Thermal Operations in Food Process Engineering: Theory and Applications
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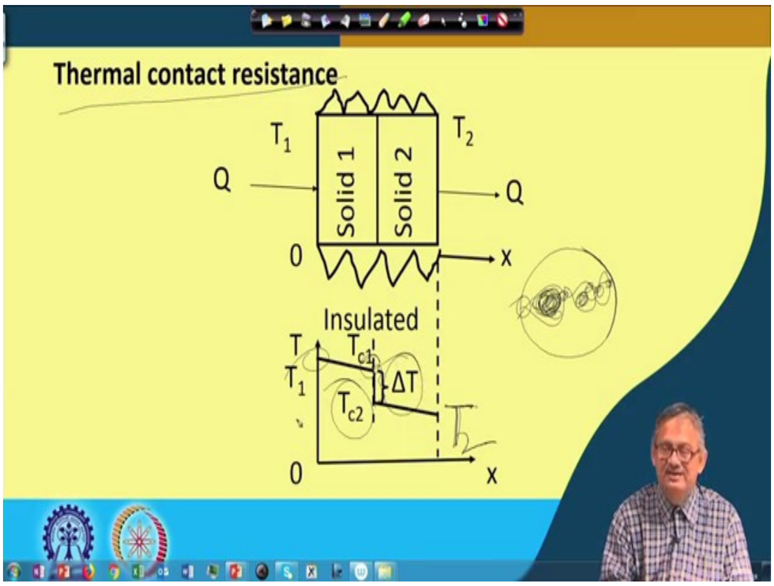
Lecture - 16
Thermal Contact Resistance & Finned Surfaces

Good morning, hope everything is alright by this time. We have finished as you remember that conductivity or conduction in Cartesian coordinate, in cylindrical coordinate, and in spherical coordinates.

Also along with that we have shown, how if there are series or parallel resistances. So, thermal contact, thermal resistance method or electrical resistance method analogy this things we have already done, 'right'.

Now, we would like to show also another thing which is very important, but cannot be a separate class. So, I am clubbing it with another very important item. I do not know whether we can finish in one class or in two classes. There is Thermal contact resistance and Finned surfaces, 'right'. So, this is lecture number 16. So, it may be that lecture number 17 may be required to be along with this, 'right'.



So, here you see what we have shown you is a thermal contact resistance, 'right'. I give you an example that, suppose you have this is one body and you have this is another body. So, when you are making them contact though apparently in our naked eye, we are not able to see that there is a gap both of course, are cylindrical. So, that is why is it is better to understand. Though there is no light is passing, but still if you see under microscope, then you will be able to know that lot of gap is there and this gap is causing a lot of heat transfer resistances, ‘right’.

So, this is what we have given one example. Suppose as it is in the board that you have two, ‘right’, let it be blue colour, otherwise it is difficult to remove. So, you have two such solids oh this is solid number 1 and this is solid number 2, ‘right’. So, if you have this two solids then they are as we said earlier also the third dimension, ‘right’. The third dimension is also under this thing infinite, ‘right’. So, that one dimensional heat transfer we can consider, ‘right’.

So, this one side is at temperature T_1 and other side is at temperature T_2 and Q quantity of heat is flowing through this, through the solids and then to through the other side, ‘right’. And, heat transfer is appearing between 0 to x, ‘right’. If, these be true then we can say that there is a this distinct juncture of 1 and 2, ‘right’, 1 and 2 they are in contact, ‘right’.

And, if you look at this under microscope, then as we said that this side is insulated, this side is insulated, and other sides are also insulated this is only one dimensional heat transfer. Then, if you have a plot this T versus x, ‘right’ temperature versus this distance, if you have a plot this is in the x direction 0 to x ‘right’. If you have a plot then you will see this is the T_1 so, T_1 temperature, ‘right’.

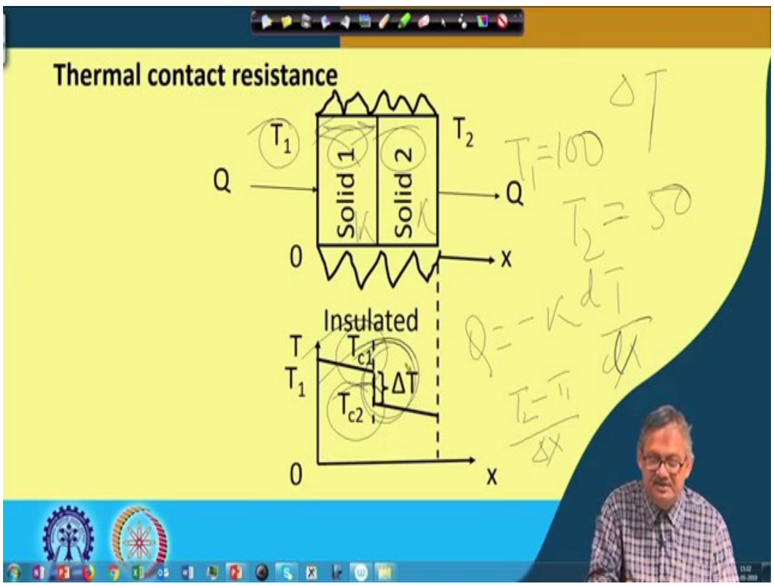
And, it is coming to another intermediate temperature say T_{c1}, ‘right’ and from there it drops suddenly a maximum to the temperature T_{c2}, and from that T_{c2} temperature it comes to T_2, ‘right’.

So, this is what is actually happening, that when you are making this contact. So, under microscope if you look at microscope, if this is the microscope field, ‘right’, then you will see one surface is like that and the other surface could be like this, ‘right’. So, there is ample I am not changing the colour otherwise it will become permanent there. So, there is ample of gap which is filled up by the present gas. Normally, it is here if it is between the two are here, but if it is something else then that also can be, and this entire fluid is under static condition.

So, there is no convection, there was no other current in this only the conduction and as we know gases do have very little conduction. So, it may act as a resistance and that is the reason why there is a sharp decline in temperature from T_{c1} to T_{c2}, 'right' and this can be amounted to delta T. So, the higher this gap the mode is the gap, the mode is this drop in temperature at the intersection. And, this intersection is this which is the intersection of the two solids, 'right'. So, this is what is known as thermal contact resistance.

And, this should have been written T_2 perhaps some how it got erased. So, this is the T_2 temperature, 'right'. So, from the temperature T_1 it comes to the junction of the 2 solids say T_{c1} and from there, because there is as we showed here in the microscopic view of the two bodies coming in contact, 'right'. So, that is like this. So, maybe here is it is point contact, here it is point contact, here it is point contact, here it is point contact, but the others are not in contact. So, they are having a gap. And, this gap is filled up by the fluid, the fluid which has very low conductivity, 'right'.

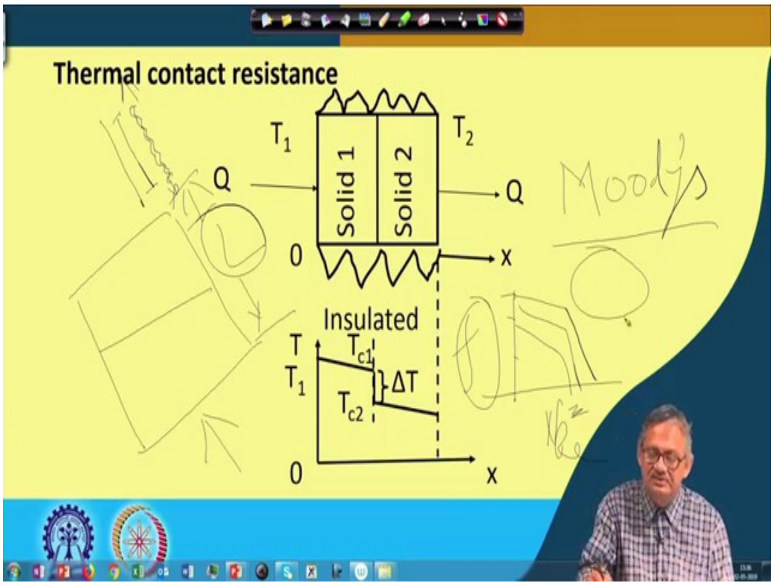
So, what will happen? So, there will be a drop in temperature from T_{c1} to T_{c2} and we can tell it to be delta T, 'right'. So, this one we should remember and this is called thermal contact resistance. We could do also a problem and this problem we can frame here itself. Because, I have not prepared to that problem, that say this one this solid has a temperature T_1 and this temperature is say 100 degree, 'right'. So, T_1 is equal to 100 degree and we have another at the other surface T_2. So, T_2 is equal to say 50 degree, 'right'.



So, find out the delta T from where this delta T_1 or delta T where this T_{c1} and T_{c2} are there, 'right', but some more things are supposed to be known, this can be done from that simple thing because solid 1 and solid 2, 'right'. Or is it maybe that both are of the same solid. Even then it does not matter, both that the same solids even then it does not matter, 'right'. Because, then you have the property values same. So, it has the same conductivity k it also has the same conductivity k, 'right'.

So, then Q as we know is equal to minus k dT/dx, 'right'. So, from there you can find out what is the value and this you have seen that it was in earlier on integration T_2-T_1 by delta x or the distance, 'right'. Of course, here we are not also said what is the distance, but you can formulate a similar thing and find out what is the delta T, 'right'. It may be required that either T_{c1} or T_{c2} may be required to know or if we know; obviously, both then it does not matter delta T can directly be found out.

So, with this the thermal contact resistance, this is a very vital when as earlier we have shown you number of series and parallel resistances, 'right'. So, but there it was one body is in contact with the other body. And, when these two bodies are in contact then, if they are not perfectly in contact, then it is the thermal contact resistance which is built up. This can be made analogous to if you have gone through fluid flow, 'right' where you have seen that there is a chart called Moody's chart, 'right'.

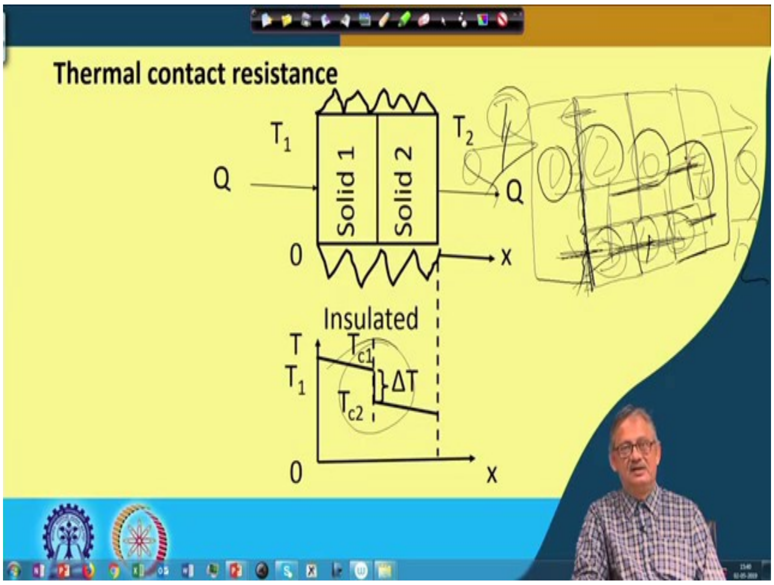


This chart is known as Moody's chart and in that Moody's chart, if you remember correctly, that it was a plot between this is the N log scale, and this is also N log scale, this was f value of friction factor and this was value of NRe, 'right'.

And, the plots were looking like this if I remember correctly plots were looking like that, 'right'. So, from there you can find out and of course, some other thing we are also required that, what is the roughness or relative roughness these things we are required, 'right', but what I mean my purpose of highlighting it is that, they are normally we say that if this is the diameter of a pipe, if this is the diameter of a pipe then ok, diameter and if this is the length of the pipe, 'right'.

So, diameter will not matter, but if this is the length of the pipe L, 'right', through which a fluid is flowing, 'right', through which a fluid is flowing. Now, we consider this L to be the length. But, in reality this Moody one of the researchers earlier, he said that no; this is not L, but this is somewhere more than L. Because he then saw under similar microscope, that he saw that this vertical line is may not be a vertical line. Actually, it may be a under microscope a zigzag like this.

Now, if you stretch it this way and this way, then you will see that this is no longer L, but a little more than L, 'right'; that means, fluid is travelling through this and in that the travel length is no longer L, it is L plus something, that is how this Moody's chart or Moody's correction came up, 'right'.



A similar to that that is why here I am also saying that if the contacts are absolutely perfect, ‘right’ then this delta T will be minimum or may be negligible or may not be there, but you do not know whether they were perfectly in contact or not. Unless you are sure that these are in perfect contact you are then you will be surprised to know that, when this heat is being transferred, then there is a resistance developed and this resistance is due to the contact resistance, ‘right’.

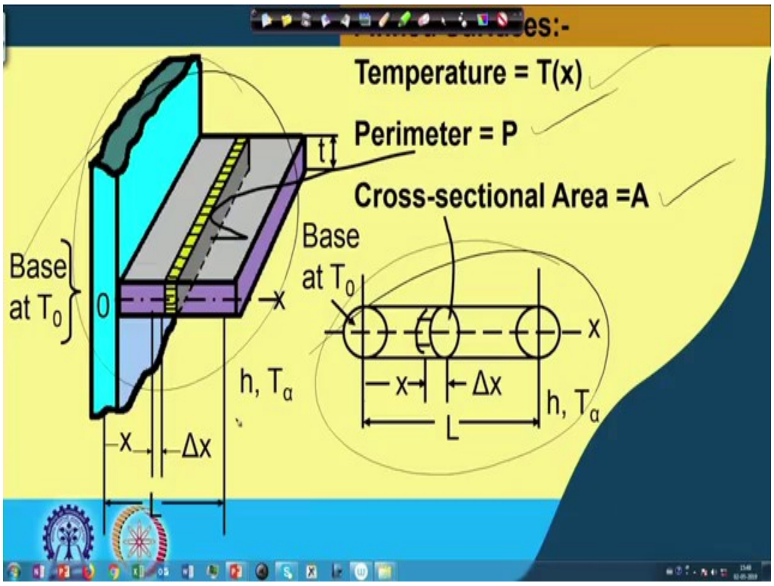
And, this we have shown with 2 solids, but it could be like the previous classes we have shown that these are in series, but it also can be like this is one, ‘right’ and this is another which is in contact, ‘right’. And, these are the two and maybe another one is here, ‘right’, and another one is here, and another one may be there, ‘right’, and all are under one like this. So, how many surfaces you have joined? The same quantity of Q is flowing through this and same is going out through this. So, you have a contact all over with say this is 1, this is 2, this is 3, this is 4, this is 5, this is 6 and this is 7.

So, you have 7 surfaces in contact, ‘right’. So, you will have one; it may have one resistance between these two, one resistance between these two, one resistance between these two, one resistance between these two, one resistance between these two and one resistance between these two and also one resistance between these two, ‘right’. So, there this same Q when it is flowing from one side to other side. So, there may be huge temperature drop from this end. So, this end is T_1 and this end is T_2 ‘right’, from this end to that end, because here it is not coming like parallel or series, ‘right’. Because, this is not coming in that, but it is coming due to the contact, ‘right’ due to the contact it is coming.

So, one resistance here, one resistance and then when you are analysing of course, whether it is going through series or parallel like this three are in series, but here also this three are in series somewhere in parallel, ‘right’. So, this series parallel comes (Refer Time: 19:02) may come in there. And, you have to find out that how much total resistance or total contact resistance has been developed, ‘right’. And, then you may have to find out that delta T.

So, this is a very important one and of course, everything is important, but has to be kept in mind, that unless we are with it we cannot explain the phenomena correctly, ‘right’.

So, after this let us now proceed to the other one after thermal contact resistance, let us now proceed to that fin tube, ‘right’.



So, this is a pictorial view because I hope we will not be able to get so much time to complete this in this class, but since there is a complicated picture which I have drawn, ‘right’. So, let us first explain that and hopefully this explanation will take this whole class over. However, let us take this that you have a surface this is one surface, ‘right’. So, in this surface you have extended the purpose of fin tube is what? Say this is a cylinder, ‘right’; this is a cylinder and this has a surface area. So, it is whatever outside ambient temperature dependent inside this is also a hollow this is hollow.

So, inside also there is a temperature, if there is a or there are difference, then there will be heat transferred through this depending on the material property etc. Now, you saw that it is not sufficient for the heat transfer the surface which is having. So, what do you do you extend the surface by attaching some more surface area, ‘right’. So, like this is one type of fin, there are many types of fins available, ‘right’, but this is one type, by which you are extending this surfers this additional and they are in close contact, ‘right’.

So, this additional surface which is built up is then taking care of the heat transfer along with the normal base surface, ‘right’. So, we have taken that, that is why, we have taken that this surface is the basic surface on which another surface has been built up, ‘right’. So, conventionally we take that the base temperature is at T_0, ‘right’. So, we have taken x direction like this. So, this is the 0 and fin here these along this x, ‘right’ and it is being transferred.

Now, for the heat transfer analysis what do we need to know that this fin has a thickness of T, ‘right’, and this base is at T_0 temperature, it has a perimeter P and it has a temperature distribution and the x direction as T(x), ‘right’ and a sectional area of A, ‘right’. So, we have taken this actually this should have been little this side, because this is corresponding to that, somehow during your drawing it went to this side. So, this is coming like this, ‘right’ and this is like that this line. So, this two lines are coming are according to this.

So, this is corresponding to delta x and this is the x direction and length of this fin is this should be from here and this also should be according to this; so, this is L, ‘right’. And, it is subjected to an environment where the heat transfer coefficient is h and the temperature ambient temperature is T_a ‘right’. So, if that be true then this is one rectangular type and if we take a similar one in the cylindrical type then, this is the cylinder, ‘right’, this is that cylinder and this is the axis in the so, 0 to x this axis is in this, ‘right’.

So, here also we take a small volume element h is here like we have taken the small volume end element delta x is this and the thickness was T, ‘right’. So, delta x and T was there, ‘right’. So, here also we take the base temperature here as T_0, ‘right’, and this thickness is taken as delta x and the length of this fin in the cylindrical form is L, ‘right’. Length of this in the cylindrical form is L. So, in the x direction total length is L, ‘right’.

So, we are not saying what about the radius or diameter, it is all about how much so, this is the base where it is connected like this, ‘right’. This was the one piece and this is extended another piece. Similarly, here also this is rectangular instead of that rectangular if it is a cylindrical, then this base would have been fixed here and we would have a length of L, ‘right’. So, the heat is being transferred in the direction of x, where the environment is subjected to h and T a. Like this one here also we have a sectional area of A and a perimeter of P, and there is a temperature distribution T x in the fin, ‘right’.

So, with this, we will proceed subsequently in the next class may be this class we will not be able to cover up, but in the next class we will do this where this figure we have to keep in mind ‘right’. We know perimeter, we know sectional area, we know the temperature distribution or we have to find out the temperature distribution T(x), 'right'. And, in one case it is like rectangular and in another case it is like cylindrical, 'right'.

So, with this let us stop today because time is up and we will do the analysis in the next class, but keep in mind that though we will also referred to I am not saying that I will not be referring to that, but that time we will not discuss more in detail we will just show it and then proceed to the analysis of the finned heat transfer, ok.

Thank you.