Fundamentals of Food Process Engineering
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Lecture - 25
Heat Exchangers (Contd.)

Hello everyone, welcome to NPTEL online certification course on Fundamentals of Food Process Engineering. So, today we will continue with the topic of Heat Exchanger. This is the last class on heat exchanger, where we will see the remaining things we have discussed most of the parts of the heat exchanger the important aspects of the design.

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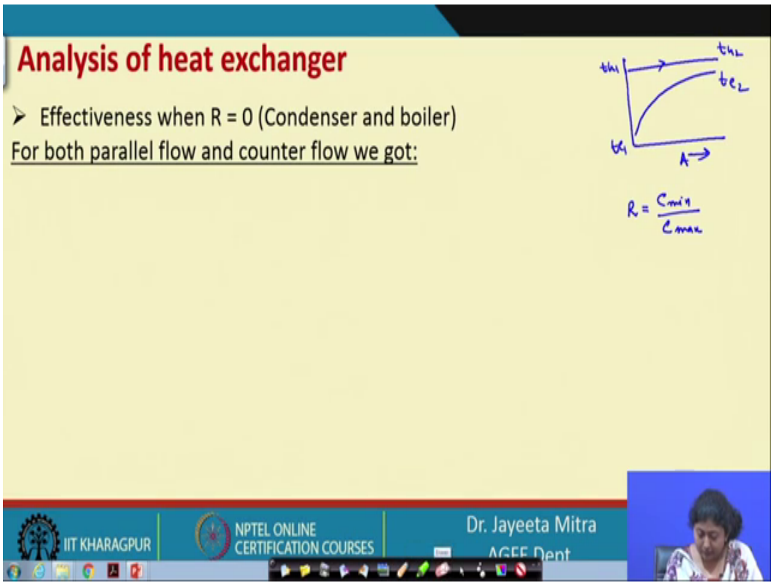

And, today we will see few numerical problem and its use in the food industry ok. So, in the last class, we have discussed the effectiveness using the NTU that is number of transfer unit method. NTU is nothing but u a by c minimum. And effectiveness in terms of NTU and another dimensionless parameter that is R which is the capacity ratio that we have discussed.

So, today we will continue with that only effectiveness when R is equal to 0. Now, when R become 0, we know that in certain cases temperature does not change where the phase change is involved ok, for example, the condenser and the evaporator. So, in case of condenser hot fluid temperature does not change.

So, if you if you see the temperature profile along the length or along the surface area, so you will find that t h will be constant and t c will be varying ok. So, t h 1 and this is t h 2. And here it is t c 1 t c 2. Now, what is R we are getting R as the capacity ratio that is the possible change of this I mean C min by C ok, C min by C max.

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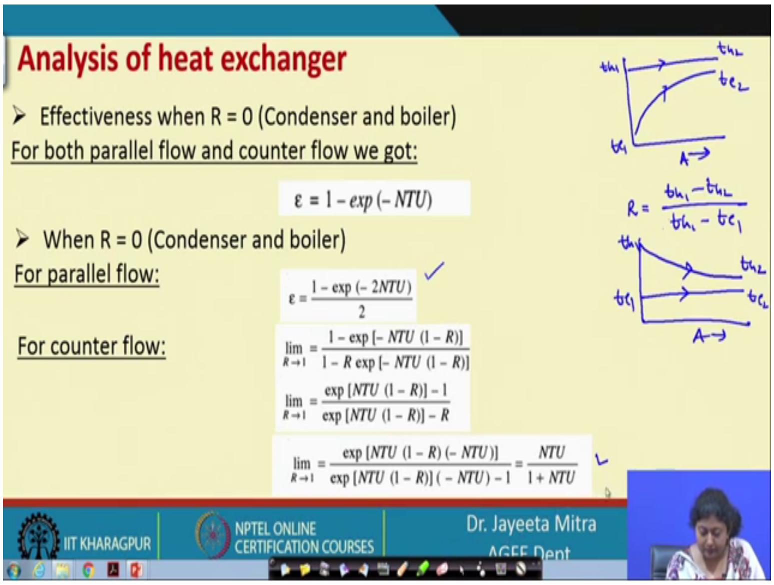

So, then what will happen that when your when your temperature of the hot fluid does not change, so the maximum possible transfer that we want to have that is expressed as t h 1 minus t h 2 divided by t h 1 minus t c 1 right. So, t h 1 minus t h 2 becomes 0, because they does not change ok. Similar thing happen in case of the evaporator, but the thing will be in case of evaporator, the cold fluid will be constant t c 1 t c 2 ok. And the hot fluid will eventually decrease t h 1 t h 2 right.

So, this will happen, so in those cases we will get R equal to 0. So, what will be the effectiveness when R is 0, that is in case of condenser and boiler, because these 2 are very important and specific heat exchanger that we very commonly use in different food processing operation.

So, what will happen that effectiveness is expressed as 1 minus exponential minus NTU. For parallel flow, effectiveness is equal to 1 minus exponential minus 2 into NTU by 2. And for the counter flow this is expressed as NTU by 1 plus NTU ok. So, this is the method how we can you know take that R tends to 1, and then we calculate this one. So, basically you have to just remember that what is the expression of that ok, when you want to use the effectiveness for effectiveness method for calculation.

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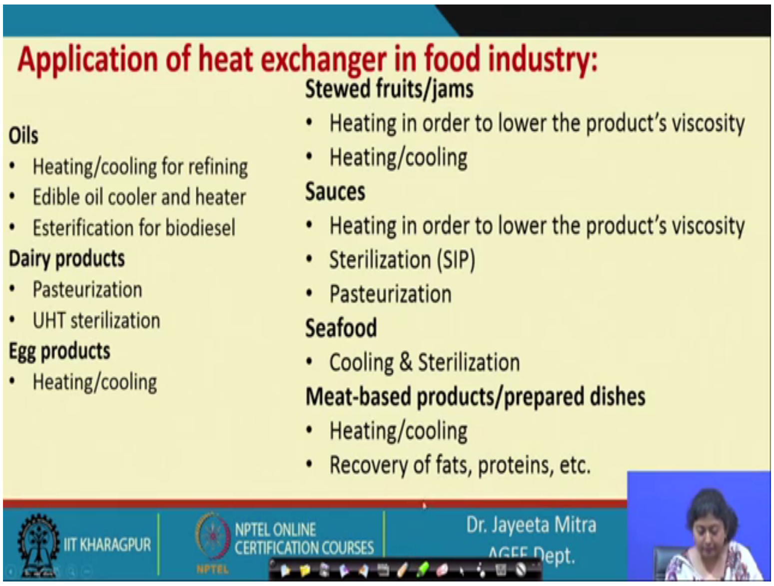

Now, in the food industry what are the various kinds of application of heat exchanger you may find we will see a few list of them. One is the in the oil industry, for heating or cooling, for refining ok, for edible oil cooler, and heater, and for esterification of biodiesel all other application. So, mostly what we do is we will see that different kind of configuration like tubular or concentric pipe heat exchanger, or shell and tube heat exchanger, or plate heat exchanger, scrap surface heat exchanger, all those are the different kind of heat exchanger that we normally use in food industry.

I will show you there how they look like, but mostly what happen that the processing fluid that we want to you know cool or want to be heated, so that is generally in the inner tube of the double pipe heat exchanger ok. And the outer casing we circulate the chill water or hot water as the requirement for the heating and cooling cases will be ok. So, edible oil, cooling and heating also done in heat exchanger.

So, then dairy products, very important application where pasteurization and sterilization this happens. In case of milk pasteurization unit, if you see, you will get both kind of you know configuration plate heat exchanger in the regeneration section, two regeneration sections are normally there. One is in the entry section, where the milk that is being received that is being heated by the pasteurized milk.

And second is it is being pasteurized in the heating section, and at the last in the cooling section, where the milk which is already been chilled that is used to lower the temperature of the hot or pasteurized milk. And the other cases, where we need to increase the temperature in the holding tube that time we use the double pipe heat exchanger or tubular concentric tube heat exchanger.

Then for egg products heating and cooling of egg and there are a different fruits and jam processing also it is used, heating in order to lower the product's viscosity or heating and cooling mechanism. So, here also we need to know that generally why we put the you know viscous liquid that we need to put in the inner tube, because cleaning and sanitation is an important part in the food industry. So, after every processing, you need to clean the equipments properly and do the CIP process, now different stage of cleaning takes place, so that no dirt or deposition should be there in the inner tube or outer tube.

And if it is there from that microorganism, may grow and spoil the food contaminate the food ok. So, sanitation is very important and keeping that in mind the design of the heat exchanger will be such that we can very well clean the material ok, because, these material are sometime we there has many dissolved particles or materials into the liquid the viscosity is also very high. So, you need to pump them ok. So all those requirement we need to consider.

Then in the Sauce industry, heating in order to lower the products viscosity; sterilization and mostly these fluids are not Newtonian kind of and that is why in our first two chapters of this particular course we have discussed about the rheological nature of the fluids. Because they will vary significantly based on shear stress, based on temperature ok, so, their structure will change.

So, for that matter those understanding of the rheological understanding of the products is also very important ok, then pasteurization of all those products sterilization heat exchanger is used. For the seafood cooling and sterilization, for meat based product and prepared dishes heating, and cooling we need to we need to perform, then recovery of fat, protein etcetera. This is also being done using the heat exchanger.

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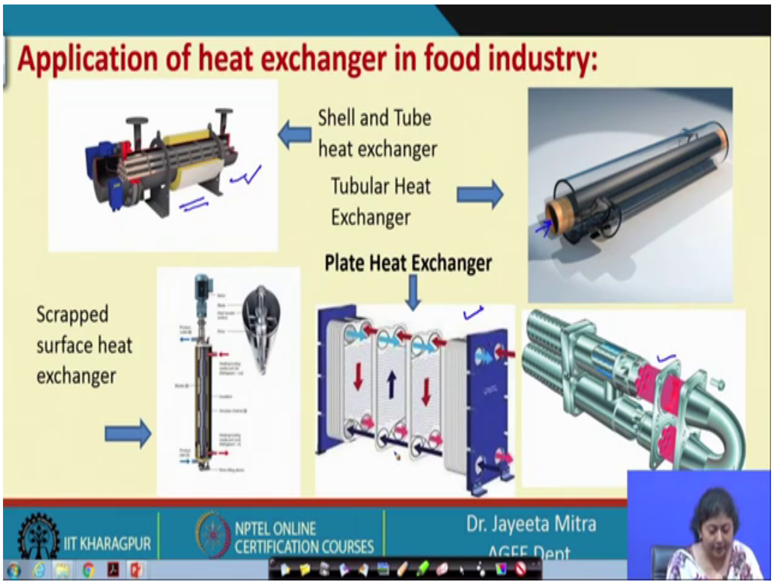

So, commonly if you look into the food industry, you will find these kind of heat exchangers. The very common one is the tubular heat exchanger ok, two concentric tube is there from the inner tube generally the liquid which is the which is to be processed that is entered. And the other the annular spaces the processing is being done using the hot fluid or the cold fluid as the requirement may be.

There may be sometime bundle of tube inside the inside one single tube that kind of configuration is also available. Shell and tube heat exchanger this is also very commonly particularly, in case of condenser and evaporator. We use shell and tube heat exchanger, because they can withstand the large variation of pressure as well.

And there also may be single shell pass, single tube pass or different configuration, like one shell pass, two tube pass or two shell pass, four tube pass like different configurations are there, the baffles are there. So, this is also very common type of heat exchanger that we often see in the food industry. And there is one more which is plate heat exchanger.

So, plate heat exchanger is very common in the regeneration section of the milk pasteurizer ok. And as in as I said already that this has very flexibility in terms of increasing or decreasing the capacity of the plant. So, you just need to add more number of plate, which we cannot do, in case of area that geometry like shell and tube or double tube like that. So, there is a flexibility.

And another very important heat exchanger that is called the scrapped surface heat exchanger. So, when we handle very sticky material, so that time what happen? Like any fruit pulp or this kind of we want to dry it or want to concentrate it, so that time you can see that the we have scrappers ok.

And there is a central shaft and there is a scrapper. So, it is fixed with that it is scrapping the surface of the heat exchanger. So, that deposition would not be there and thereby the heat transfer coefficient the value of that can be maintained. Because if deposition happens, so heat transfer will be lowered ok, that will offer a scale deposition and resistor resistance to heat flow. And those material which is stick to the wall will be you know burnt eventually. So, that is why scrapped surface heat exchanger is used in those cases ok.

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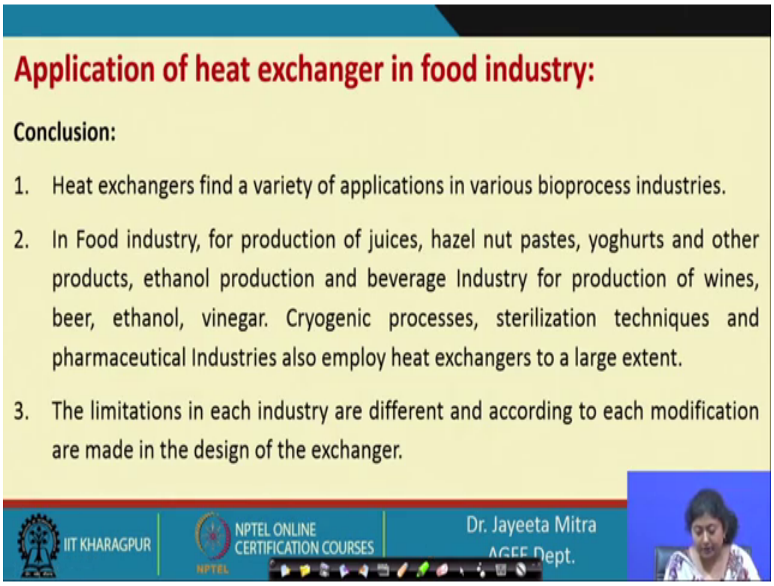

So, we can conclude saying that heat exchangers find a variety of application in various bioprocess industries. In food industry, for production of juices, hazel nut paste, yoghurt and other products ethanol production and beverage industry for production of wine, beer ok. All this material in the cryogenic processes, sterilization techniques and pharmaceutical industries also employ heat exchanger to a large extent ok. And the limitation in each industry are different and according to each modification are made in the design of the exchanger ok. For that matter when you need to have very large surface area, but the you know the volume is very small.

So, what we can do? ne thing if the phase change involve, we can design multiple pass shell and tube heat exchanger right to increase the surface area; or else what we can do? We can design the compact heat exchanger as with the fin ok. If we need to have one fluid and another air most of the cases ok, so though depend on what is the requirement, and based on that we can design.

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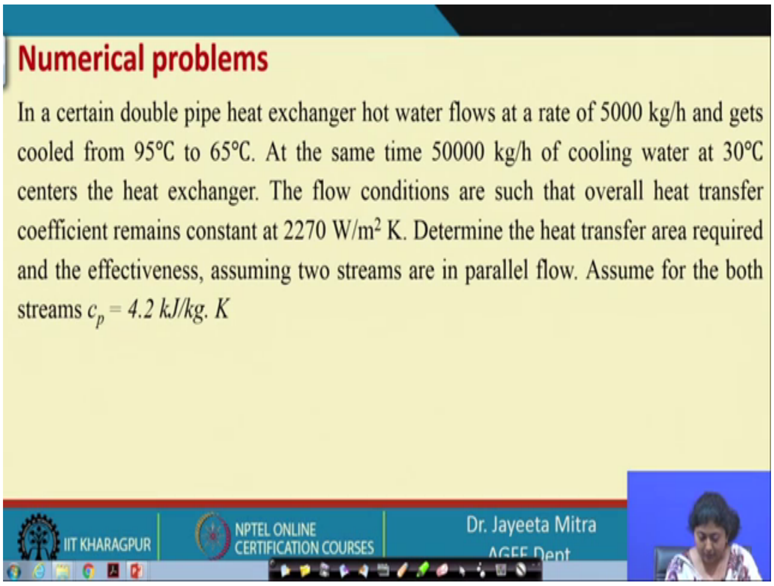

Now, we will solve one numerical problem, so that you can understand that how we proceed. So, the problem is in a certain double pipe heat exchanger, hot water flows at a rate of 5000 kg per hour and gets cooled from 95 to 65 degree Celsius ok. So, this is the temperature profile of the hot fluid. At the same time 50000 kg per hour of cooling water at 30 degree Celsius enters the heat exchanger ok. The flow conditions are such that overall heat transfer coefficient remains constant at 2270 watt per meter square kelvin. Determine the heat transfer area required and the effectiveness assuming, no are in two streams are in parallel flow fine. So, assume for both stream c p will be 4.2 kilo joule per kg kelvin.

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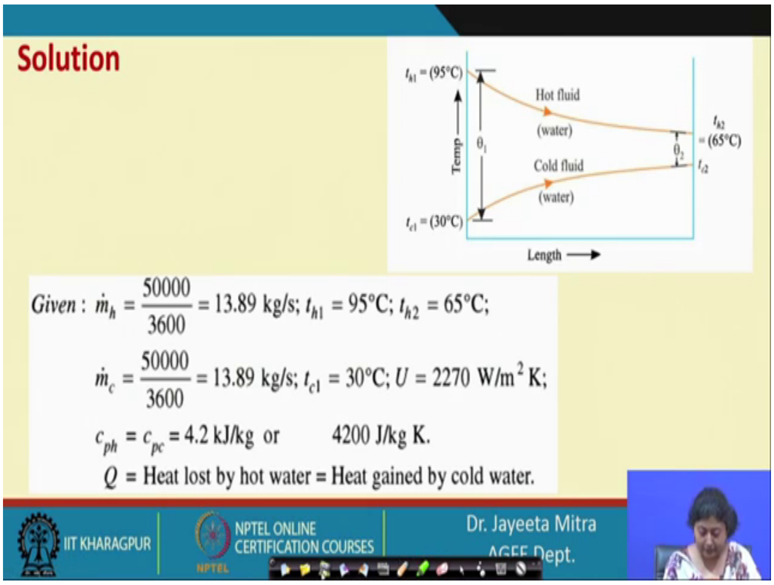

So, first we will see what is the configuration. The configuration is both stream are parallel. So, we have drawn the temperature profile along the length or along the surface area also you can see this will be t he same. So, temperature of the hot fluid inlet was 95 when it is reducing to t h 2 that is 65 and inlet temperature of the cold one is 30 degree and we do not know what will be the t c 2 that we need to find.

So, what is given that flow rate m h dot ok, now flow rate is given kg per hour we have converted that to k g per second; t h 1, t h 2 is given. Similarly, for the cold fluid also we have converted to k g per second divided by 3600 and U is given which is constant 2270 ok. So, m c p delta t of hot and cold will be equal to u a delta t ok. So, this u is given c p is also given 4200 joule per k g kelvin, so, the heat loss where the hot water will be gained by the cold one ok.

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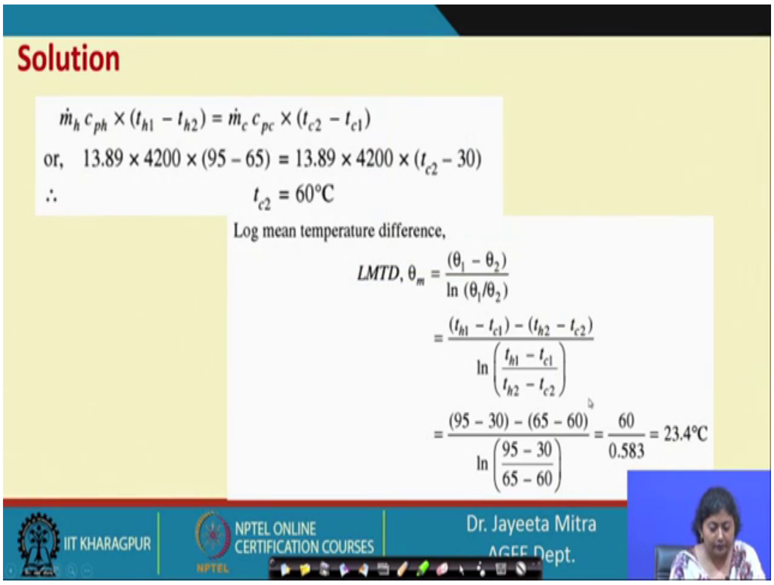

So, then what we can do is mass flow rate of the hot into specific heat of the hot into temperature drop t h 1 minus t h 2 that will be equal to mass flow rate of the cold fluid into specific heat of the cold fluid into t c 2 minus t c 1 that is the temperature gained by the cold fluid. And solving this because all the values are known accept t c 2, so we are getting t c 2 as 60 degree.

Now, if we want to calculate the area, so what is needed because Q equal to for calculation of the Q, we need the temperature drop between the two fluids ok. And we need to find then log mean temperature difference between these two fluid. So, the log mean temperature difference we have calculated we can do otherwise like theta 2 minus theta 1 divided by l n of theta 2 by theta 1, it will come same. So, here t h 1 minus t c 1 95 minus 30 minus t h 2 minus t c 2 65 minus 60 divided by l n of t h 1 minus t c 1 95 minus 30 by 65 minus 60. So, what we are getting 23.4 degree Celsius.

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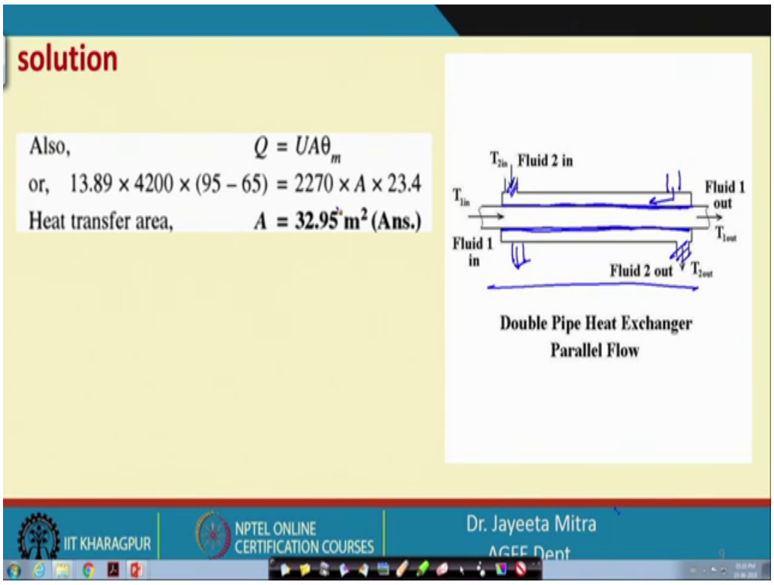

So, then Q equal to U A delta t or log mean temperature difference theta m. So Q that is for any fluid if you take because if we consider no loss no heat loss, so whether the cold fluid is giving the heat or the heat is cold fluid is taking heat or the heat is coming from the hot fluid that is equal. So, mass flow rate into C p into temperature drop by the hot fluid that is equal to U value 2270 into area into 23.4; that is the log mean temperature difference. So, we are getting an area 32.95 meter square.

So, it was given that it is a double pipe heat exchanger. So, it will look like this double pipe parallel flow. So, it will be look like this with the surface area of heat transfer that you are getting this surface area ok. So, this is actually 2 pi r l and this will be 32.95 meter square.

Now, since here only the area is given and U is already given to us. So, we need not to bother about inside and outside area. So, here this area will be the outside one thickness is not known to us. So, we will calculate this one. And here the flow is in the parallel flow.

So, if it could have been asked counter flow problem, so we have designed this in this fashion it is entering from this and coming from this. So, it will be like this ok. And also theta m we need to calculate based on the counter flow heat exchanger, so that time the direction of the theta direction of the temperature, two temperatures stream two fluid stream will be the opposite one. So, here we will stop. We have completed all the discussion related to the heat exchanger ok. So, in the next class, we will move onto another chapter.

Thank you.