. So, if you have a simulation problem, now what would be our approach to solve this problem? So, before going in to that approach we would now like to have a look into the fin details as I have told you that this offset strip fin 1 by 8 19.86, what does it mean? And what are the information's which we have for about this fin? So, if you now look into the that part let us have a look in to that part.

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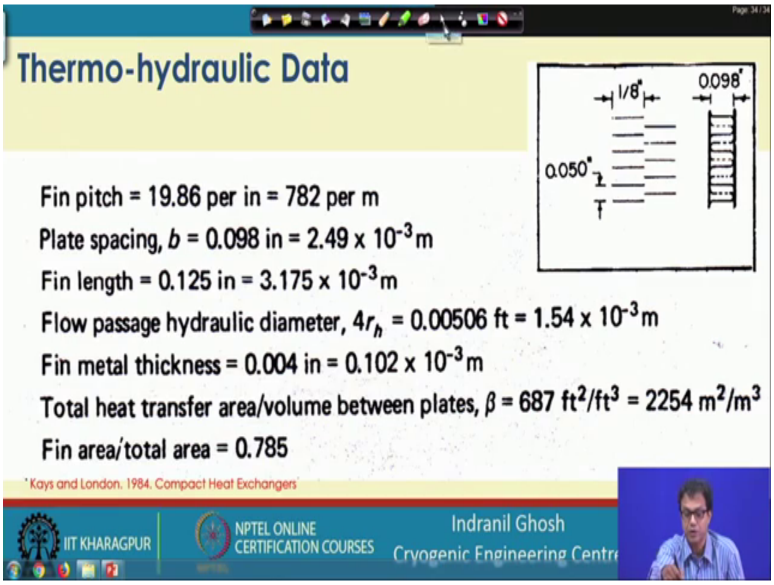

So, these are the fin specification if you go back to the case in London Compact Heat Exchanger book. You will find that this is the geometry corresponding to this geometry this is what is given. So, as I was telling you that 1 by 8 what is meant, it is basically meaning that it is the lands length, or this is where you know this is the flow where this is the flow side. And their after certain distance of the lands length this strip fins are offset. So, here you can see from the top you that this fin and between this fin there is another fin in between.

So, it is getting offset and this lands length of the fin length is we often call it fin length or we often call it lands length. So, this is equals to 0.125 or 1 8th of an inch. So, in terms of the meter this is 0.31 3.175 into 10 to the power minus 3 meter. So, we have the fin pitch the other parameter as you can understand that 1 by 8 h and 19.86, that 19.86 corresponds to, 19.86 corresponds to the number of fins per inch. And this corresponds to I mean 7 80 to 82 number of fins in 1 meter. In a meter it would be able to accommodate some 782 number of fins. So, from there you would be able to estimate how many number of fins are there if you make one-meter-long length of this fin. So, we are going to get some 782 number of fins. So, this is one fin between one this is it is having some primate thickness.

So, between this point to the beginning of this one, this is the repetitive block and this fin this is the fin spacing. So now, we have the fin pitch so, that will give you the fin spacing. And this is the plate spacing, this is the plate spacing means this is the fin height. So, the fin height or the plate spacing that gives you the b is equals to 0.098 inch or in meters this is 2.45 or 49 millimeter. And fin length or the lands length already as I you have told you that it is a 0.125 inch or 3.175 millimeter.

So, we have the as soon as we have talked about the this fin, we know about the say this is what is the fin height, this is fin spacing. And the fin thickness is also given fin metal thickness that is also given. It is 0.1 2 0.102 millimeter. And that is what is fin thickness that is, I mean, this between this is 0.1 2 0.102 millimeter. So now with this information you know exactly what is the free flow area. So, that is how the free flow area you know the fin the heat transfer area to the volume between the plates is also known.

And also we know the flow hydraulic diameter. So, this hydraulic diameter is basically we estimate in terms of the free flow area and the heat transfer surface area and the length of the fin. So, from there we would be able to estimate this hydraulic diameter, it is already been given for this type of fin. And it is this much 1.54 mm is hydraulic diameter of this fin. Then we have the total heat transfer surface area divided by the volume between the plates.

So, this beta this an important parameter. So, when we know the overall volume of the volume between the plates, we would be able to estimate the total heat transfer surface area. So, because that is also again we it is something where which we need. And another information that has been given regarding this one is fin area by the total area of this is again something which is very important for us if we look into this parameter, we will come across this value when we talk about the overall fin efficiency of the I mean heat exchanger.

So, if you remember that we have talked about this is the there are the 2 plates connected between them there is a fin. And we have this eta f the fin efficiency of a single fin, but it is not a single fin there are multiple fins associated with it. So, we will you know coordinate it with eta 0.

And eta 0 and eta f, you will find their correlation rated by the overall this is the overall fin efficiency, and they are correlated with individual fin efficiency by this fin area by total area A f by a. So, that will come across. So, all this you know values we will be necessary particularly for estimating the heat transfer or the stimulation of the heat exchangers are given in this one. This we have taken from case in London book. So, it is not only this about the geometrical part, then we have the characteristics of this fin. I mean we have talked about the geometrical parameters, then we need to now talk about what is called the heat transfer and free flow thermo hydraulic data.

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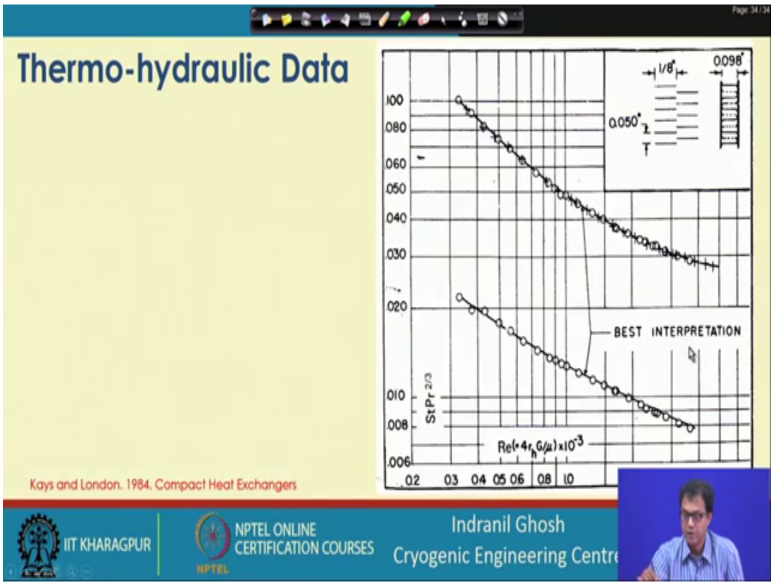

So, we have again talked about it or we have shown you earlier that, this is expressed as a function of j and f. This j is basically the standtl number and Prandtl number to the part two third. So that is here it is given as standtl number Prandtl number to the power to third. And this all this dotted points I mean this points are on the experimental values; so, this is the best interpretation. So, we will have both the numerical values as well as this graphical values for this 1 by 8 h and 19, sorry, 19.86 specification off strip offset strip fin. Similar, type of different type of fins and with different geometrical parameters you will find in the case of London book those who are interested can look into this consult this book.

So, here we find that both the j and f this is j is expressed in terms of the standtl number and Prandtl number to the power to third. And this is how it varies with Reynolds number. So, we have to first estimate the Reynolds number, then we have to you know get I mean the corresponding to that Reynolds number we will be calculating this standtl number and Prandtl number to the part 2 third of the j value, and this standtl number contains that heat transfer coefficient that requisite you know what we are looking for a particular site.

And we also have this friction factor which will be necessary if someone wants to calculate the pressure drop, you may remember in some of our earlier calculations we were trying to estimate the pressure drop according in the fin through the fin passages. And there you have been told about that, this is the friction factor if you remember in that example, we have been told about the Reynolds number.

And corresponding to Reynolds number and the fin specification we are supposed to find like that you know the corresponding value of the friction factor. So, this is how we estimate the friction factor and the j factor, or the I mean from the j factor we estimate the heat transfer coefficient. And so, as soon as we specify the fin; that means, the fin details are known, we have all the geometrical parameters necessary for the fin and we also know: what is the frictional factor or what is the j factor.

So, please mind that these values have been estimated experimentally. But there are also correlations available for the offset strip fin or the wavy fin or for the different plain rectangular fins or others. And one can also use those correlations while estimating the heat transparent pressure drop; j and f factors from those correlations, but I mean at any time the experimental data are found to be more reliable ok. So now, we will go to the next where we will I mean this is cross flow.

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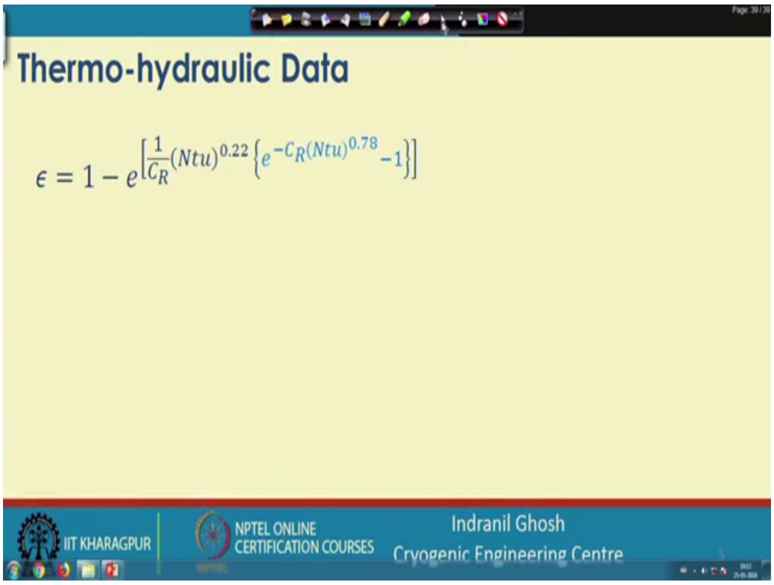

Exchanger this expression if you remember that, we have this expression for the epsilon into and the C R value or the capacity rate ratio. So, here we find that this is this particular correlation is meant for the cross flow heat exchanger cross flow type heat exchanger. So, these are the things which we have already come across, these are the information already available to us. So, based on this available information now we have to frame our I mean try to solve this simulation problem, and one by one we have to go into it. So, as you can understand that, since we are trying to solve this simulation problem, where we have a complete knowledge of the heat exchanger geometry.

So, if we have the geometry known to us what is the approach that we will take it is u know we have to think about. Like whether this (Refer Time: 22:08) approach will be applicable or not. So, if we look in to the temperature differences can, but we do not know exactly: what is the temperature difference. Because we are trying to find out the exit temperature so, we do not have the knowledge about the temperature differentials at the entry and exit. So, we will not be able to apply the (Refer Time: 22:36), we can assume some kind of exit temperatures. But that will always give you a kind of iterative solutions so, we will not go into that.

So rather, we will try to look whether we can have an estimate about the next NTU number of transfer units. If you look at this expression for the NTU, what it talks about is UA by C min. Now let us look whether it is possible to estimate these parameters. UA tells you basically the overall heat transfer co efficient or 1 by UA is the overall heat transfer coefficient. That will have both the hot sight, then we have the wall resistance, then we have for the this is for the hot sight, then we will have the you know for the cold sight. And there will be say eta 0 A hot, and then h hot, and then you have the similar terms for the cold side. And this R w is the resistance offered by the separating plate.

So, if it is separating plate, the fluid is trying to flow from heat is trying to flow from here to here. This because of this finite thickness of this wall, this will also gives raise to some kind of resistance to the flow of heat, and that we have taken into account here. So, theoretically speaking we have the, I mean, since we know the fin specification we would be able to ideally calculate this A h.

We would be able to calculate the overall heat transfer coefficient, I am sorry, overall efficiency of the fin, and this h h that is the hot side heat transfer coefficient. So, ideally we are supposed to evaluate this UA of necessary for estimating the NTU. And the other part that C min what is the minimum capacity fluid we would be ideally able to estimate I mean evaluate and we will be basically able to calculate the NTU value. And this once we know the NTU we know from this relation: what is the epsilon.

So, once we know the epsilon our relations I mean epsilon from the epsilon is related to the inlet and the exit temperature, and we can easily calculate the exit temperature. And when we know the exit temperature it is not difficult to find out the heat duty from the ms delta hot and cold science. So, our basic aim would be to now estimate the NTU; when we find that we have to calculate the NTU, we need to now find what is the UA. And when we find UA, we need to find what is eta 0. And not only that eta 0 we need to find out h h and also the heat transfer surface area.

So, for that we need to go systematically one by one, first of all to start with we need to have an idea about how many number of layers of air and this gas streams are there in this particular heat exchanger. And once we know the number of layers available for the gas and the fluid side, then we have an idea about the heat transfer surface area available for the gas side as well as for the air side.

So, we will try to first estimate, because we have the overall dimension of the heat exchanger known to us, overall heat transfer I mean number of heat overall dimensions of the heat exchanger known to us, then we can estimate the total number of layers for the air side or for the gas side, because we also know what are the number of I mean the overall dimension of the fin and the plate thickness I think we have missed about the plate thickness. The plate thickness has been given, I mean, what is that separating plate thickness that has been given as 0.5 millimeter, this is equals to 0.5 mm.

So, we know this point this is the thickness of the separating plate we know about the fin height, what is the fin height that has been already been told. So, we would be able to find out how many such layers constitute, I mean, if we put 1 over the other in between off course there will be the other layers. One layer of hot fluid stream, one layer of the gas stream and like that the total number of layers will constitute that heat exchanger.

So, this that would be the total heat exchanger; like that similarly, I mean number of layers on this side and this side will constitute the total dimension. So, since the total dimension is given, since the individual fin details are given we know the separating wall thickness. So, we would be able to find out what is the number, what are the numbers of the fins associated with on the gas side and the fluid side. Sorry, the air side; so based on that information we will be able to do the other calculations. So, we will look into that in other class.

Thank you.