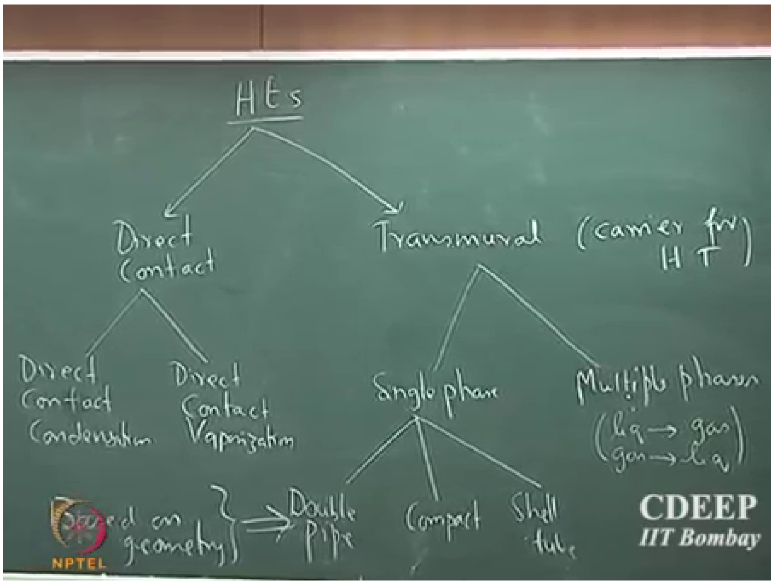
Heat Transfer
Prof. Ganesh Viswanathan
Department of Chemical Engineering
Indian Institute of Technology, Bombay

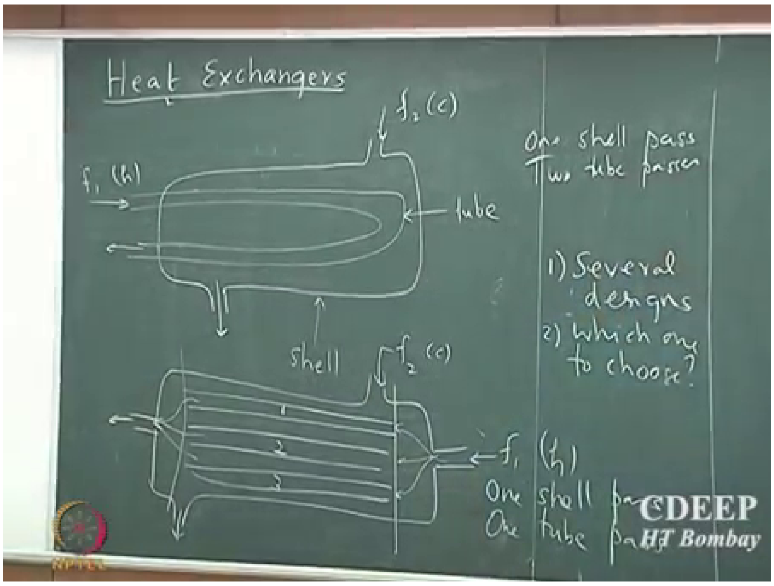
Lecture - 57
Parallel flow heat exchangers

Now, the third one is the shell and tube heat exchanger some of you have already seen in your bios and lab and some of you may have seen industry also.

(Refer Slide Time: 00:32)



(Refer Slide Time: 00:36)



So, the idea is you have a shell, you have a shell and then you have a tube you have a tube and there is one fluid which is flowing through the tube, let us say it is the hot fluid and let us say that there is another fluid which is let us say cold fluid, which is flowing through the shell ok. So, the outer one is called the shell and the inside one is called the tube.

So, there are several types here so, now if you look at this specifically this shell and tube design. So, the fluid which is going through the tube is actually going around and then turning back and so, what you have is this is what is called as the one shell pass, this type of heat exchanger shell and tube is called one shell pass and two tube passes ok. And the way to see that is the hot fluid goes through the shell once and whatever it; whatever heat exchangers it experiences that is it, but then when it comes to the tube you see that the tube actually travels twice inside the inside the shell and that is why it is called the two tube passes ok.

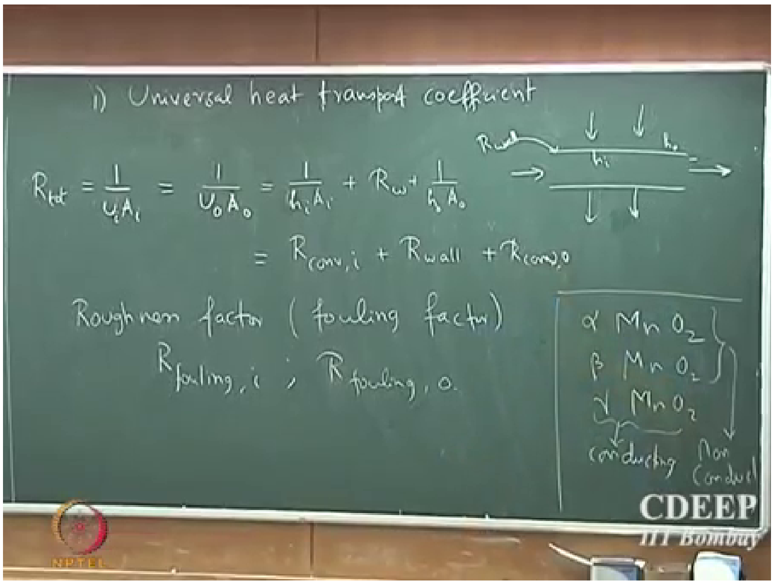
Now, one can always draw a one shell pass and one tube pass, the way to do that is way to visualize that is ok. I have three tubes tube one tube, to and tube, three . Now I have an inlet stream here and let us say this is f 1 and this is hot fluid and I have an outlet stream here, and this is let us say the cold fluid comes in and goes out. So, here the hot fluid which comes into the shell and tube heat exchanger, they get distributed into these three channels ok.

And then when they go through these tubes they experience heat exchange only for one length scale of the shell ok. So, then they come out they go out together. So, this is what is called one shell pass and one tube pass ok. So, simply based on these two examples and in fact, you can have multiple shell passes you can have multiple tube passes. So, multiple shell pass would be that I could join these two shells together where the outlet fluid of f two grows as an inlet stream to the second shell. So, now, I have two shells and several tube passes ok.

So, I can always do that. So, this immediately you realize that there are several possibilities I should rather say several designed for a given problem for a given amount of heat exchange for a given set of fluids you can have several possible designs. So, the question is how which one is the correct one which one to choose. So, that is an important question. So, here you know the design the technical design and the economics, they play a strong role here particularly when you look at heat exchange. Both in terms of the cost of construction and in terms of cost of pumping the fluid with respect to watch the extent of heat transport that is desired. So, the. So, this is the first time you will see in this course where the design and the economics are related; although it is always there, but then we never looked at the economic point of view. So, this is the first time we talk about where the design plays a strong role in the amount of money that is spent in in the industry for heat exchanger any question so, far?

By the way it is important to note that, most of the heat exchange process in all the industries that I had listed, they actually you shall into heat exchanger. Because you have extensive amount of flexibility on how you want to design in order to achieve the heat transport that you want ok. So, it gives you a lot of flexibility in terms of both increasing the heat transport area and with keeping the pressure drop in mind and keeping the efficiency in mind alright. So, what we need the first aspect we need to discuss in terms of designing heat exchanges the universal heat transport coefficient.

(Refer Slide Time: 06:16)



So, we discussed about it very briefly when we talked when we actually dealt with conduction, we also discussed about it when we actually dealt with convection internal flows very briefly we did that. So, suppose if I have if I have a tube, where I have a fluid which is flowing through this tube and I have another fluid, which is either flowing along the curved surface or parallel to the curved surface it does not matter. So, I can always define a an outside heat transport coefficient has 0 and I can define an inside heat transport coefficient h i and a resistance that is offered by wall for heat transport coefficient.

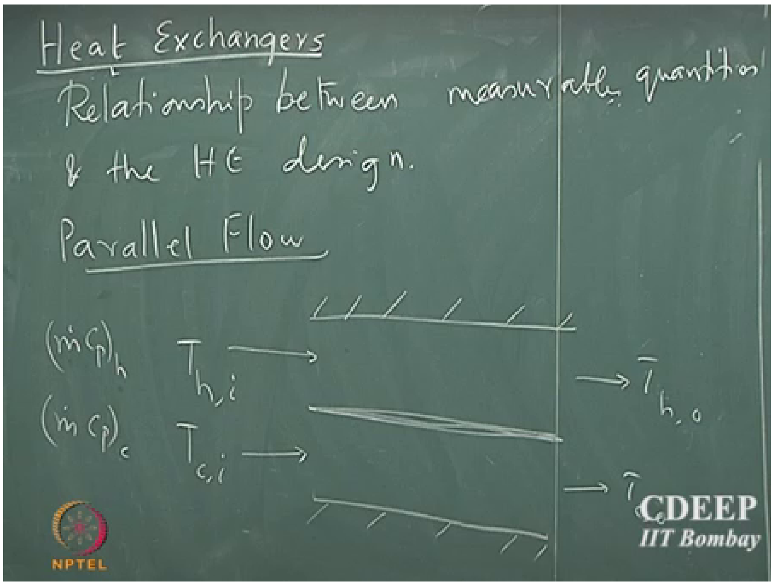
So, that comes from the conduction in the wall and these two comes because of convection given heat transport. So, I can always define the heat transport coefficient one by U A. So, now, you have to distinguish between the inside and the outside surface area of heat transfer ok. So, one by U U inside define based on the inside surface area that should be equal to how are the inside and the outside here universal heat transport coefficient related yeah ok, but that is also equal to 1 by U o time A o right. So, the universal heat transport coefficient defined based on the outside surface area we have already seen this ok.

So, now so, that should be equal to 1 by h i A i plus the resistance offered by the wall plus 1 by h o times A o ok. So, 1 by U i A i is something like a a total resistance what is the total resistance offered for heat transport. So, that should be equal to the resistance offered for convection, convection given transport in the inside of the tube plus the resistance offered by wall for heat transport, plus resistance offered by convection outside the tube ok. So, that is what tells you what is the effective resistance for heat transport from the inside to the outside or vice versa depending upon where the hot fluid is flowing.

Now, in addition to that what we never considered so far is, we always assume that the inside and the outside surfaces are smooth ok. So, we never accounted for the roughness factor we never accounted for the roughness factor and also more importantly what is called the fouling factor. Now what this fouling factor is, is that whenever there is a fluid which is actually going to flow through. So, remember that most of these fluids that for which heat transport has to be done they are very corrosive.

For example, if you look at sulphuric acid plan, we want to heat the heat sulphuric acid sulphuric acid is very corrosive. So, it is really going to affect the interior surface, which is available for heat transport and so, that kind of disturbance that is offered for the heat transport because of corrosive nature or some deposit that the fluid might actually leave on the surface. So, all that is accounted for in something called the fouling factor ok. So, we will simply represent that using some resistance. So, I call it fouling inside and resistance for fouling factor outside.

(Refer Slide Time: 11:06)



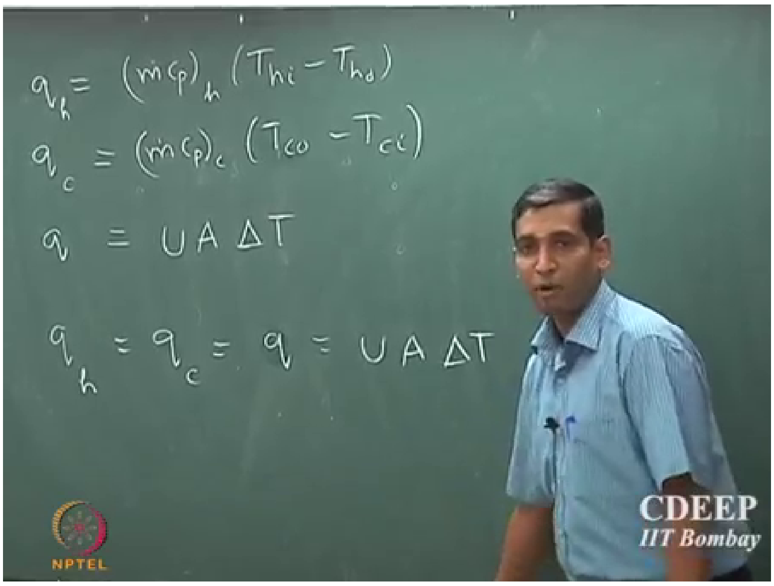
Relationship between measurable quantities and the heat exchanger design ok. So, let us say we start with a parallel flow case or a co current flow. So, let us take a very simple case of two chambers ok, I have two chambers and you have a hot fluid, which is flowing through let us say the upper chamber and we have a cold fluid which is flowing through the lower chamber and you have a wall here.

So, it is a trans mural heat exchanger and. So, there is heat that is transported from the hot fluid to the cold fluid. So, let us say that the inlet temperature is T h i and the outlet temperature of the hot fluid is T h o, and the inlet temperature of the cold fluid is T c i and the outlet temperature is T c o ok. And let us assume that there is no heat loss from the both these surfaces let us assume, that it is a an adiabatic situation and if I also say that m dot C p h is the capacity of the fluid m dot is the mass flow rate of the hot fluid and C p is the specific heat capacity of the hot fluid and similarly I can throw this m dot C p of a cold fluid.

Now, suppose I assume that the axial conduction is negligible remember this is never the case actual conduction is always there except that, there are some situations where you can say that the convection mode is dominating over the conduction. Some of this aspect you will actually see in your reaction with in class later something called a peclet number, which characterizes the time scale for dispersion and time scale for convection and. So, depending upon the peclet number one could actually sort of discern as to when the axial conduction or actual thermal dispersion is important ok.

So, relief means when is axial thermal dispersion is important and then if you assume a steady state and constant property. So, now, what I am going to do is, we are going to write a simple energy balance in order to monitor the heat transport in this system and bring everything in terms of the measurable quantity. Remember that the measurable quantities are the inlet and the outlet temperatures of the hot and the cold fluid ok. So, we are going to bring everything in terms of the measurable quantities what is the total heat that is lost by the hot fluid q.

(Refer Slide Time: 14:06)



I know the capacity m dot C p. So, its m dot C p hot fluid multiplied by T h i minus T h o. So, that is the amount of that is the rate at which the heat is being lost by the hot fluid.

So, if I put subscript h that is the amount of heat that is lost by the hot fluid, and what is the amount of heat that is gained by the cold fluid easy right. The m dot C p cold fluid T c o minus Tc i. So, remember that the outlet temperature of the cold fluid is higher than the inlet temperature because it is being transported from the hot fluid to the cold fluid. But we also know that the total amount of heat that is transported is equal to U A into some delta T. We do not know what the delta T is, in your lab experiments you would have used delta T log mean temperature you are going to see why it is log mean temperature. We briefly saw it when we discuss the internal flows they are going to see with it with lot more details in tomorrow's lecture.

So, if supposing if it is adiabatic where there is no heat loss from the two walls, then q h should be equal to the amount of heat that is gained by the cold fluid and that also should be equal to q equal to U A delta T ok. So, we still do not know what this delta T is you have been told that it is delta T l m t d, but we are going to see rigorously why it is delta T l m t d and in fact, why delta T, l m t d is the representative temperature difference for any heat exchanger.

So, what we showed when we discussed internal flows we said delta T l m t d we derived it for pipe heat you pipe flow, but we are going to show in the next couple of lectures that delta T l m t d is the representative log mean temperature difference for any heat exchanger. Does not matter what you use ok. So, we are going to see that in the next lecture and probably another lecture after that as well ok.