Heat Exchangers: Fundamentals and Design Analysis

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Lecture - 44
Heat pipes and Heat pipe heat exchangers (Contd.)

Hello everyone, if you recall we have started a new topic, very unique heat transfer equipment we are trying to learn that is heat pipe. And as I have told heat pipe is not a heat exchanger itself, but heat pipe could be the part of a heat exchanger, and when it is used to construct a heat exchanger, which are known as heat pipe heat exchangers. They are very efficient in transporting thermal energy that means for a small temperature difference they can transfer a large amount of heat.

And as I have told heat pipes has got wide operating range etcetera, which we will be learn in detail, but still we are in the introduction to heat pipe. So, let us see that how is this device, what are the basic features etcetera. So, the topic which I am continuing is heat pipes and heat pipe heat exchangers.

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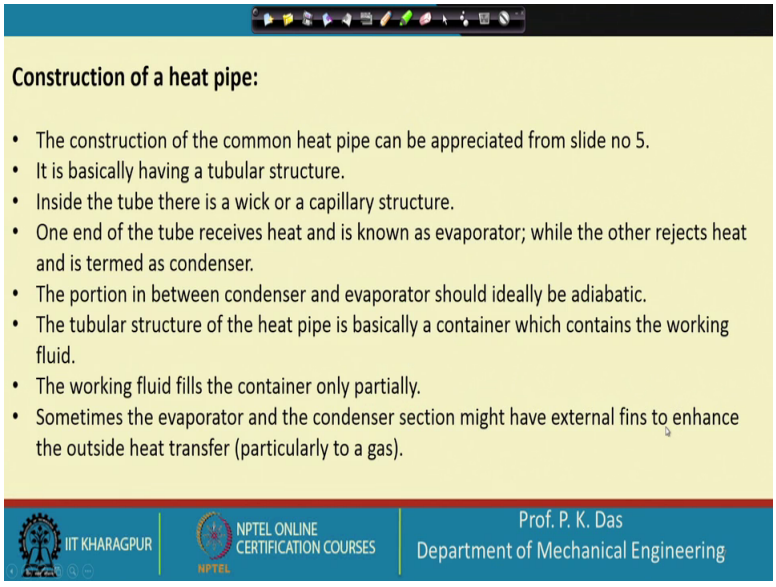

And the last lecture what I have told that heat pipe is basically heat pipe is basically some sort of an improvised version of heat, some sort of an improvised version of thermos siphon. So, the construction of common heat pipe can be appreciated from slide

number 5, number you just forget the number, because the number will change um, but I am going back to that slide, so that it will be easier for you.

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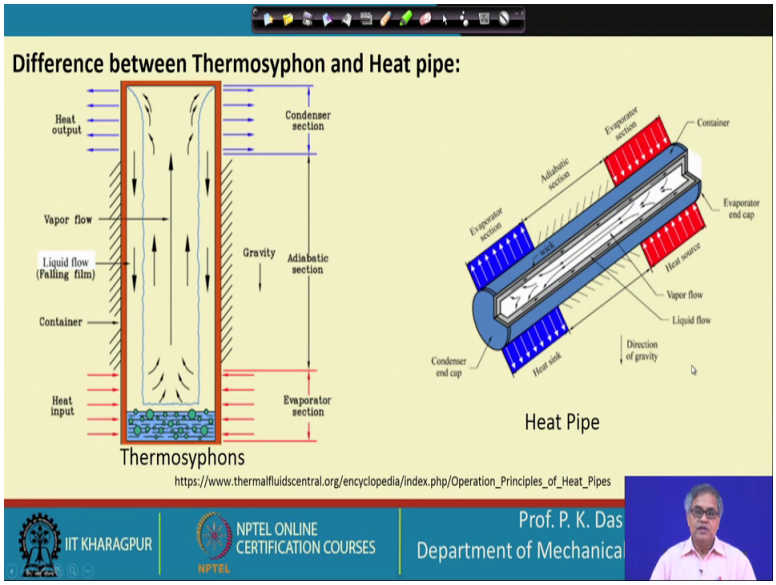

So, some sort of a previous slide I have to go, and let me go to a slide of the previous lecture, where show this is the construction of a heat pipe. So, now, let us try to understand the construction of a heat pipe. And then again we will go back to the current slide. This is from your previous lecture. Now, what we can see the most common construction of a heat pipe is that it is having a cylindrical tube. So, cylindrical tube mostly it is metallic tube, and metals of high conductivity. The wall could be thin depending on the design, but generally a thin wall tube. In the tube, we will have certain amount of liquid, which is known as the working fluid.

Again we will discuss sometimes regarding the working fluid. The working fluid has got a very large range. Cryogenic fluid could be there, there could be liquid metal as working fluid. And once you put the working fluid then generally this the metallic cylinder is sealed sorry, metallic cylinder is evacuated partially evacuated and then it is sealed. And then in this metallic cylinder there is another very important structure, which I have mentioned that is the wick structure or capillary structure, which provides the return path of fluid from the condenser to evaporator.

So, now, if we come to this diagram once again, so there is an evaporator section where heat input will be there, where the heat pipe will receive heat from outside, inside there is

capillary structure within this container. So, this container the blue colour is the container. The capillary structure there is a cut away view, we can see the capillary structure by the by this gray colour we can see the capillary structure. So, here there will be liquid, and this liquid will evaporate. So, here there is a vapour space, and the vapour is moving in the upward direction, here it will condense and come back.

So, evaporated section, condenser section, in between there is an adiabatic section, where very negligible amount of heat transfer takes place, and inside there is a capillary structure and the working fluid. So, this is the construction of a common most conventional heat pipe. And as the name suggest that it is having a pipe like structure and most of the cases it is like it is having some sort of a circular cross section. It is not mandatory that it should have a circular cross section we will see later on, but that was the earlier design or initial design and that is the design till today for most of the applications.

Now, let us go back to our current lecture and the slide for the current lecture. So, we were here, the construction of the common heat pipe can be appreciated from an earlier slide, which I have shown. It is basically having a tubular structure. Inside the tube there is a wick or capillary that I have told. One end of the tube receives the heat, and known is known as the evaporator. The other end heat is rejected, and this is known as condenser. As the name suggests in the evaporated section evaporation will take place. And in the condenser section condensation will take place.

So, phase change is involved that is very important. The portion between the condenser and evaporator should ideally be adiabatic or in practical cases there will be very small amount of heat transfer from the portion, which is sandwiched between the evaporator section and the condenser section. The tubular structure of the heat pipe is basically the container, which contains the working fluid. The working fluid fills the container only partially, so this is also I have told. Sometimes the evaporator and condenser section might have external fins to enhance the outside heat transfer. So, this part we will see later on also, but now let me explain it that what I like to say.

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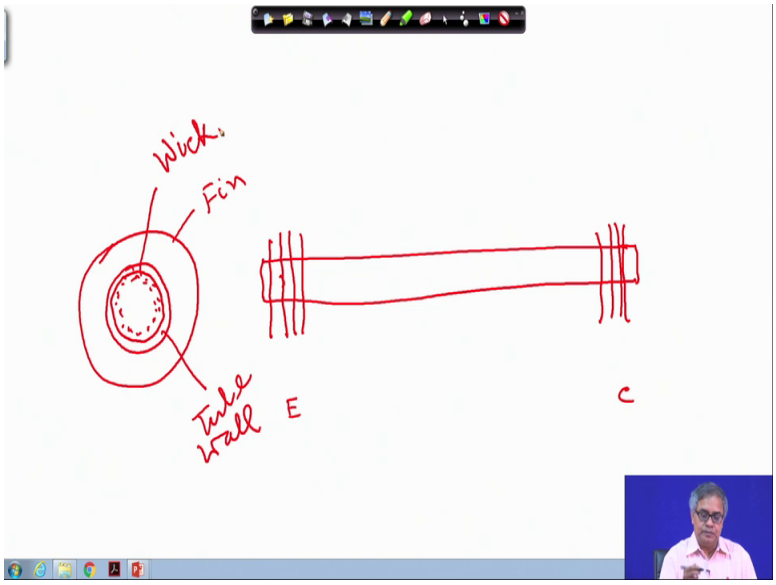

Let us say this is the heat pipe from outside it just like look like a tube or pipe. So, this side is the evaporators, this side is the evaporator section, and this side is the condenser section. So, on these parts there could be fins, because heat pipes can transfer heat from one gas to another gas. Let us say from a hot gas to a cold gas, so outside we can see that gas is there or basically heat pipe can be part of a gas to gas heat exchanger.

So, gas side heat transfer coefficient is very small. So, to improve the gas side heat transfer coefficient there could be fins like this. These are radial fins, if we see a cross section, so the cross section could be like this. So, this is the fin, this is the tubular wall, and this is the capillary structure. So, this is fin, this is tube wall and what I have shown by this dotted line this is the wick. So, in the evaporator and condenser side we can have this kind of fin. So, this is the common construction of your heat pipe.

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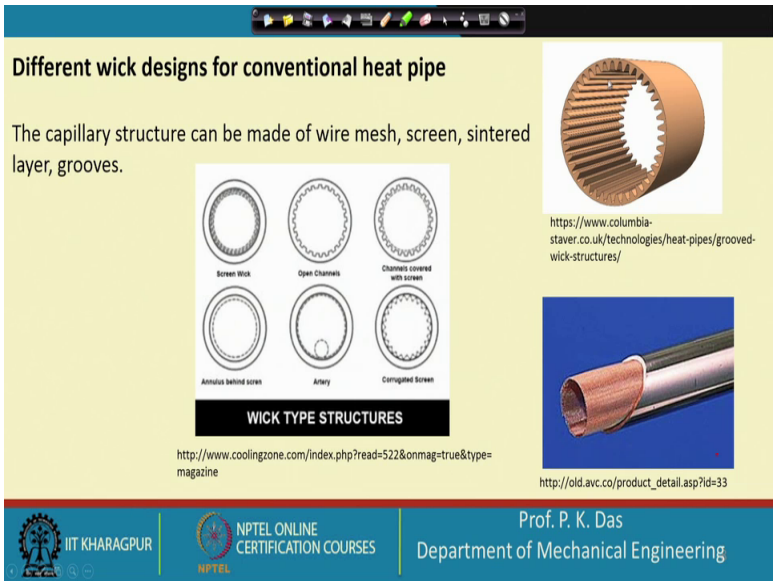

So, out of all these things, out of all these things what is very unique of heat pipe construction is the wick. And here I have shown different kind of wicks commonly used in a heat pipe. Now, I like to mention that these are not all inclusive that means there could be many other kind of designs of wicks structure. So, in this particular case we have got screen or screen type of wick. So, screen type of wick is nothing but some kind of wire mesh, and the wire mesh maybe one layer of wire mesh or several layer of wire mesh is kept inside. So, you can see this is tube wall, and just adjusting to the tube wall close to the tube wall. We have got wire mesh or this is called your screen type wick.

Another thing could be there that suppose this is the tube and on the tube we have got groups, and small channels or groups, so which is shown in an exaggerate manner over here, in the diagram on the right and left we have got this group structure. So, this group structure also provide capillarity and also provide the return path of the condensate. So, we have got wire, we have got groove. And here we can combine both that means here we have got groove and at the outside of the groove we have got screen or wire mesh.

So, it is the combination of channel covered with screen or wire mesh. Then the wire mesh that can be slightly away from the wall here so, we can see there is an annular gap between the wall and the wire mesh. So, this annular gap is generally filled with condensate or liquid. And this can be also one design for the return path of the liquid. Then there is something called; there is something called artery. So, these are for high

performance heat pipe. So, here we can see that there is a spatial structure. And these are mainly the use was there in space system. We will find or we will discuss that in space, there is a lot of space crafts and space systems there are a lot of application of heat pipes.

So, there we need a good thermal control, a good reliability and for the good reliability we have to ensure very efficient and reliable return path of the liquid. So, here there is a structure which is called artery. There could be different kind of artery structure, and with this through the periphery, of course the liquid is coming back. And through this arterial structure also there will be some sort of a return of the liquid. So, this is another design and then there is a corrugated screen kind of a thing. So, this is also another design, but as I have told that these designs are not all inclusive there could be some other design. Many other innovative design of the capillary structure.

So, capillary structure there are many ways of making the capillary structure. At least three ways let me tell you there could be others. One is that we are putting some sort of wire mesh or screen inside the tube. So, this is one variety. Another variety could be that we are providing some sort of paths or grooves, small grooves. This could be small grooves, so that capillarity is in action. This is another third that there is a solid metal wall. Inside the solid metal wall just adjacent to it there could be a sintered or porous layer of these should be open pores. Pores should to be connected to one another, but need not be straight pore.

So, there could be some sort of circuitous root or kind of zigzag root, because the different pores are randomly connected, so that could be another way. So, here we can see this is the outer tube, and this is this sintered layer. So, this is also another way of having the capillary structure. So, there are many other ways of having the capillary structure, but the principal or main ways of having the capillary structure has been described over here. Now, if we go to the next slide, some design variation of heat pipes.

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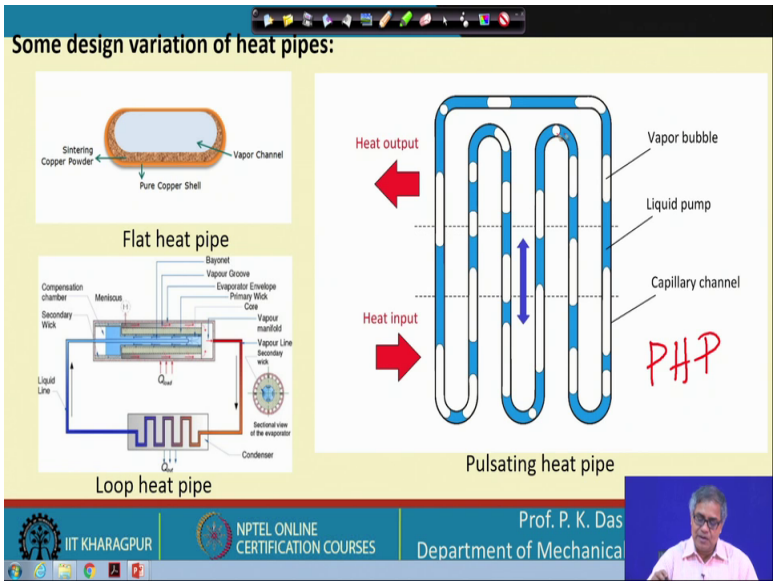

Again let me tell you that the course is in such that we have to cover different type of heat exchangers. So, on heat pipe we will not be able to spend very large amount of time, but some of the unique variation let us tell, let us discuss again with this rider that these are not all inclusive there are many variations possible. The first variation what I like to show at the left hand top so, this is some sort of a flat heat pipe, earlier so far the heat pipe has been described that it is some sort of a cylindrical structure with circular cross section.

This is also a cylindrical structure we are seeing only a cross section, but it is a flat pipe. So, it is long normal to the diagram it could be long, but this is a flat pipe. And this is flat pipes are very handy when we have to go for compact systems, electronic component cooling of laptops, and some such devices, we will see another photograph later on. So, this is one thing. Then I am coming for some sort of a loop kind of a structure. So, the heat pipe below is known as loop heat pipe. So, a loop heat pipe the difference between your normal heat pipe and loop heat pipe is that in the normal heat pipe again let me explain it little bit that would be good.

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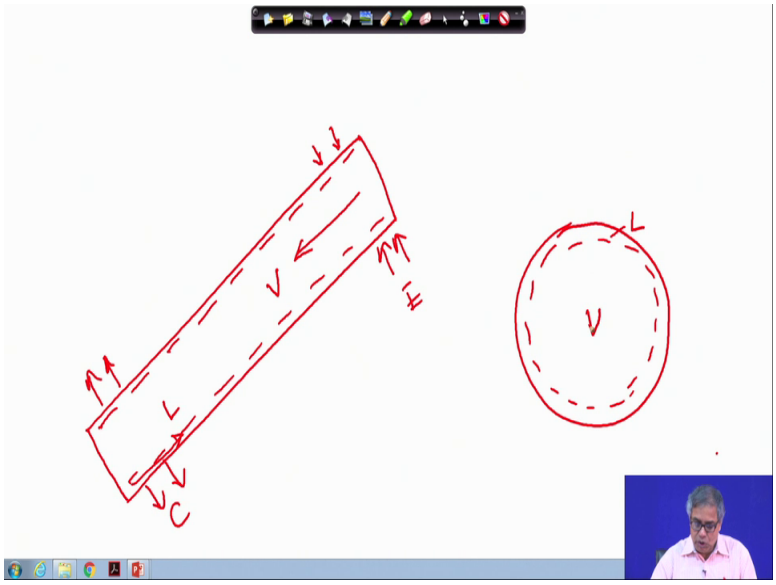

A normal heat pipe is something like this. Let us say this side is evaporator. There is capillary structure inside. So, vapour moves in this direction V and here it is condenser. So, this is your condenser, this is your evaporator, and liquid moves in this capillary structure, so this is liquid. If we take a cross sectional view, then this is vapour and this is your liquid. So, vapour moves through the core of the heat pipe. And liquid moves through the periphery of the liquid, periphery of the heat pipe where this wick structure or capillary structure is there.

So, there is a counter current flow. Vapour moves in this direction from the arrow you will understand. So, let us say in the cross section, if the vapour moves out of the figure, the liquid moves into the figure. So, there is a counter current arrangement of vapour path vapour flow and the liquid flow. Now, in loop kind of heat pipe, the vapour path, and the liquid path are different. They are not present in the same construction sorry same cross section. So, if we go back to the slide again, here we are showing a loop heat pipe, loop heat pipe.

And you see the blue colour. The blue colour shows the liquid path, liquid length liquid line. And the red colour here shows the gas line or the vapour line. So, there is a structure, the structure is very important. This is kind of a structure, which is having number of compartment. One there is a bayonet, then there is vapour group evaporator, envelope, then priming V core etcetera. So, one has to go into details, otherwise it will

not be in a short time it cannot be described, but what we can see basically that liquid path and vapour path are different. This is called loop heat type.

Then on the right hand side I have shown a what is known as a pulsating loop heat pipe or pulsating heat pipe. So, popularly this is known as; popularly this is known as PHP pulsating heat pipe. So, pulsating heat pipe the advantage is that that there is no capillary structure. So, there is kind of meandering or serpentine kind of a loop. And through this loop there will be alternate path of liquid plug, vapour slag like that. And there will be some sort of a pulsation as you can understand, but ultimately the vapour plugs will go to the condenser section. They will be generated in number large number in the evaporated section.

They will go to the condenser section they will condense over there. And mostly liquid along with some small number of vapour bobs will come back to the evaporator. Again more number of vapour plugs will be generated. So, this is your pulsating loop heat pipe. So, pulsating loop heat pipe the number of these are called number of turns. So, what one can see in this particular diagram that we have got 1 number of turn 2, 3. So, 3 turns are there. And if we increase the number of turns, then what happens this pulsating loop heat pipe can operate at any kind of orientation.

If there is less number of turns, then evaporator has to be at the bottom part of the heat pipe. Condenser has to be at the top most part of the heat pipe, but if we can increase the number of turn, there could be very large number of turns 40, 50, 60 etcetera. So, if we really go for large number of turns, and then what we will have that it becomes independent of gravity at any orientation this kind of heat pipes can operate or there should be a very nominal very small inclination at that nominal inclination it can operate.

It really did not be always in the vertical orientation. So, this is your pulsating loop heat pipe. So, 3 different type of heat pipe I have shown. In the first heat pipe I want to create this impression that it is not always of circular cross section, flat heat pipes are there. Secondly, I have shown one example where the vapour and liquid paths are made different. And again in some part of the heat pipe there is this wick structure not in all the part, but in some part if we go back to the slide, so here we have got kind of wick structure.

And then the hard variation which I have shown, which I have written as PHP so, there what we can see that we have got a no wick structure at all. So, without wick also we are able to provide or able to design kind of heat pipe. So, this gives you at the beginning the different type of designs possible. And what one can have by varying the design intelligently, one can have different kind of heat pipes for different application. Now, with this let me go back to the next slide.

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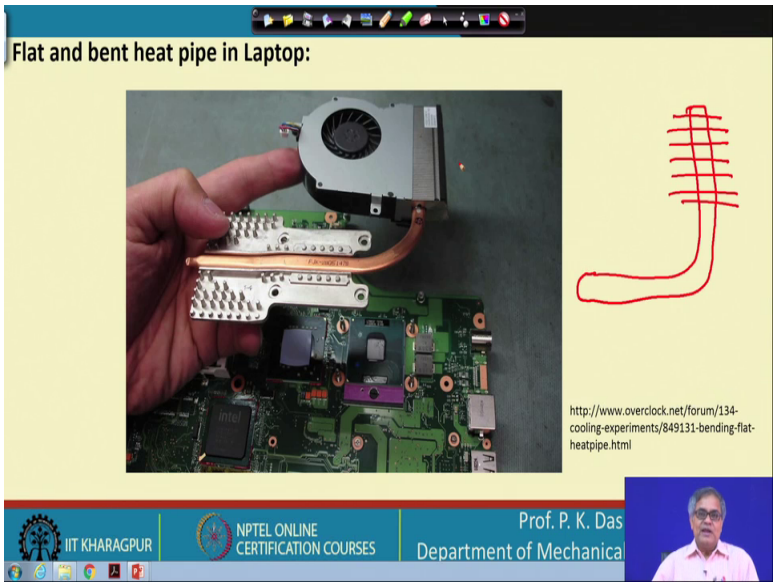

So, this is one slide where you see the use of a flat heat pipe. So, I have written this is a flat bent heat pipe in laptop. In laptop if somebody has opened, probably one can see the laptop this kind of a heat pipe. Let us take little bit of time and explain what is the working principle. So, here in the laptop you know all the thermal, all the equipment electronic equipment, thermal management is one of the problem. And the electronic component that will generate heat that has to be dissipated very efficiently.

So, what we can see that here there are lot of heat generation. And so, from here heat has to be picked up. So, if heat has to be picked, so this is picked up by the evaporator section of a heat pipe. The heat pipe is basically let me draw the side only. So, heat pipe is basically having some sort of a structure like this. So, you need not have the feeling that the heat pipe is always a straight pipe. This is a bend pipe in more crooked kind of configuration is possible.

You see this is bent and this is flat. So, the heat pipe from the evaporator section it will pick up heat and then it is going here this is your condenser section. Now, this is the condenser section. In the condenser section ultimately the heat has to be given off by the given up to the ambient. So, here for efficient transfer of heat, what we are having? This condenser on the condenser section we are having fins, which I have mentioned earlier. So, basically we are having number of fins over there. So, here heat is dissipated.

So, how heat is dissipated? So, on this fin structure if we circulate air at a high velocity, then it will be dissipated. So, for that we have got a fan over here. The fan of your laptop that is over here and here from the fan the air will come it will take up the heat and will come out of the laptop. So, on this side we have got something called a spreader, which will collect the heat bring to the evaporator. This is a flat tube and bent tube. This is the condenser section here the outside heat transfer is enhanced by providing fins, and by providing an air flow over the fin structure. Heat is ultimately deposited or rejected to the ambient atmosphere. So, this is very important. This is one of the very important component of your laptop. The laptop will not perform well if the thermal management is improper. And you see in the thermal management heat pipe is taking a very crucial role.

So, with this information I like to end my lecture today and so, thank you. And I think this has given you some sort of exciting information for a very unique heat transfer equipment, which can be used in different application. Only one application we have seen today that is your laptop, but there could be different application, I will come to that advantageous, limitation, design etcetera; I will come to those aspects.

Thank you.