Heat Transfer
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Lecture – 56
Introduction and example

So, today we are going to switch to the next topic this heat exchanger.

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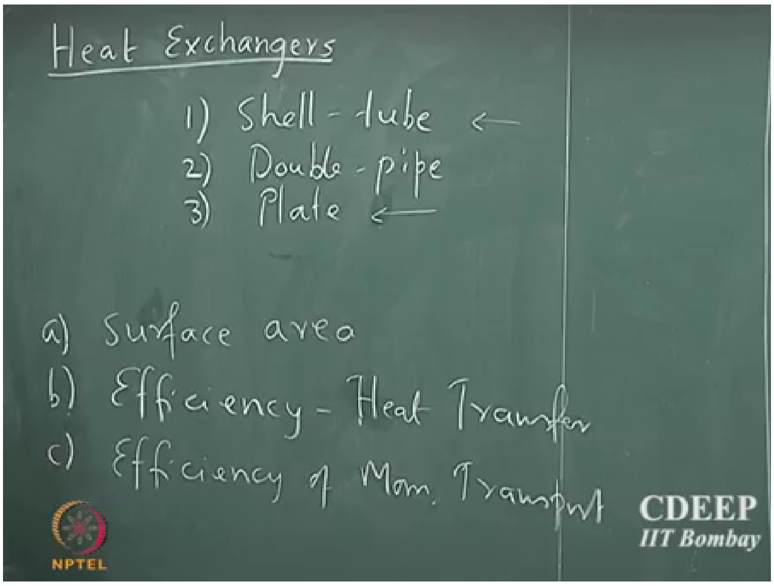

So, heat exchanger I mean as you have already seen; already three types you have seen you have seen shell tube, you have seen double pipe, and you have seen plate heat exchangers, why are they using different; so you already experienced three different types. So, why do we need different types of heat exchangers? Why do you use shell and tube in any thought; it is if you do not know will explain that today, but did you ponder about it ok.

Let us ask a simpler question why do we have double pipe heat exchanger the lab? Why not shell and tube? What is the purpose of the lab experiment? You will require heat transfer coefficient for all of them is heat exchange which is happening between one fluid and another fluid. In all these types there is no exception to that. And in all these types the two fluids, which is exchanging heat they are not in contact with each other anyway right.

You have you have a tube basically you have a wall in between and the heat is transported from the fluid to the wall and from wall to the other fluid. So, that is common to all these three. So, why do we use different heat exchangers for different of different situations ok? So, one possibility is surface area heat transported. So, efficiency ok, I could still use the same heat exchanger with similar inlet and outlet temperatures, so what really matters is; these two aspects not just the temperature.

The efficiency can actually be looked at in two ways: one is the I would say transport rather heat transport efficiency. We will actually define mostly two lectures down the line, how to define efficiency for these kinds of equipments and how do you use that aspect into designing the heat exchanger equipment. You also had to worry about the efficiency of momentum transport, is where the pressure drop plays an important role.

So, depending upon the nature of the fluid that you choose as he rightly pointed out depending upon the viscosity and other properties of the fluid, you will have to use different heat exchanger in order to maximize the benefit that you would get in terms of saving energy and also getting maximum heat transport that is correct; because the pumping cost is going to be minimal, if you have high pressure drop these; so if you want to pump a viscous fluid, you never want to do it in a plate heat exchanger will actually I will sketch, how these plate heat exchangers and a parallel plate heat exchangers, how they look like and you also do not want to use a small tube diameter you know shall and tube you have tube which are which have a very small diameter you will have a very serious issue in terms of transporting those fluid inside the tube. So, so design aspects comes into play as to, which part of the heat exchanger you have to flow what kind of fluid.

So, you cannot; so there is no specific reason ah; in fact, there is there is no specific reason for your lab experiments as to, why you should put mono ethylene glycol in the in the inside tube and water on the outside; and there is one specific reason the reason is that which is not a very strong reason to do that, but particularly from the lab experiments point of view; yeah the hot fluid is your mono ethylene glycol right, we are cooling the mono ethylene glycol. So, if you now flow mono ethylene glycol in the outer tube, then you also have to worry about the amount of heat that is lost to the surroundings.

So, it is for that purpose that it is been made to flow inside. So, that has been worked out ok. So, so pumping cost is actually very very important, when you design these kind of heat exchangers. So, based on this one can actually classify heat exchangers into two broad classifications.

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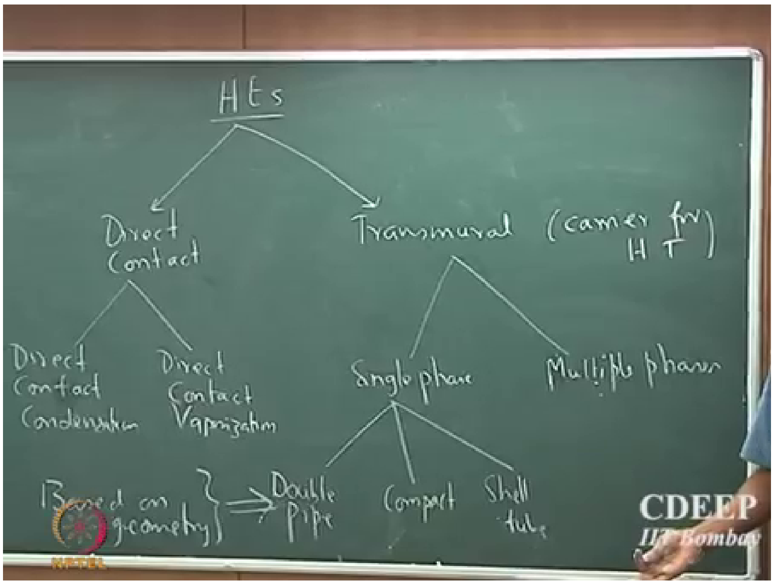

So, one is called the direct contact heat exchangers direct contact heat exchanger and the other one is what is called as the transmural. So, all the heat exchangers that you have seen or sort of heard about, they are all primarily transmural, that is there is no in direct contact heat exchangers we briefly alluded to this in the last lecture.

So, in the in the case of direct contact condensation; so, direct contact heat exchanger is where the fluid as actually in contact with the other fluid directly. Transmural is where you have a solid which is present inside like a metal for example, and that metal acts as a carrier for heat transport.

So, in transmural heat exchangers you need a carrier for heat transport. So, unlike in direct contact you need a carrier for this particular case ok. So, of course, in direct contact you can have two possibilities, you can have direct contact condensation, which we already briefly explained yesterday and you can have a direct contact vaporization. So, note that both of these they involve a phase change and of course, you would expect that these two liquid should be invisible otherwise the purpose is lost, if their fluids are miscible then it is no point in going for these kinds of a heat transport processes ok.

Now, in transmural you can actually have two types: one you have a situation, where only single phase of both the fluids are involved and one in which there is multiple phase ok. Multiple phases are involved for example, it could be like a vapor stream and a liquid stream or you can have a condensation process or you can have a boiling process etcetera ok. So, in single phase you have three types ok. So, this three types is actually based on geometric classification.

So, you have double pipe double pipe and you can have compact and you have shell and tube ok. So, typically when you have multiple phases ok; so, geometric classification so this is geometry classification these three are based on geometric classification and in principle even when you have multiple phases involved you could use these three depending upon those three factors that we actually discussed a short while ago; like what are the important factors you have to consider while designing heat exchanger. So, remember that if you have multiple phases, let us say one of the phase is let us say condensing steam it is a very common process where steam is now passed through the heat exchanger and the steam condenses and the latent heat is now used to heat another fluid.

So, you have to be very careful as to how, which kind of heat exchanges you choose, because now you have to pump steam, which is in vapor phase and the density of steam is not as high as density of water. So, you have to take all that into account, when you actually design and when you choose what kind of heat exchanger is used ok.

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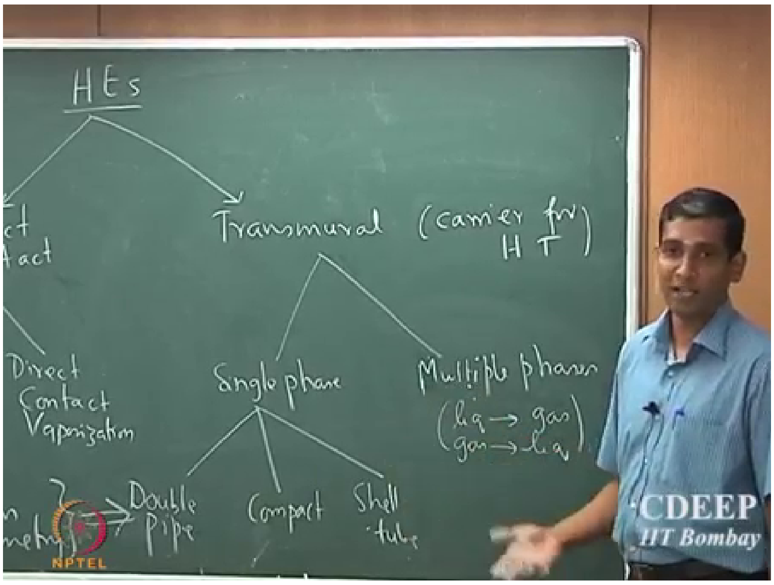

So, now what we are going to see. So, of course, multiple phases you will have going from liquid to gas phase or gas phase to liquid phase both these cases and you have to decide, which one to use you would probably never use a double pipe when you have a liquid to gas or a gas to liquid when you have multiple phases and we will see why that is the case in a short while ok. So, one can easily realize that heat exchangers are really the workhorse.

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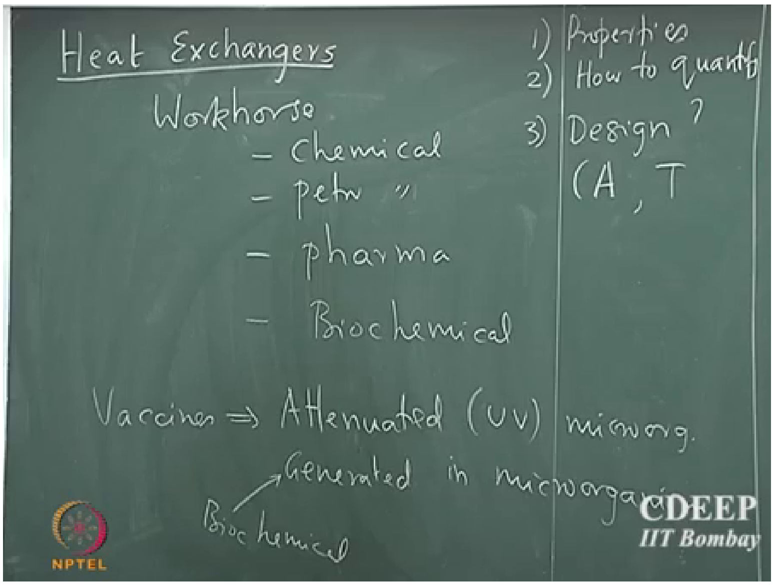

Workhorse of many industries not just chemical you have it is a workhorse of chemical of course, chemical industries, petrochemical, but in addition to that it has strong implication in pharma; in pharmaceutical companies when you go you will see lot of these heat exchangers, because some of these drugs that they make they are not always made at room temperature they are all made in reactors.

So, really in pharmaceutical companies it actually plays a very critical role, because the precision with; which you want to make the drug is significantly higher. You would never want to sacrifice on the precision of the composition of the drug. So, the temperature of the material, which is going into the reactor to get converted into the drug plays a very very significant role. So, heat exchangers and precise design of heat exchangers and efficient use of heat exchangers plays a very important role in pharma industries. They also play a strong role in biochemical industries for example; you know some of you may not know some of you may know how a vaccine is made; how many of you have had vaccinations, I am sure everyone has had vaccinations some time or other in your life so far.

So, you know vaccines are not direct chemicals some vaccines are attenuated microorganisms ok. So, some vaccines they are attenuated, typically using ultraviolet radiation, microorganisms and some vaccines are actually generated they are generated in microorganisms. So, the way the second one works is you use some of the microorganisms which can secrete some chemicals some compounds it can secrete. So, you tweaked the organism you cheat the organism and you modify it is makeup and then you make it to produce large quantities of that particular vaccine.

So, this is done in; so these are called as; so you have biochemical reactors biochemical reactors, which can be used for producing some of these vaccines in the bulk quantity. So, remember that when you when an a vaccine comes into market you really need like several lakhs and lakhs of vials, because there will be. So, many people who would want to get vaccinated. So, for generally for vaccination against virus if the first route that is used and all the other vaccinations, typically it is the second route which is used not always true, but typically ok

So, here precise control of the biochemical reaction is extremely important in order to get good quality vaccine and also good quantity vaccine. So, quantification is a strong function of the amount of vaccine that is produced in the reactor is a strong function of the temperature at which the reactor is operated. You will see a lot more about temperature controlled reactions in your reaction engineering class, but it plays a very strong role here.

So, heat exchangers are used in order to heat some of these fluids and therefore, you can see that they are ubiquitously found in lot of industries which is useful. In fact, we do not know that heat exchanger is used in several of these places. We are going to see what are the properties of different heat exchangers, how they look like? What are the characteristics; then we are going to look at how to quantify the heat exchange process.

So, remember that the measurable quantities here are the inlet and the outlet temperatures and the flow rates, which is what all of you have measured in your lab experiment double pipe experiments you know what the flow rates are; you know what the inlet and the outlet temperatures are. So, based on this experimentally measurable information can we quantify the extent of heat transport and can we use that information to design, design heat exchanger for a given system.

For example, it might be that; I want to transport let us say x amount of heat transport rate ok. Let us say the heat transport rate is q that is the amount of heat that I want to transport. What is the correct or the optimum design that is I should choose? And what is the type of the heat exchanger that I should choose and what should be the area of heat exchange; what should be the flow rate? So, those kinds of questions are actually very important in terms of handling heat transfer.

So, we are going to see how do you design or obtain some of these parameters we will not see all of them, you will see a lot more of these when you actually look at the process equipment design in your I think seventh or eighth semester, where all of these will be once again put together and you look at much more details about the mechanical design of heat exchanger. So, we will not look at the mechanical design, but we will primarily look at the area of heat transport estimating the temperatures inlet outlet temperatures depending upon the heat exchangers.

Like you could have a question that ok; here is my fluid, which is entering the heat exchanger at a certain temperature and here is the area of heat exchanger and I want to know, what should be the outlet temperature or what will be the outlet temperature. So, those kinds of questions we will try to answer in the next few lectures. And I will show you different methods that can be used for estimating these parameters ok.

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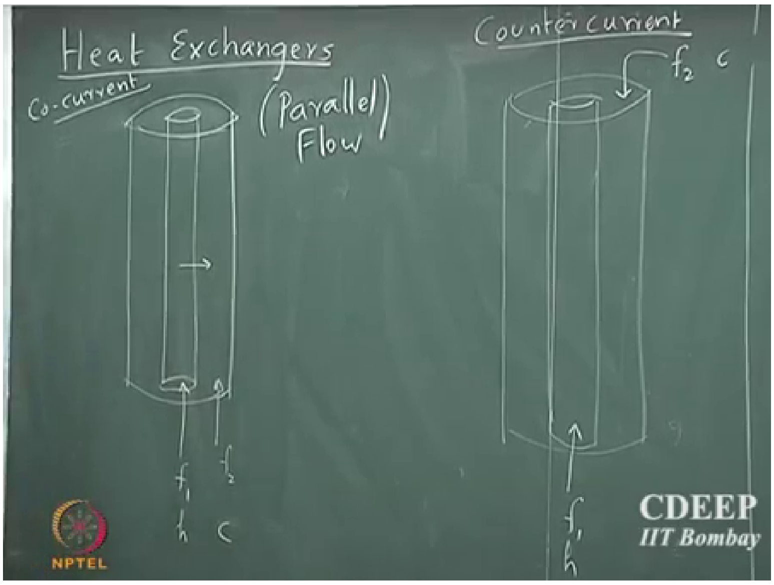

So, double pipe all of you have seen very simple we just have two pipes. So, we have a double pipe heat exchanger and you could have one fluid let us say I call it fluid one, which is flowing through the inside tube and I could have another fluid, fluid two, which is flowing through the outside tube ok. And the sub h; sum I use subscript h to refer to hot fluid and subscript c to refer to cold fluid. So, let us assume that the fluid which is going to the inside tube is the hot fluid and the fluid which is going through the between the concentric circles is the concentric cylinders is the cold fluid ok. So, you expect that there is heat transport from inside to the outside all right.

So, now we could have a similar; so this is called the co current operation, where both streams are actually flowing in the same direction they are going parallel to each other, this is also sometimes called as parallel flow heat exchanger parallel flow and co current flow they all mean the same ok. Now, you also have another situation was to have another situation, where it is called the counter flow counter current flow ok, where you have let us say fluid one which is flowing through the inside tube and it is a hot fluid.

Now, you higher fluid two which is actually flowing counter currently to the first fluid ok. So, they are actually flowing counter current to each other. And there are some advantages with this kind of design and we are going to see what those advantages are and why it is advantages over the other one. So, one of your experiments in the lab is of parallel flow, if I am right the other one is a counter flow; I do not know which one is parallel flow laminar or turbulent ok. So, laminar flow is our parallel flow and the turbulent flow is a counter flow in your lab experiment ok.

So, now let us look at the second one, which is the compact heat exchanger.

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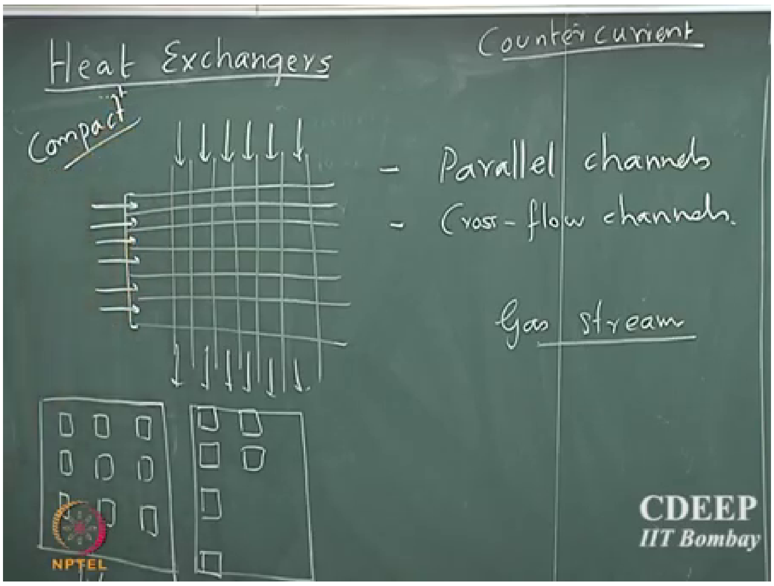

A typical compact heat exchanger a most of you probably would have seen in your if you have seen you have a car or if you have noticed you will see that the radiators that you have in the front even excellent example of compact heat exchangers ok; where you have the only difference there is that you do not have two fluids where it heat exchange is happening it is just one fluid which is carrying heat from inside to the outside the airstream which is carrying from inside to the outside, but in compact heat exchanges industries, what you can have is; you can have a situation where you have one fluid, which is flowing through the pores of this array ok.

Going from one direction to the other direction and you can have another fluid which is actually flowing through the other matrix and it is designed in such a way that they are not mixing with each other remember that it is; so you must remember that it is a three dimensional array it is not a two dimensional array. So, you have a three dimensional array and then you make sure that the tubes are aligned in such a way these plots are aligned in such a way that the fluids do not mix with each other ok.

It is like a monolith how many of you have seen a monolith. So, this will be like a cascade of monolith, where you will have you will it is a three dimensional object, where you will have these slots which is going inside and you can have two possibilities; where you have simple parallel channels we will have parallel channels ok, where the fluid is like probably just try to sketch a top view of that. So, you can have slots like this ok. So, this is the top view. So, you have one fluid which is going through these slots here.

So, if I draw a side view you will have non aligned slots like this ok. So, you can have another fluid. So, this is the side view and this is the top view ok. So, you have one fluid, which is flowing through these tube another flowing which is a wave fluid, which is actually flowing to the other side and the reason why it is compact is you can have a situation where you arrange several of these slots tiny ones and pack them all together.

So, these kind of and; so one possibility is you can have parallel channels like this or you can also have you have a cross flow channel you can have cross flow channel heat exchangers. So, depending upon the properties of the fluid the flow properties or the momentum transport, you can use compact heat exchanger different types of compact heat exchangers.

For example, if you have a vapor stream you are exchanging heat between two gas streams or two vapor streams, then you really do not need that much pressure drop you know really do not need to pump it that much. So, the amount of energy that you require to pump vapor stream or a gas stream inside the compact heat exchanger is significantly less compared to that of pumping of fluid or a liquid to through this tube. So, this is really ideally suited for heat exchange between gas streams and it is found in industry very fairly very commonly it is founded industry ok. So, that is the compact heat exchanger, this is the compact heat exchanger.