Heat Exchangers: Fundamentals and Design Analysis.
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Lecture - 30
Plate fin heat exchanger: Numerical (Contd.)

Welcome to this lecture, we are trying to solve a numerical problem relating Plate fin heat exchanger. So, in the last class, we have looked into the problem statement and we said that it is a basically rating problem where some of the entry, I mean some of the parameters are known to us and heat exchangers specification was completely given. So, we have to find out what are the exit temperatures and we have seen that, we have to calculate first of all the number of plates associated when in the gas and the airstream.

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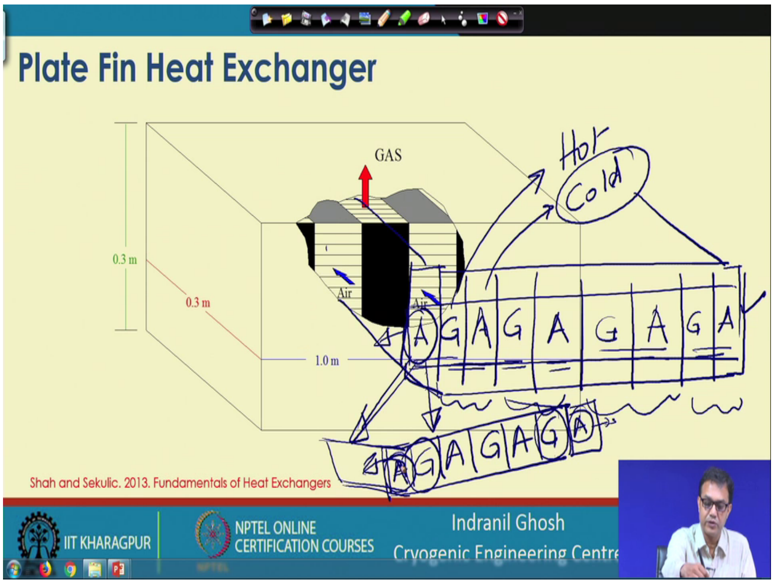

So, while trying to do that if we look into it, we will find that. We have alternative layer of air and the gas. So, if we look into this say we have gas stream of we call it G then we have one passage designated for G then the next passage is designated for air then you have again G then you have air. So, like that it will continue we have air then G and so on. So, the basic unit we can say that gas and air, gas and air alternative gas and layer are flowing through. So, this is typically for a 2 stream exchanger we tried to look for alternative hot and cold fluid stream and in this case the, we have also designated that this gas stream is the hot fluid stream and the air stream is the cold fluid stream.

So, and obviously, the entire heat exchanger you know we have another dimension on this side, but what we have not told in the last class is that, this though it is the building block like G A G gas and aired gas and air alternatively flowing. The last one is air, but we will add a additional layer on this side this is also of air why because this is relatively colder then the hot I mean of course, though it is warmer then the ambient air.

So, we intend to keep a kind of cemetery ov for this entire heat exchanger and we will talk about this requirement of this symmetry in context to the plate fin type heat exchanger later on and for time being we have to assume that we will keep an air stream at the end. So, that why not its G I mean why not we put it like G A G A G this could have been an alternative arrangement like this the nth streams could have been the gas stream.

But you can see that this gas stream being the hot stream and it will need more number of insulations at the end or we need higher insulation at the end. So, that we put the air streams at the end. So, that this is more closer to the ambient temperature and we land up with a less requirement of the I mean what is call the insulation. So, this entire heat exchanger stream if we now look at we have say air then we have gas, air, gas.

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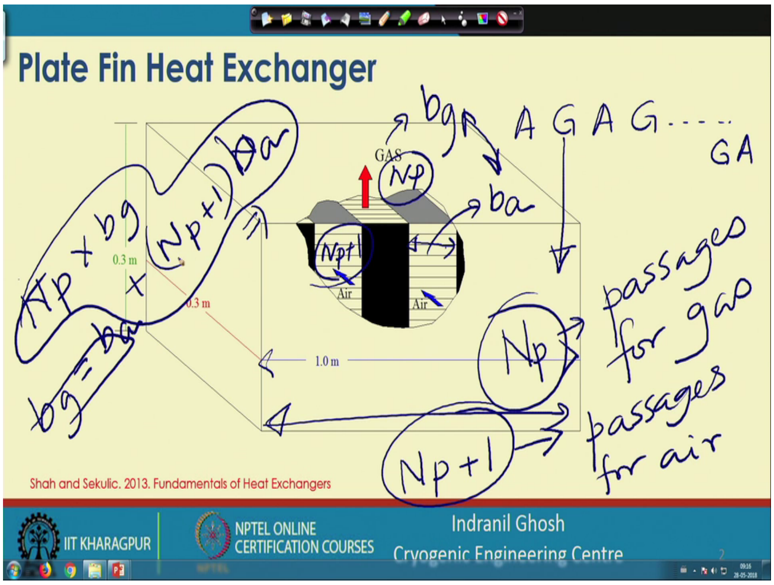

So, like that we have G A. So, now, if we say that there are N p number of passages for the passages for the gas. If we have N p number of gas then we have N p plus 1 number of passages designated for passages, designated for air. So, altogether we have how many

N p plus 1 and N p number of gas and air passages. So, we have N p number of gas passages and we have N p plus 1 number of air passages over this entire length.

So, if we know this N p and N p plus 1 thickness of each gas layer and we know that already we have said that both the sides are having the similar type of fins and if we designate this b gas for the height of the fin and; that means, this is the fin height, this is the fin height and this we designate as fin of air, though we know that b g height of the fin of the air side is equals to height of the fin on the gas side.

So, this is the b g and b a both are similar. So, now, we can have N p number of passages corresponding to the gas. So, we have N p into b g plus N p plus 1 into N sorry b a and this should be equal to this 1 meter length, but it is not so, there is something else. We have the thickness of the plates. So, we have to add the plate thickness with these one and then equate with 1 meter then only we would be able to find out the number of passages N p.

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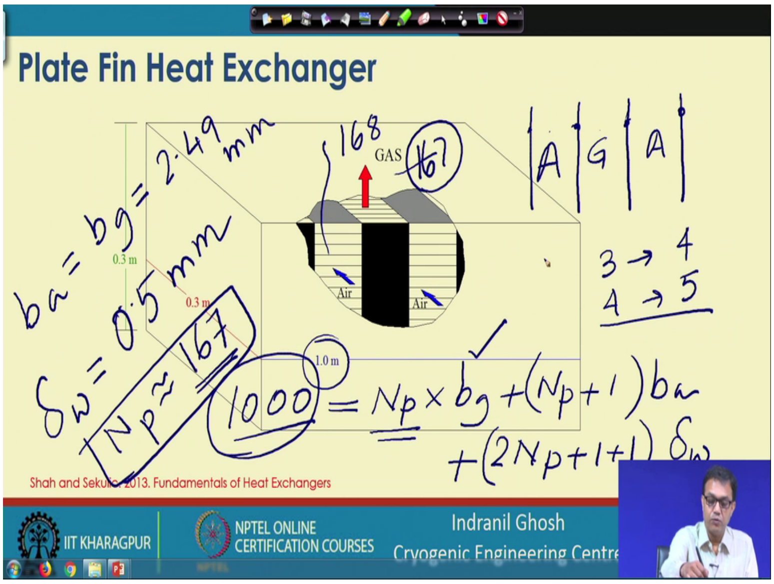

Now if we look into that then we will have N p into b g plus N p plus 1 into b a plus how many number of plates are there. If we have 2 layers of say the gas and air and say another air, so we have 1 2 3 number of streams then we have 1 plate 2 3 4 number of separating plates. So, for 3 we have 4, if we have 4 number of streams we have 5 number of plates. So, always the if we have N p plus 1 plus N p. So, it is 2 N p plus 1 number of plates we have 2 N p plus 2 number of separating layers and that will be multiplied by the thickness of the wall or the separating wall and that will be equal to that 1000 mm.

So, here this b g is given in how much it is given as the plate thickness, plate thickness delta w, delta w is equals to 0.5 it was given 0.5 mm 0.5 mm and then we have b a equals to b g the fin height that is equals to 2.49 millimeter. So, this is also converted in to millimeter, this 1 meter has been converted into millimeter and now we can estimate the number of layers from this one and we will find that it is approximately coming the nearest whole number is equals to 167.

So, we have N number N p number of this many layers of the gas passages. So, we have 168 number of air passages in that case. So, now, we can understand that we have 168 number of such air passages and 167 number of gas passages arranged in cross flow arrange, cross flow pattern and we now have to go to the next estimation I mean, but we are looking for is basically the overall UA.

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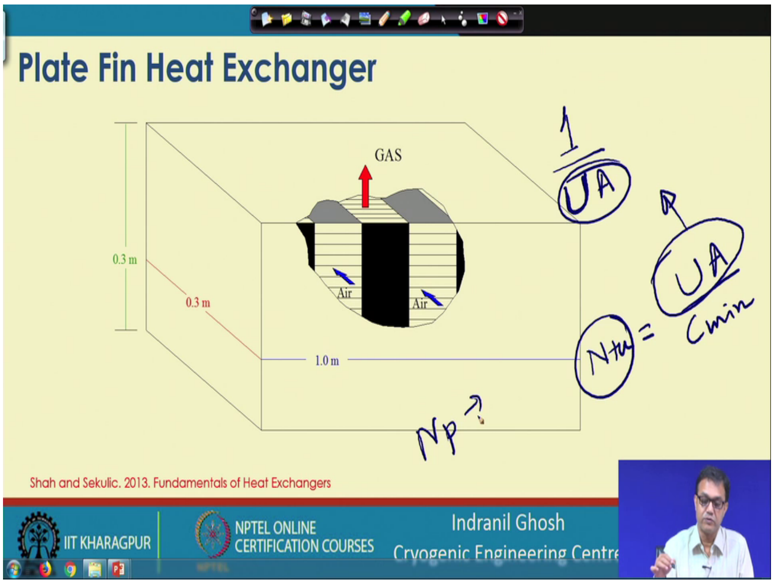

I mean this UA we are trying to calculate because that will give us, if you remember in the last class we have talked about that we intend to find out the Nusselt number sorry the Ntu, we wanted to find out and that Ntu is basically UA by C min and that UA by C min we want to calculate and for calculating the UA we are trying to you know evaluate all this numbers N p and from N p we have to find out the area and so on.

So, now if we look into it first of all we have arrived at the total number of layers. So, we can till now try to find out what is the total number of frontal area, I mean what is the frontal area. Frontal area by telling the frontal area what we mean is that this is the frontal area for the air stream and the frontal A frontal A for the air is basically this surface area.

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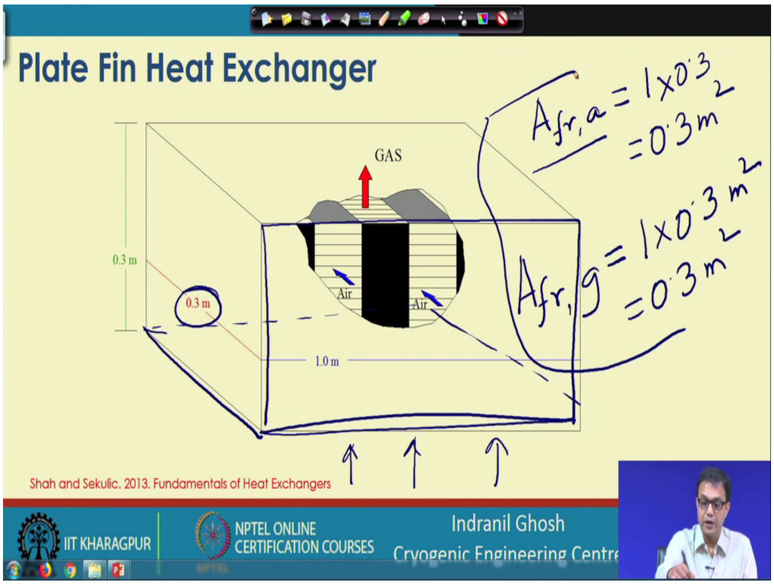

So, it is equals to 1 meter multiplied by the 0.3 meter. So, it is equals to 0.3 meter square for the air and for the gas A fr, g. So, what is flow side this is the flow, but this is the way it is taking place. So, this is the surface area. So, it is having 0.3 meter long and this is the other 1 dimension. So, this is also 1 into 0.3 meter square. So, we have 0.3 meter square, both the frontal area for the air and gas are the same. So, now, what we have the frontal area information with us.

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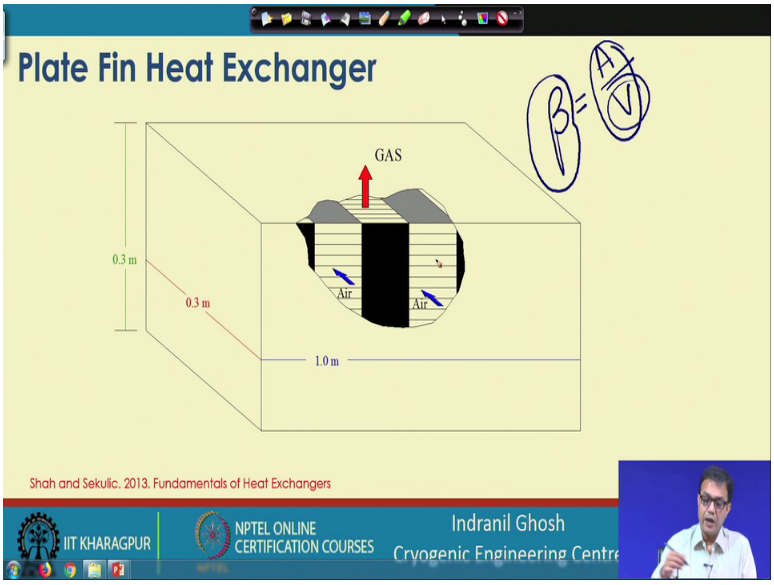

Now, we can also try to find out the volume between the plates because why this necessary because we know we have been given some parameter beta and that is has already been told about each type of fin and since we know beta we can try to find out the heat transfer area from that one, if we are able to estimate the heat exchanger area between the plates.

Basically this beta is the in the very first class we have talked about this is there is nothing, but the heat transfer area per unit volume and we will try to now calculate the volume between plates for each fluid stream and volume between the plates for if we look for the gas side what we have is the fin height, fin height is known to us.

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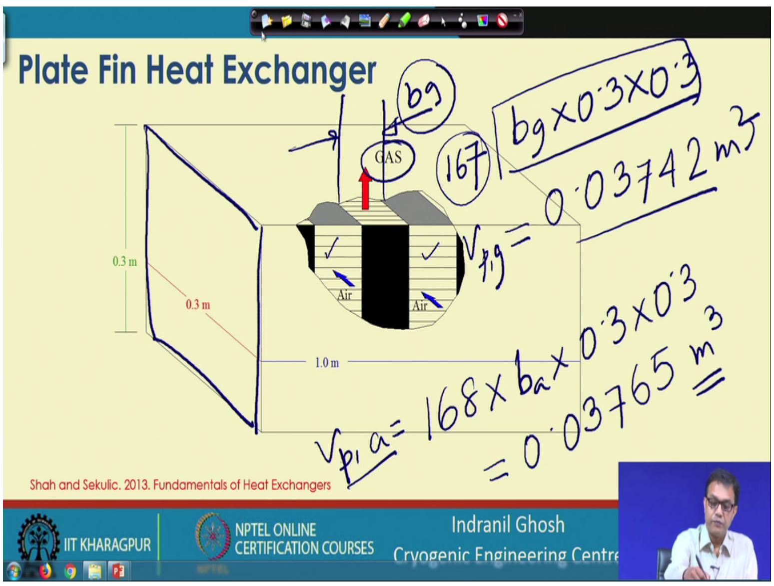

This is b of g we have designated it as b of g and this is one dimension, the other dimension is this 1.3 by 0.3 meter and its thickness is say as if b g. So, we have how many such layers b 0.3 multiplied by 0.3 and multiplied by b g. So, that is the number of a single the volume of a single layer of the gas stream.

So, how many such layers are there we have N p is equals to 167 number of such layers are there. So, this is what is the total amount of volume between the plates, on the gas side. So, this comes out to be 167 multiplied by b g into 0.3 into 3. So, that will come out as 0.03742 meter square. Now similarly now we can try to estimate the volume occupied by this between the plates volume between the plates for the air and; obviously, you can understand that this is the air we have 1 more number of layers in this 1. So, we have 168 multiplied by b into a and multiplied by 0.3 into 0.3. So, it will be slightly higher than this volume I am sorry this is a basically a volume it is meter cube.

So, we have this number will come out as 0.03765 meter cube. So, this is the volume between the plates for the gas and this is a volume p between the plates for the air side and this is the volume between the plates for the gas side, V p g and V p of air. So, now, we have the information about the volume between the plates. So, we can now try to estimate the heat transfer surface area associated with the gas side or the air side. So, if we look into that part we will be now able to calculate the heat transfer surface area, because we know b g that has been given as 2254 meter square.

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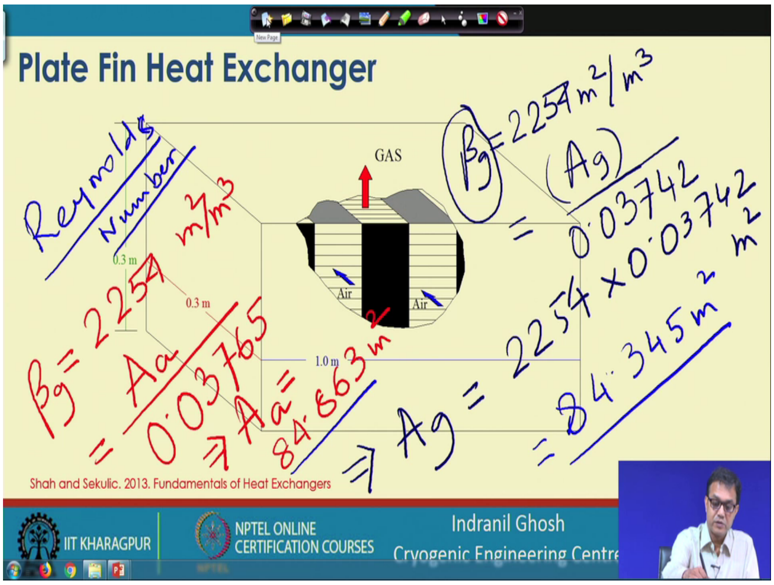

So, that is equals to the heat transfer surface area a that is say the gas side and the volume between the plate that we have now calculated just now we have calculated for this is equals to 0.03742 meter cube and it will come out to be this is beta g its a unit was sorry meter square per meter cube and this is equals to this is in meter square and this is in meter cube. So, we have a for the gas side is equals to 2254 multiplied by 54 multiplied by 0.03742.

So, this many meter square is the surface area associated with the gas side now similarly on the for the air side we can write this same type of fin is there. So, it is again 2254 and that is equals to this is meter square per meter cube and that is equals to A of the air side divided by, we have calculated the volume between the plates and that is slightly different for this one this is 765. So, this will correspond to A of air and on this side we will have slightly higher heat transfer surface area associated with this, this will come out to be 84.863 meter square and if we calculate the same figure for this one this should have been 20 sorry 84.345 meter square is the gas side heat transfer area and the air side heat transfers area is slightly higher than the gas side heat transfer area. So, now, we have the heat transfer surface area estimated by from the configuration of the heat exchanger.

So, once we know the heat transfer surface area one of our requirement is the estimation of the Reynolds number, if we have to calculate the Reynolds number, Reynolds number if we have to calculate then what we need to know is the free flow area and the mass flow rate. So, we have been told about the volumetric flow rate, we have now been able to calculate the heat transfer surface area. Now we need to calculate the free flow area and we will now estimate it from the information given on the basis of the information given related to the hydraulic diameter.

So, the hydraulic diameter for this heat exchanger has already been given for the each passages has been known to us and if we know the hydraulic diameter from that hydraulic diameter we can try to since that hydraulic diameter gives relation between the free flow area and total heat transfer surface area, we should be able to estimate the free flow area from the knowledge of the hydraulic radius and the hydraulic diameter and the heat transfer surface area.

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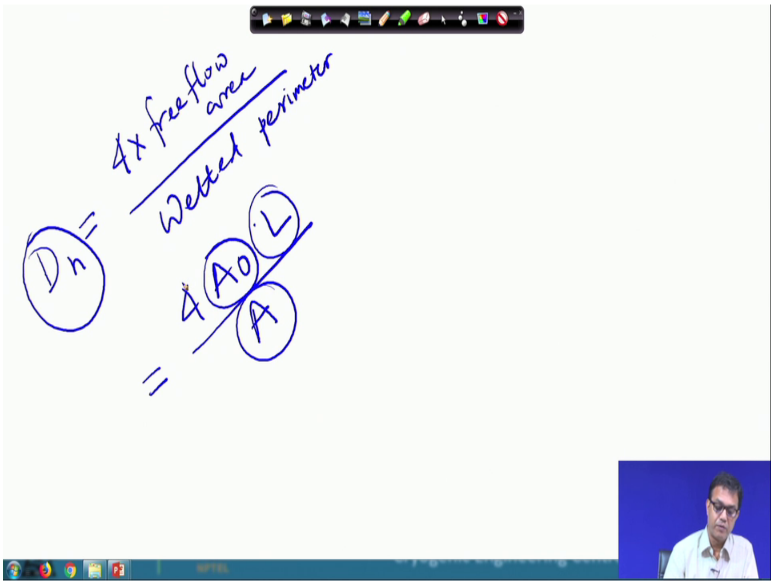

Now we know that the hydraulic diameter definition, we have written it like this the hydraulic diameter Dh is equals to 4 times the free flow area. This was the free flow area and divided by the weighted perimeter. So, we had the free flow area that was the definition we have adopted for the hydraulic diameter and this is weighted perimeter.

Now, if we multiply both the side the denominator and numerator with the length and we will find that this is just nothing, but 4 into A 0 into L divided by this is p and that p multiplied by L is nothing, but the heat transfer surface area. So, we have this information of this hydraulic diameter. We have the information about this heat transfer area. We know the length and what we need to calculate is the A 0 from that relation. So, now, if we go back to our this dimension, so this is what air side and gas side we have calculated.

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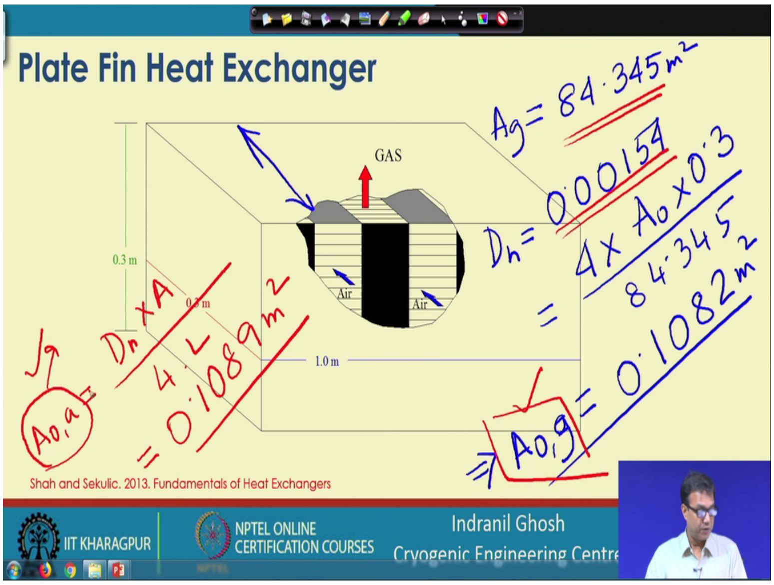

We have been able to calculate the heat transfer area and that heat transfer area for the a g is basically. A gas side was 84., the gas side has been estimated to be 84.345 meter square.

And now if we look at the hydraulic diameter Dh that has already been given for this heat exchanger and we know it to be 0.00154. So, that is equals to 4 times the A 0 and then we have the length of it is equals to this is the length, this is the dimension and that is equals to 0.3 meter and divided by that heat transferred area that is equals to 84.345. So, from there we would be able to calculate A 0 and this is A 0 for the gas side. So, we have the A 0 hydraulic diameter multiplied by 84.345 and then we have divided by 4 and 3. So, this will come out to be 0.1082 meter square that is the amount of heat transfer associated with gas side.

Now if we look into the similar heat transfer area for the air side what we need to find out is basically in the similar relation only thing is that this parameter will change the hydraulic diameter being the same type of fin used, we have the similar dimension for the hydraulic diameter and we will be able to correlate them and this is for the air side this will come out to be Dh multiplied by the heat transfer surface area divided by 4 into L.

So, this is just nothing, but if we put this parameters it will come out to be 0.1089 meter square that is the heat transfer area associated with the air side. Obviously, since there are there is 1 number of I mean one more layer associated with a air this heat transfer surface area will be more on the airside.

So, now we have the knowledge about the heat transfer area we have the knowledge about the free flow area and this is I am sorry this is the free flow area we have calculated based on the heat transfer surface area. Now once we know the heat transfer surface area and the free flow area we can also calculate the what is called the void I mean sorry the sigma G if you remember that we have also taken that sigma is equals to a frontal.

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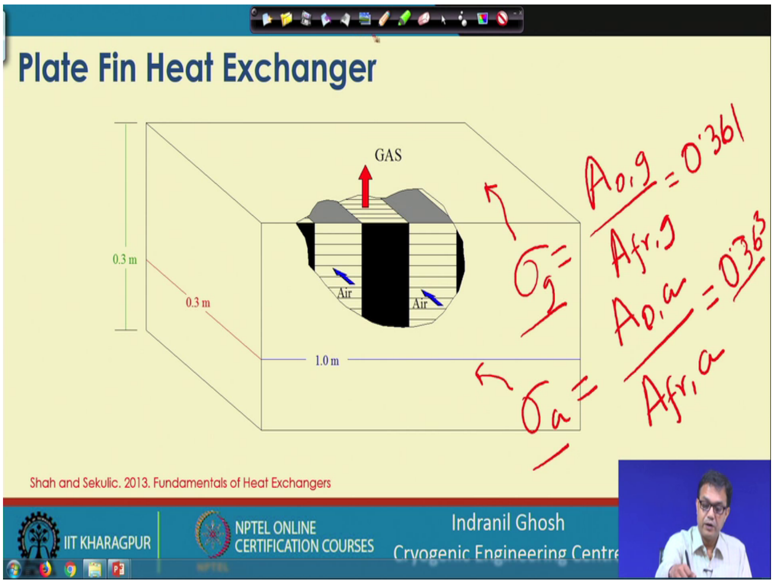

Sorry a free flow area for the gas side divided by A frontal area for the gas and similarly the sigma for A free flow area of the air side divided by A frontal area for the air side. So, this will come out to be 0.361 and this will become 0.363. These are the values for the sigma and this sigma will come as the I mean in terms of the pressure drop correlations and other correlations this becomes useful.

So, we will now gone to the next parameter that we can estimate on the basis of this one. So, that is already we have arrived at the free flow area. Now what we need to find out is the, now we can try to find out the what is called the Reynolds number, but before going to the Reynolds number what we need to do is that we need to calculate the different fluid properties.

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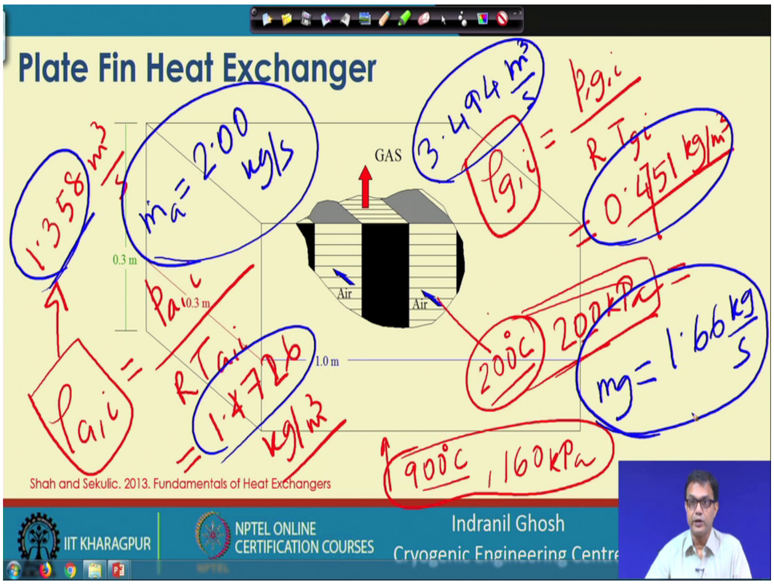

So, we know that this air is entering at 200 degree centigrade whereas, that gas was entering at 900 degree centigrade and we know the corresponding pressure for this air and fluid side. So, if you remember this gas was gas pressure was 160 kPa and this air side was 200 kPa was the corresponding pressure and if we now know the temperature and pressure, so we should be able to find out the density for this, I mean in let density of the air and the gas both of them basically are nothing, but the air, but we are calling it as air and we are calling it as gas.

And now here if we try to find out the density of air at 200 kPa, so we can use the use it as a considered it at to be a ideal gas and the corresponding pressure relation. So, we can use the pv NRT relation to the ideal gas law and then we have this rho g is equals to p, g, i divided by RT g i and from there we know if we put this one we will get value of 0.4751 kg per meter cube as the density of the gas at the inlet. Similarly rho of air at the inlet can be considered as a p a, i divided by R T a, i and this will come out to be 1.4726 kg per meter cube.

So, now, we know the corresponding density at the entry and the exit and we have the knowledge about the volumetric flow rate. So, we will able to calculate the mass flow rate of the air and the gas. So, multiplying it with the volumetric flow rate we have the volumetric flow rate of the air. So, we have the volumetric flow rate of air given as 1.358

meter cube per second and the volumetric flow rate of the gas given as 3.494 meter cube per second. So, we can now calculate the mass flow rate of the gas side.

So, multiplied by this flow rate multiplied by this density so that will give you this one as the mass flow rate mg is equals to 1.66 kg per second and similarly on this side the mass flow rate of air will come out to be 1.358 multiplied by 1.4726. This two parameters, if we multiply we will find it to be nearly 2 kg per second. So, the mass flow rate of air is more as compared to the mass flow rate of the gas. So, based on this we will be able to go to the next step or calculating the minimum fluid and then the what is the minimum capacity fluid and based on that we will have to make the other estimations.

Thank you for your attention.