Heat Exchangers: Fundamental And Design Analysis
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Lecture – 24
Plate fin heat exchange

Welcome to this lecture. The topic that will be discussed today is about the Plate fin type heat exchangers. This plate fin type heat exchanger is completely a new type of exchanger we have not discussed in the previous lectures as you will be able to understand from the; I mean following slides.

So, before going into the details about plate fin heat exchanger, let us look where it belongs to in the classification of the heat exchangers.

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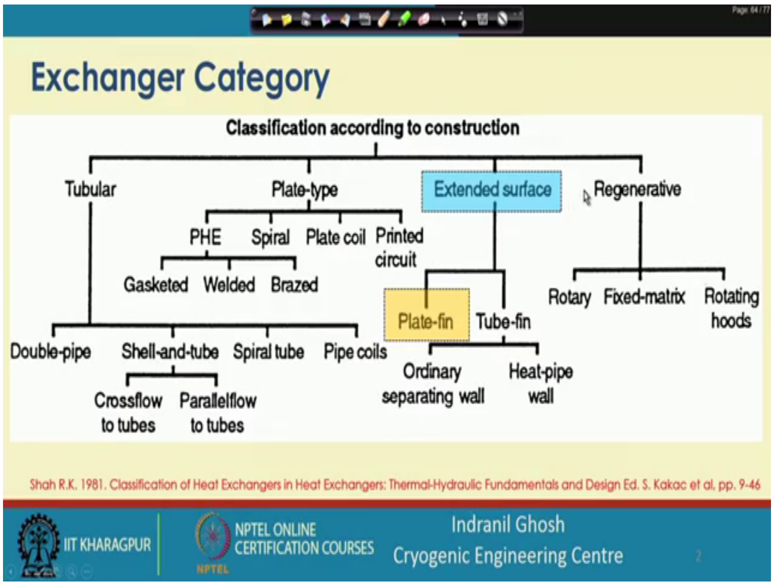

So, according to the classification and classification according to the construction, we find that there was class of exchanger that we have the extended surface heat transfer there was a class where we had heat exchangers with extended transfer surfaces.

And one of the derivative of these extended surface heat transfer is of plate fin type and that is what we call it plate fin type heat exchanger.

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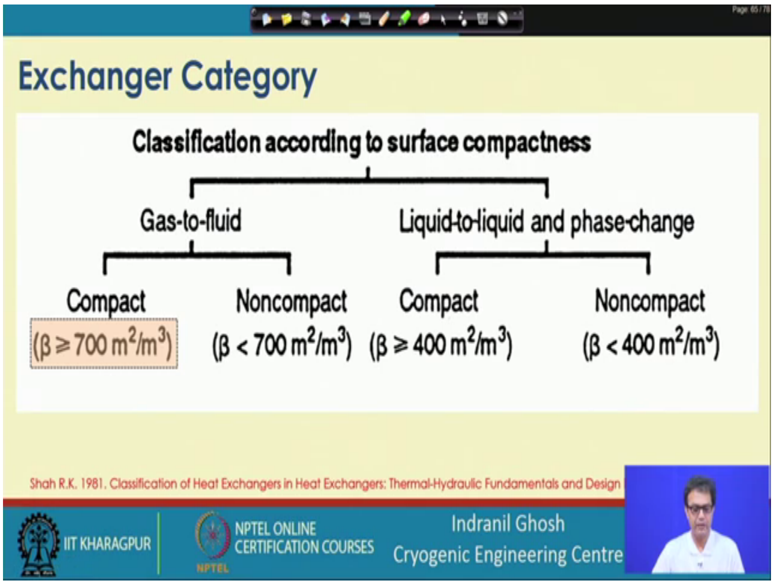

So, if we look into the other classification where we will be able to find where it is likely it is belonging, you will find that there is a classification based on the surface compactness and if you look into that classification we will find that there is a class of exchanger which is compact and that compactness is defined by a parameter beta which is defined as a demarcation is between the compactness and non compactness is 700 meter square per meter cube.

This classification has been recommended by Professor R. K. Shin his classification of heat exchangers in the heat exchangers thermal hydraulic fundamentals and design that is the book edited by S. Ghakak and et al. So, we will be following this nomenclature of calling the heat exchanger as compact if the compactness factor beta is more than 700 meter square per meter cube.

So, this particular plate fin type of heat exchange belongs to that category that it will be more than 400 meter square per 700 meter square per meter cube; particularly, this is a gas to fluid heat exchanger and in this region compactness is defined by 700 meter square per meter cube and we will define it as compact heat exchanger.

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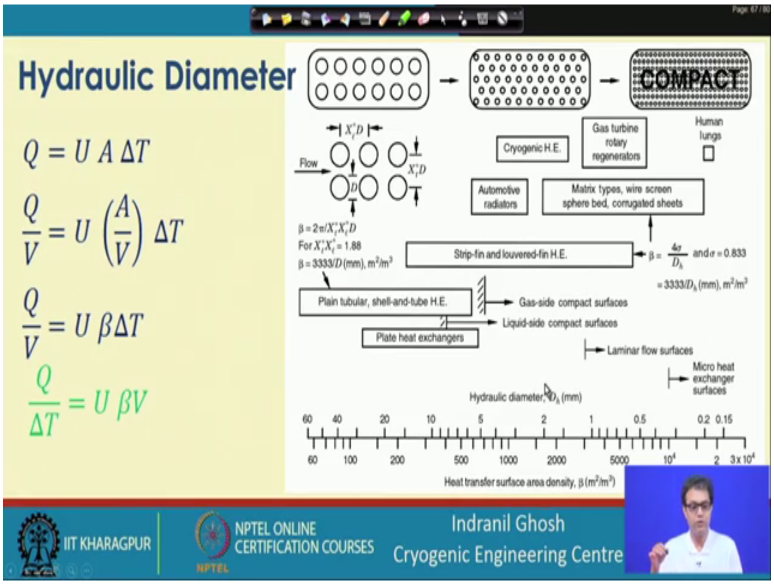

So, if we now look into the hydraulic diameter from the hydraulic diameter point of view or if we look into the basic heat transfer equation, we find that the heat transfer is basically related to the overall heat transfer co efficient and the delta T and this delta T ln basically the log min temperature difference. And if we divide both sides by the volume of the heat exchanger, we find that it is giving as Q by V, the heat transfer accordingly volume that can be achieved, it is a function of the overall heat transfer co efficient and not only that then we have A by V and delta T.

Now, this A by V, the area per unit volume that is what is the beta factor that is what we are trying to define and then we also have the log mean temperature difference. Now, this parameter the amount of heat that we can the heat load per unit delta T is basically we can find that it is a function of beta and V and also the U.

So, if we have a very high a beta value, we can expect a small value of delta V which will be you know, if Q by delta T is constant is remaining constant then for a given Q by delta T, we have U fixed and beta if we have the larger value we can expect that the smaller value will be able give us the desired effect. So that means the heat exchanger can be made compact. So, if you look into that one so far, we were looking into the tubular exchanger where the typical hydraulic diameter is of the order of this region where you see this is the I mean plain tubular shell and tube heat exchanger and on this side, the louvered fin or etcetera strip fin these are basically the heat exchanger play fin type heat exchangers and the cryogenic heat exchangers all other type of matrix and other heat exchangers basically belong to that you know compact heat exchanger range. So, hydraulic diameter is of the order of this is where we have the hydraulic diameter and this is where we have the surface area density. So, nearly about 700 is the demarcation between the compactness and the non compact heat exchanger.

So, here some are here we have the 500, 600, 700 that is the limiting line between the compact and non compact heat exchanger. So, basically this plate fin type exchanger belong to that compact heat exchanger with the typical surface density more than 700 meter square per meter cube.

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Now, if we look into the construction of these exchanger, this is a real time heat exchanger just to show you how it looks like, we should actually have the length scale it is a you can understand that this is a length and we have one fluid from one to the other end directly from design to it design and another field it is entering here, it has two exit; it can come out from these end it can also come out from these end.

So, it is also I mean this is another I mean advantage of you can say the characteristics of this plate fin type of heat exchanger where multiple exit or intermediant entry and exit can be possible in this type of heat exchanger ok.

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So, in another picture pictorial view, I will show you here this is another plate fine type heat exchanger you can see glimpse of the fins.

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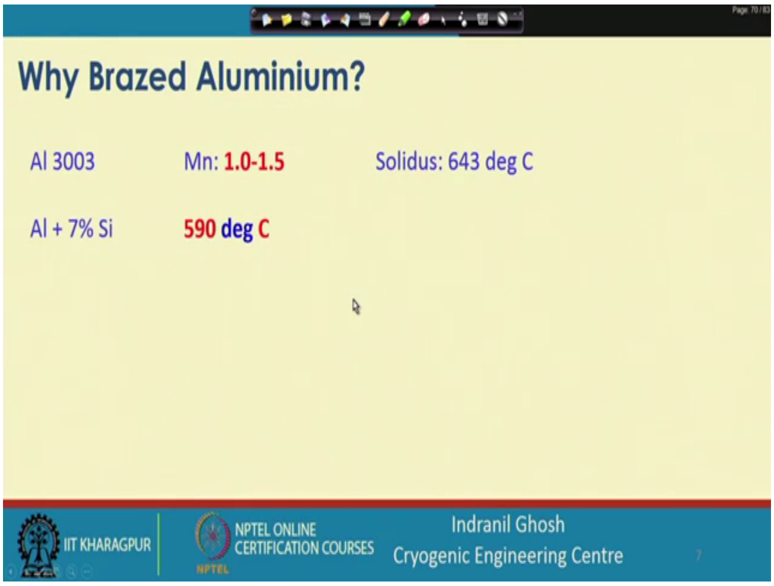

These are the fins where sorry, we will be discussing about this geometry later on. So, this is the cross flow type plate fin type heat exchanger where this is made of brazed aluminium. There are terms brazed and aluminum plate fin type heat exchanger. This is also a plate fin type heat exchanger which is made of aluminium and that aluminium is bridged with each other. So, that it is a special type of plate fin heat exchanger which is brazed aluminium plate fin heat exchanger.

So, we will talk about in details. First of all, let us have a look into the details of this why we go for aluminium while we go for brazing of it? So, first of all, these aluminium is one of the; I mean good thermal conductivity material with light witness, I mean this kind of exchangers are widely used in automobiles or in aircraft.

So, this is the way to strength ratio of these material is always and looked after I mean, is a parameter which we always look for. And we will understand that the brazing is the only option particularly for the type of fins we are going to join in case of a plate fin type of heat exchanger, we cannot do the regular welding though aluminum welding it is possible, we cannot do the welding of fin surfaces with the plates are manually.

So, we have to go for a automatic joining of the plate with the fins which we will be talking later on. And so, this particular properties like low I means high sorry the high strength to weight ratio, this weight is small and it is strength is high and it is having moderately good thermal conductivity. So, we go for and also it can be bridged.

So, that is another affordable parameter particularly we go for the aluminum 3000, 3 3000 series, particularly this is a other than any element aluminum and particularly it is a manganese based and it is percentage is about 10 sorry, 1 to 1.5 percentage of manganese, it will be there and it is solidus is 643 degree Centigrade .

So, if I have a plate and we will be connecting the fins on top of it and it is like this we will be joining this is a kind of fin we will be joining and this is the plate material. So, on top of it, we want to have a kind of filler material or the I mean which is this is the brazing material this may brazing, material is aluminum plus 7 percent silicon. So, it is melting point even as soon as the add the 7 percent silicon, it becomes 590 degree.

Whereas the solidus of this parent material this is 643 degree Centigrade. So that means, this is filler materials will melt fast, but this parent material will not melt at the time, but this difference in temperature is very small. So, we can understand that we need a very precised temperature furnace, I mean furnace if the temperature control in the furnace is very stringent and we have to maintain the temperature of the furnace basically, we will talk about the manufacturing of that brazed aluminum plate fin heat exchanger we will discuss in details at that time.

So, we need to maintain the temperature of the furnace, so that this parent material should not melt I mean it will of course, ensure good we need to ensure a good brazing between the fin and the plate, but at the same time, we also need to ensure that there is no you know a kind of hole or formation of any leakage so that one fluid which is flowing on this side and the fluid flowing on this side should not leak and that is what we need to ensure.

So, generally it is vacuum brazed, if these units are made in vacuum brazing furnace. So, we need a very stringent temperature requirement for manufacturing this kind of heat exchangers.

So, we will come to that part later.

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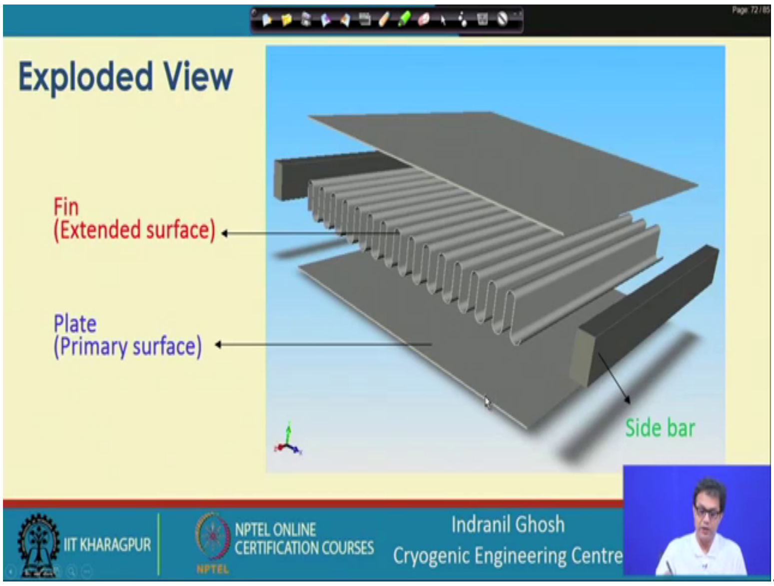

So, here is the exploded view for a particular layer of the plate fin type heat exchanger. We have one layer of primary heat transfer surface area. Basically, this is an as I told in the initially that this is an extended type heat transfer surfaces.

So, according to that classification, we had a primary heat transfer surface area and then this is what the primary heat transfer surface area. Now we have an another primary heat transverse surface area on this side and between this primary heat transfer surface area, we have the extended heat transfer surface area or the fin. So, in between these two plates of the primary heat transfer surface area, we have some fins or extended heat transfer surface.

So now, the purpose of this fin is and here what we have is something called side bar, this is what is side bar; on this side also it is a side bar. So that means it is basically like this that we want to make a channel.

This channel is made of one primary surface area, another primary surface area; in between what we have is the fin. This fin is serving both the purposes of or it has double I mean the purpose of this fin is basically to provide extra or extended heat transfer surface area. At the same time, it gives mechanical stability or construction stability like it gives some strength to the construction so that under pressure, this will not bulge.

So, this mechanical stability of this one will also be purpose for this one. So, now, we can understand that each of this surface is to be adhere to this plate and this one has to be adhere to this plate to have good thermal joint, we need a good thermal contact between these two; other bulge there will be when the heat is getting transferred. So, there will be the resistance between this fin and the plate. So, that is not desirable. We want this fin to be completely attached thermally to this upper surfaces.

So, we need a good bonding between this point, this point, this point and in fact, all the surfaces should be adhere to this primary heat transfer surfaces area and this fins are to be attached. So, it is understandable that it is not possible for someone to make physical joint because it first of all, it will not be accessible even if it is not accessible even if it is accessible, it is impossible to make or ensure that each and every point of it is joined with the primary surface area. Now, as you can understand that we have two primary surface area in between we have the fin and now imagine this is a cross sectional area and we have say a fluid flowing from these end to other end.

So, we have to ensure that the fluid is not spilling over from this side or this side. It should not go out of this one. So, what you need to do for this purpose that we should have a kind of side bar on both the ends. So, this will put a barricade on this side and another barricade on this side. So, we are confining the liquid within this zone and this zone is created by this one where we have primary surface area and the fin and it is bounded by two side bar.

So, this is the exploded view for a particular layer and so, we can expect that on top of it we will put another layer so that will form the, this is an exploded view of the two layered one.

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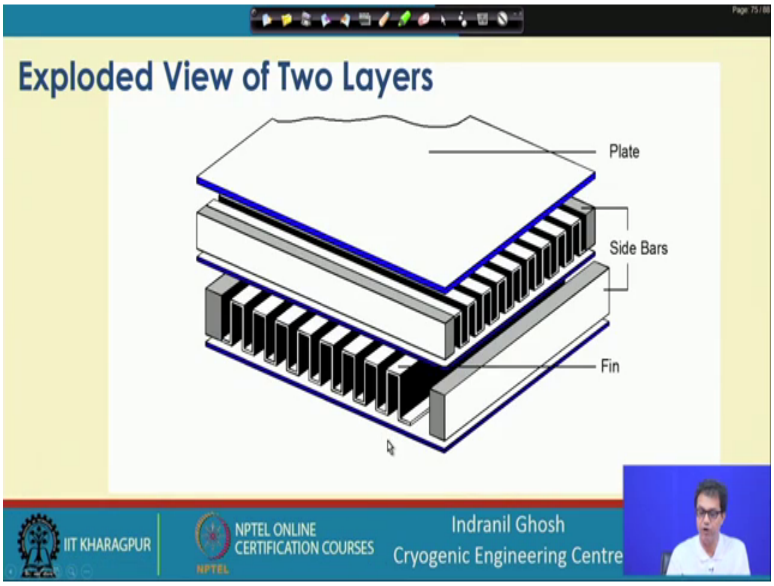

So, here what we have is one fluid, this is the primary surface area, this is another primary surface area, these are the primary surface area and we have one fluid flowing from this end to this end. So, these are the extended heat transfer surface area fin.

And now, imagine we have put on top of it another layer where this is the plate which is the primary area separating this fluid to mix with this fluid. This fluid is entering from this end and we have another separating plate on this side. So, for this fluid, this is the side bar; for this fluid, we have this side bar and on this side, we have another side bar. So, this between this two primary surfaces, we have fin and two plates, two side bars.

So, this is one channel for this fluid. Similarly, on the other side what we have is this primary surface area and then we have this is the primary surface area and what we have here is I am sorry this is one surface area, then we have another surface area here this is confinement this is the side bar these are two side bar and these are the fins. So, this whole unit becomes an exploded view and this is for this particular channel is meant for this fluid.

So, like this, we have this fluid getting distributed between several layers and this is for if it is this layer is designated for this channel and the alternative will again be for this fluid say if we call it fluid number 1 and this is a fluid 2, we have this channel designated for fluid 2, the next channel will be designated for the fluid 1. So, like that we have this is a two fluid stream heat exchanger and as you can understand that each fluid flow is taking place at 90 degree.

So, it is a cross flow arrangement. So, when we talk about the flow arrangement, will come in details. So, this is the exploded view and like this we make you know a stack of the heat exchanger and then we go for the complete heat exchanger matrix or something like that. So, here what we have is the plate, this is the plate, this is side bars, these are the fins and as the name suggest, the plate fin comes from this nomenclature I mean this nomenclature, this is fin, this is plate and as a whole, this unit becomes a plate fin heat exchanger.

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So, this is a typical brazed aluminum plate fin heat exchanger. We can have a look into this small video. This is a brazed aluminum plate fin heat exchanger.

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So, here as you can understand that this is the side bar. We are not able to see this particular area. So, the fins are located at this point, these are the fins. So, this channel through which the fluid is flowing, you will find that this is blocked at this end and this is blocked at this end so that the fluid is flowing in this direction.

So, this is basically nothing but the rectangular hollow header which is aligned the fluid to come on this side and allow the fluid to flow through this end and this black color one whereas, that white one is basically nothing but the side bars. So, if we look into the video, this is the other side, we will come to, we look into this details.

So, now you see this is what is the side bar and the corresponding side on the other end, I mean just we have come from that end to this end, you find that this is the plate or the primary area and with that primary area between these two primary area, we have the fins they are added to each other I mean with the it is brazed at this point, at this point and this particularly this is an olefin and here we have a side bar.

So, this is a side bar. If you look at this end this particular fin this geometry this end you have it is not feasible at this position this is the end and this is the end it is blocked. So, these are the side bars. So, when the fluid is flowing in this direction, the fluid will flow this channels through this channels to this channel this channel it will flow through and it will not pass or mix with the sidebar or this is the side bar this is another side bar, these are the side bars and the fluid is not able to mix with the fluid flowing on the other side through this channel.

So, basically this is a again a cross flow type heat exchanger were we have both the fluids I mean not mixed it is unmixed, both the fluids are unmixed and this is basically you can understand that this is of slightly longer length than this particular one. So, this is wider, this is smaller.

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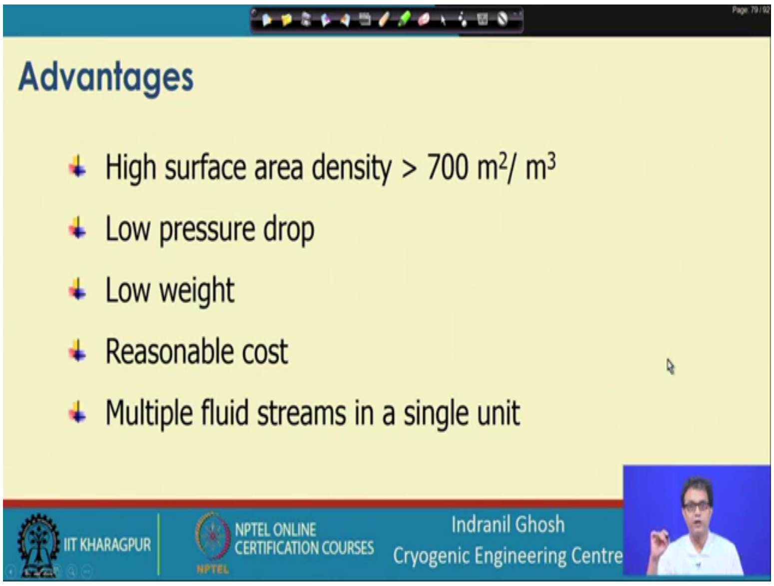

So, now what are the advantage of these particular type of heat exchangers. The advantage of brazed aluminum plate fin heat exchanger as we have discussed earlier that it is a compact heat exchanger.

So, it has a very high heat transfer surface area density and it is most of the time it is more than 700 meter square per meter cube; that means, we get very good compactness. In fact, we will find some of the trigenic heat exchangers, they are quietly really big but if they were not compact, they would have been still bigger in size. So, as compare to this surface area density, we have relatively low pressure drop any heat exchanger designer, they will try to make a heat exchanger where we have high heat transfer.

But the pressure drop penalty is comparatively smaller. So, here we have the thermal performance desirable thermal performance of the heat exchanger but not a very high at the cost of large pressure drop. So, it is having a moderate pressure drop and since it is made of aluminum, we have the low weight of for this heat exchanger and it is not really very costly though the particularly the fabrication technique determines the it is cost and the number of units which are made on the size of heat exchanger that determines it is cost. And we have I mean another big advantage of this particular type of heat exchanger is that it can handle large number of stream in a single unit.

So, basically that makes this plate fin type heat exchanger multi stream heat exchanger. So, it handles multiple streams, multi stream heat exchanger. So, multiple stream heat exchanger are accommodating multiple streams within a single unit is obviously, advantageous. So, we get we will later on see how this plate fin heat exchangers allow the handling of multiple streams within a same unit.

Then, we also have the advantage particularly with respect to this plate fin type heat exchanger is that we have the intermediate entry and exit of the fluid streams. So, that gives big advantage of flexibility in the handling of the fluid streams. So, not only it handles multiple streams, it also helps intermediate entry and exit of the fluid streams in the heat exchanger.

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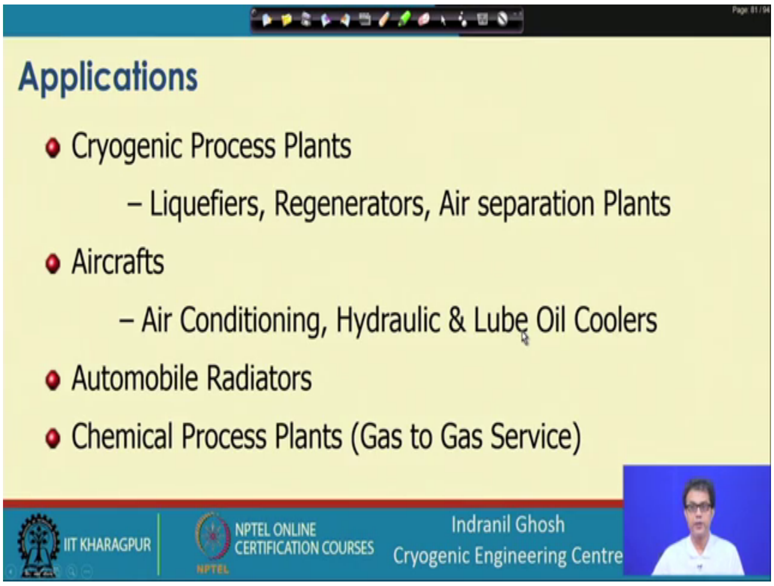

So, next is its application where are the places where we find it is application. So, in the most of the cryogenic process plants, these days cryogenic liquefaction plants, then air separation plants then we have the regenerators and as I told you this is the air separation plant we have the main heat exchangers, the where the air is being handled and then we have the condenser reboiler in between the double column unit.

So, the condenser reboiler earlier used to be a shell and tube type or tubular exchanger. These days you will find frequently that these are replaced by plate fin type heat exchangers. So, most of the cryogenic process plants heat exchangers are of very high effectiveness and most of the time we will look for heat exchanger effectiveness around and I mean 0.9 to 95 or so, I mean otherwise some of the processes will I mean will not at all start if the heat exchanger effectiveness is very small.

So, we have very stringent requirement for the heat exchanger effectiveness in case of cryogenic heat exchangers. So, we find that brazed aluminum plate fin exchangers are meet that requirement of high effectiveness heat exchanger in cryogenic engineering. Moreover, in aircrafts the requirement are slightly different here you will find that the heat exchanger effectiveness is not that high, but we need to be a very light weight and their the air conditioning hydraulic and lube oil coolers in the ram air cooling etcetera are done in case of I mean heat exchanger made out of brazed aluminum.

And some time it is blazed stainless steel to meet the high temperature requirement of the handling high temperature requirement in the aircraft, we find that some of the exchangers are made of stainless steel. Then in the automotive automobile radiators, we find that frequently these days we are using the brazed aluminum plate fin type of heat exchangers.

And in chemical process plants where we have gas to gas service, this is particularly important why do we go for a gas to gas I mean heat exchanger I mean why should we rest it to the gas to gas as you can understand that the hydraulic diameter of the fin passage is being very small.

So, we have a requirement of I mean basically clean fluid. So, if any kind of darts or I mean contamination is there in the process stream, you will find that though slow passages are getting choked. And if anything such happens often it is not possible to clean it if it is not getting dissolved through some of the chemicals we will find it is not possible to get it clean. So, this cleanliness of the process which streams is one of the primary requirement for this kind of heat exchangers and in chemical process plants where the gas and gas to gas particularly service where it is mostly cleaned.

And you will find that brazed aluminum plate fin type heat exchanger are frequently in use. Another, while about the limitations or I means applications of this brazed aluminum plate fin type of heat exchangers, we can understand that when it is brazed aluminum plate fin type exchanger obviously, it is high temperature requirement is limited; it cannot go more than something like you know it is solidus temperature.

Similarly, or very close to the solidus temperature, but on the other hand in that case, you need to go for the stainless steel type blazed stainless steel plate fin type heat exchanger and moreover as you can understand from the construction of these type of plate fin type heat exchanger that probably you cannot go for very high pressure I mean when the process streams are of very high pressure, we cannot really recommend the use of this plate fin type heat exchangers.

So, it is the moderate to low pressure when it is the exchangers are I mean are of very good use.

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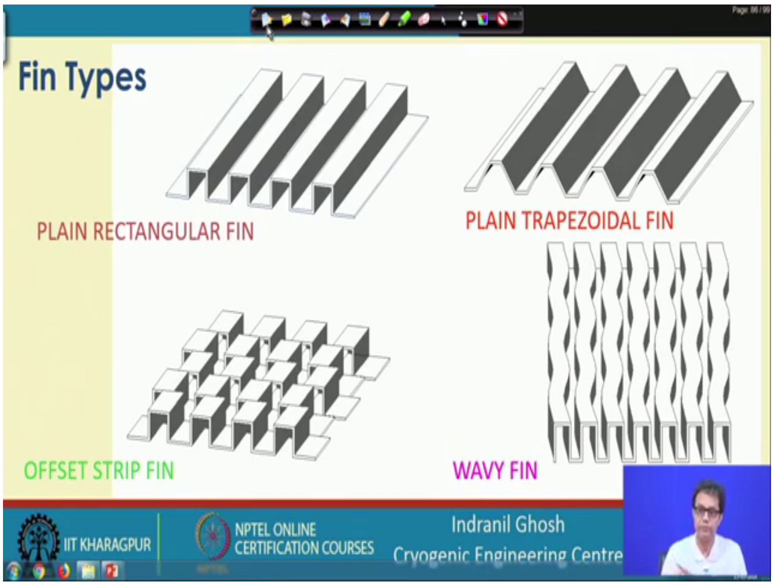

The now, what are the fin types, I mean there are why should there be any fin and particularly when we talk about the fin the extended heat transfer surfaces, this fins as I told you it gives up a mechanical stability and also it gives extended heat transfer surface.

So, if we look at that again that equation if we look at Q equals to U into A into delta T, often this delta T ln is dictated by the process stream. We cannot really have a control on this log min temperature difference. We may not have control on much control on the overall heat transfer coefficient. So, we have to manage with this area heat transfer surface area.

So, we augment with the heat transfer surface area with the extended surface heat transfer so, this is what is this fin. The role of those fin is to enhance the heat transfer surface area along with the, mechanical stability or the construction stability so, not only that, it has the third purpose. When we have a straight rectangular plain rectangular fin, we find that the flow will be developed within a few millimeter or depending on its size at the entrance length after the entrance length the flow is fully developed and there is a constant heat transfer co efficient for the entire region.

Now, what we need to do is that I mean if we want to change the heat transfer coefficient I mean, if it is regular plain regular or rectangular plain fin channel, so, we do not have that option of breaking that boundary layer. So, that is also true in case of plain trapezoidal fin. So, after certain entrance length, we will find the flow is fully developed and there will not be any change in the, there is no change in the fin geometry I mean there is no change in the heat transfer coefficient because of it is fully developed.

But, in case of strip fin geometry we find that the flow is it is slightly offset as we can call it as offset strip fin. This is slightly after certain length this is called lance length after this lance length, this is known as lance length after the lance length this as you can understand that as if the flow passage has been sipped it, it has you know it was flowing like this.

Now, suddenly the path has been broken and you know it has been shifted like this, this channel is been shifted. So, after coming the flow after coming over here, it finds that there is another you know fresh generation of the boundary layout at this point. Similarly, again after going at this point it will find that there is the flow has to developed at this point

So, like that the flow is getting developed, I mean at every regular interval and in this offsets strip fin we this purpose of this offset strip fin is to not only enhance the heat transfer surface area, not only give the mechanical stability, it also enhances the heat transfer surface area just because of the fin construction.

So, another fin is of I mean used that is wavy fin in this type of fin it is a continuous fin. Here, you can see there is a discontinuity in the fin we are interrupting the fin at regular interval but in this type, this is the continuous fin geometry, but still it is waviness gives us the desired flow separation at regular interval and breaking of the boundary layer at regular interval causing enhancement either heat transfer surface and heat transfer coefficient and along with the enhancement in the heat transfer surface area, we get enhance in the heat transfer coefficient.

So, this is a wavy fin; along with that, we have a perforated plain perforated heat exchanger. So, in the rectangular it is not shown here, in the rectangular plain rectangular fin if we have a you know perforation on this surface on this surface that regular interval if we make perforations, then we find that it is also a kind of interrupted fin. So, the fluid will come here and it will have a passage or it is or this flow will try to go inside or that flow it fluid will try to come out of that perforation. So, thereby giving a breakage in the boundary layer, that also we often use in plate fin type heat exchanger.

Thank you; thank you for your attention.