Thermal Operations in Food Process Engineering: Theory and Applications
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Lecture - 44
Heat Exchangers (Contd.)

Good morning. So, you are handling or we are tackling with the heat exchangers, 'right'. And we have done till now play tube tabular heat exchanger or shell and tube heat exchanger, 'right'. So, this is one side of the industrial use, there are many others, 'right'. So, we come to that heat exchangers in continuation, that heat exchangers contd there should be also written that heat exchanger continuation, ok.

So, in this class we will follow that heat exchanger further and we will come to the plate type heat exchanger, 'right'.

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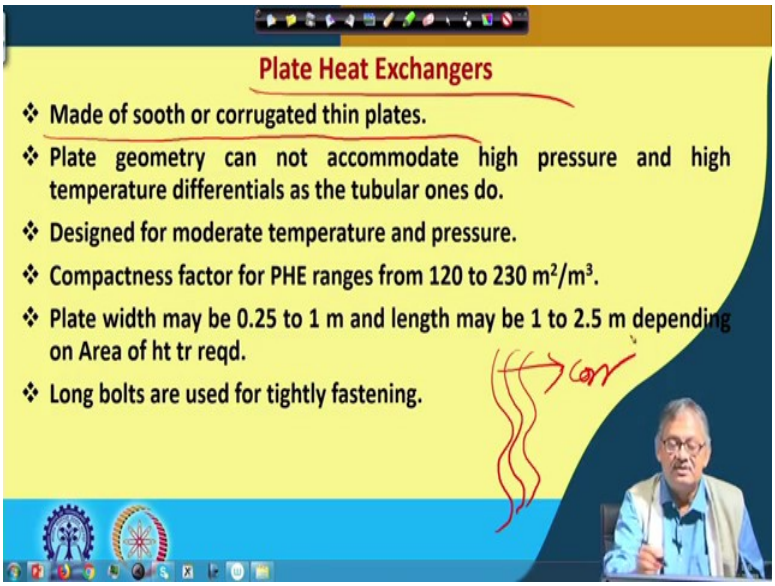

Plate heat exchanger is again one which is very widely used in particularly dairy industries or in most of the food or chemical industries, 'right'. That food and dairy industries or chemical industries, plate heat exchanger is very widely used. The beauty of this is that unlike that shell and tube heat exchanger where with respect to the efficiency and the floor area required, 'right'; the floor area for plate type heat exchanger required is much much less, 'right'.

For the same efficiency the floor area required for establishing that tubular heat exchanger or shell and tube heat exchanger is much much more compared to that of the plate type.

But as we said earlier that tube and shell or shell and tube heat exchangers they are very easy to manufacture as well the price is also low, 'right'. Of course, this plate type heat exchangers are not so easy compared to that of the shell and tube and the price is also not so low compared to that of the shell and tube, but every it is also true that the say one heat exchanger cannot serve everywhere all the time for all the applications that is the fundamental reason why there are so many types of heat exchangers available, 'right'. So, let us look into plate heat exchangers.

So, if we look at plate heat exchangers we can say that it is made of smooth or corrugated thin plates, 'right'. You will see that plate types are like this, if one plate is like that another plate is like this. Similarly, number of plates will come one over the other and these are called corrugated, 'right'; these are corrugated, 'right'. Plane geometry cannot accommodate high pressure and high temperature differential as one which was handled by the tubular type heat exchangers, 'right'.

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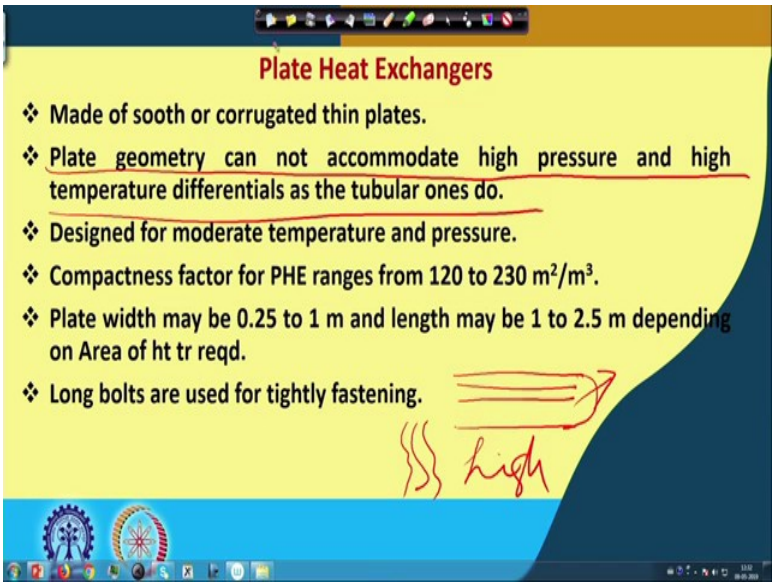

Tubular type heat exchangers which we had seen earlier, so if it is a tube and if it is the shell so that shell and tube they were handling very high pressure. But this plate type heat exchangers they are not that high-pressure handling instrument, 'right'.

So, designed for moderate temperature and pressure. Shell and tube heat exchanger as it was able to handle high pressure, similarly a high temperature difference also it can handle. But plate type heat exchangers they are neither capable of handling high pressure as well as handling high temperature difference. So, a moderate type of temperature as well as pressure handling is done by the plate type heat exchangers.

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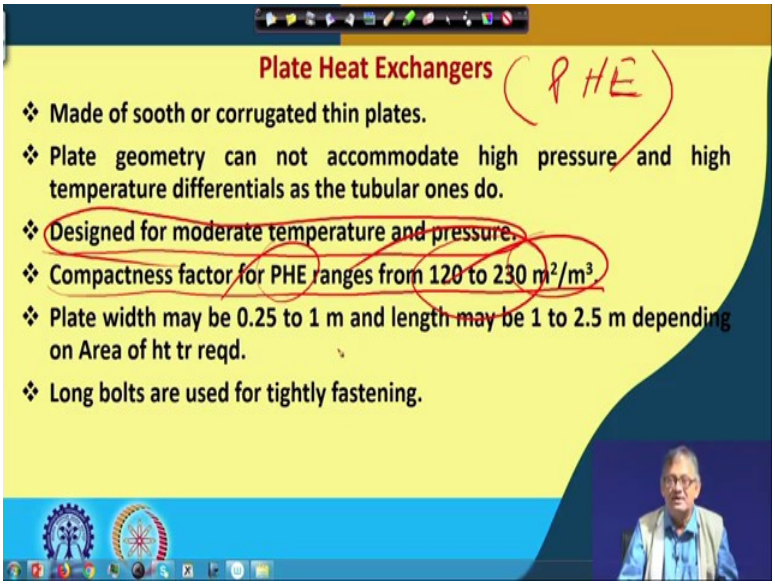

Compactness factor of the plate heat exchanger, PHE means Plate Heat Exchangers, 'right' which you can easily write here PHE, 'right'; that means, plate heat exchanger. The compactness factor for the PHE ranges from 120 to 230 m^2 / m^3 that is compactness. So, per meter cube how much meter square we are getting. The one which I said just now that tabular type heat exchanger is more voluminous, so when you are putting in the floor or in the industry you need lot of floor area, 'right'.

So, that is one disadvantage because the place where the floor price is very high there it will become rather a disadvantage, one of the. It cannot be a unit, unit cause will dictate that application whether it is tubular or plate. There is n-number of reasons to select one, 'right'. So, here one such is their compactness that is meter square per meter cube available, how much meter square surface area or area for heat transfer is available per meter cube of the instrument, 'right'. So, that is around 120 to 230 for plate type heat exchangers.

Plate width may be around 0.25 to 1 m, ‘right’. So, this plate width may be around 0.25 to 1 m and the length may be again by between 1 to 2.5 m this is between, ‘right’ this, oh this is b, ok, fine. That may be 1 to 2.5 m depending on the area of the heat transfer required.

Long bolts are used for tightly fastening these plates, ‘right’. So, normally these plates if there this width then a long bolt that may be used to tighten it, to tighten these plates together, ‘right’. So, these are some of the features of the plate type heat exchangers. There are, there will be some more and let us look into that.

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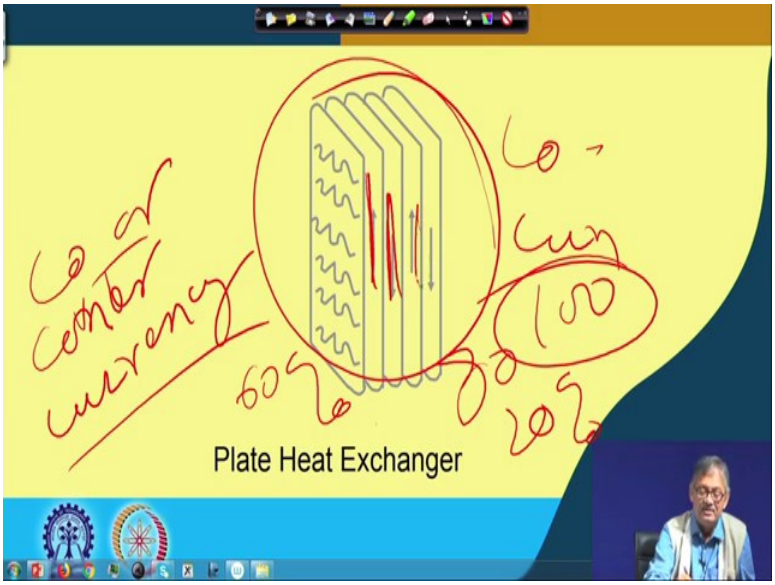

This is a typical plate heat exchanger which it looks like as we said that this is a corrugative like this one, ‘right’ this is a corrugation, ‘right’, and number of plates, this is one, this is one, this is one, this is one, this is one like that number of plates are here. We have given as one example that these many plates, but it can be as many as big as this or even bigger, ‘right’. So, maybe 30, 40 or 100 players depending or even more depending on your capacity required etcetera, ‘right’.

So, these plate heat exchangers as it is corrugated as it is like that and they are thin and the flow arrangements are that depends and depending on the flow arrangement this can be said the flow type can be said either co-current or it can be counter current, ‘right’. So, that is how in this heat exchangers the co or counter currency. There is a term called co or counter c o u n t e r counter currency that is determined in this type of heat

exchanger co-current or counter current; how much is co-current or how much is counter current. If it is 100% out of that, whether it is 80% counter, current 20% co-current or 60% counter current or 40% counter current etcetera that will dictate will be determined by this flow pattern, 'right', this flow pattern through the plates, 'right'.

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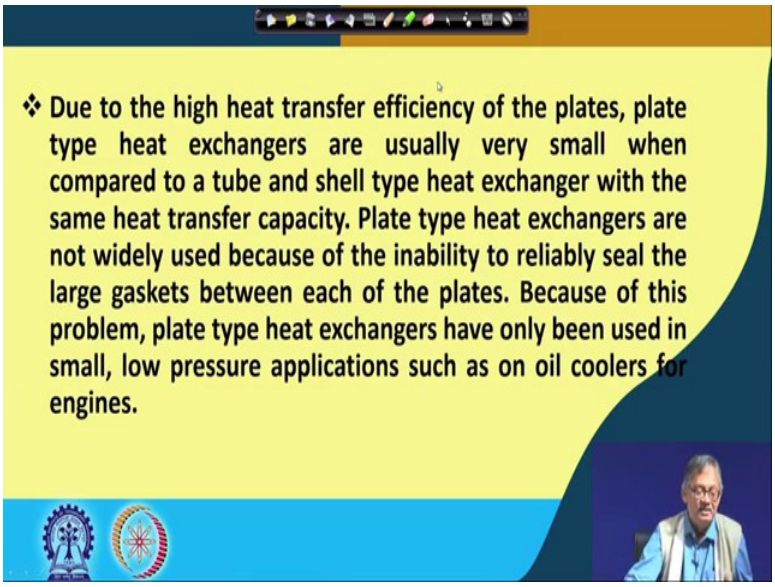

So, this is a typical pictorial view of plate heat exchanger. And due to the high heat transfer efficiency of the plates, plate type heat exchangers are usually very small when compared to a tube and shell type heat exchanger with the same heat transfer capacity. Plate type heat exchangers are not widely used because of the inability to reliably seal, the large gaskets between each of the plates, 'right' as we have just seen that this one, 'right'.

So, these one plate sorry, these one plate and the other plate, these one plate and the other plate they are, 'right' they between them there is a gasket and all the plates are having gaskets. And these gaskets are also separating the fluids. And in most of the cases this gaskets use may be a little difficult because if it is not properly sealed then there can be possibility of leakage, mixing of the fluid which is not desirable because you do not want that your product should come in contact with the another fluid thereby in food we call it to be contaminated, 'right'.

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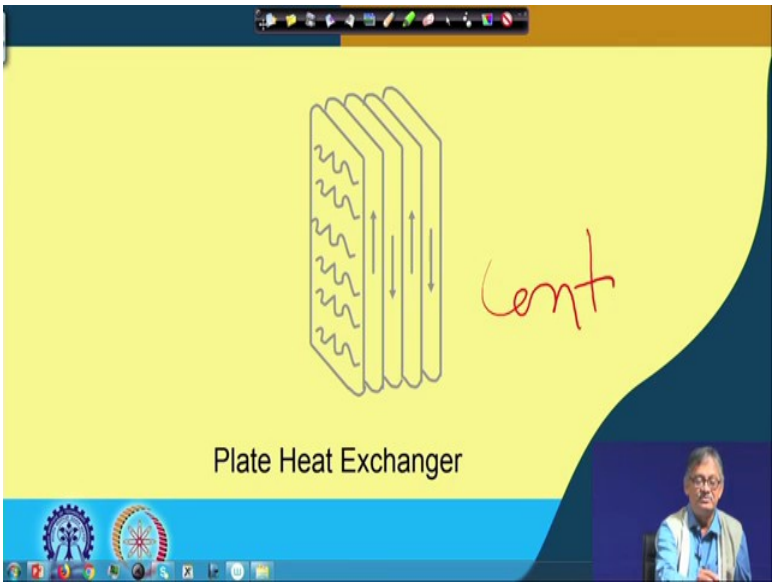

So, that you may not be asking for or that you may not be looking for. That is why as we said that in the plate type heat exchanger it could be a very very difficult thing to rely on the seal of the large gaskets between the each plates, 'right'. So, because of this problem plate type heat exchangers have only been used in small low pressure applications such as on oil coolers for engines, 'right'. Such as oil coolers for engines; in engines also, you will see this type of plate type heat exchangers are there.

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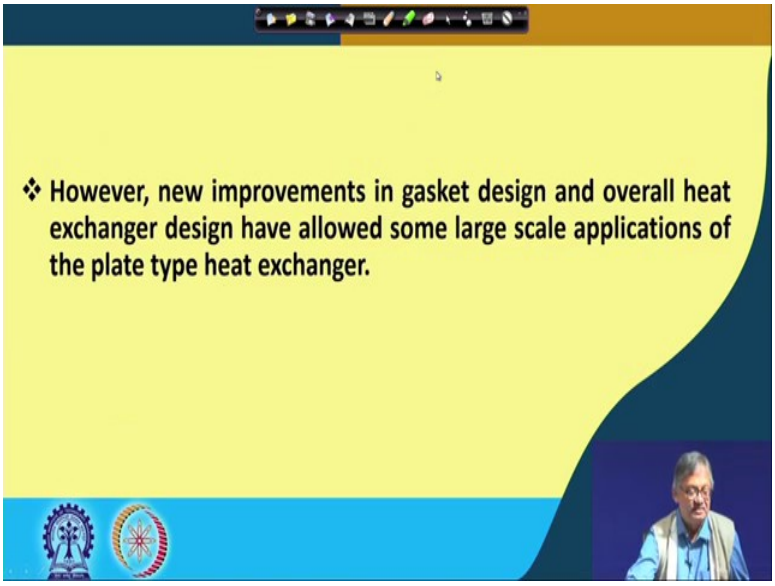

There are some more features for this plate type heat exchangers, that new improvements in gasket design all over and overall heat exchanger design have allowed some large scale applications of the plate type heat exchanger, 'right'. So, these gasket design obviously, with time with the time the new and new advent of the gaskets and the plates the this difficult part is gradually taken care of maybe in future they, it can be totally leak proof and in that way the application can be more and more.

The moment you can make it leak proof with pressure then the application of this will extend to a very far end and may compete with the tubular heat exchanger. But it is difficult tubular, heat exchanger you have no such gasket and gasket is the one of the main reason why the plate type heat exchangers have so less application compared to that of the tubular or shell and tube heat exchanger.

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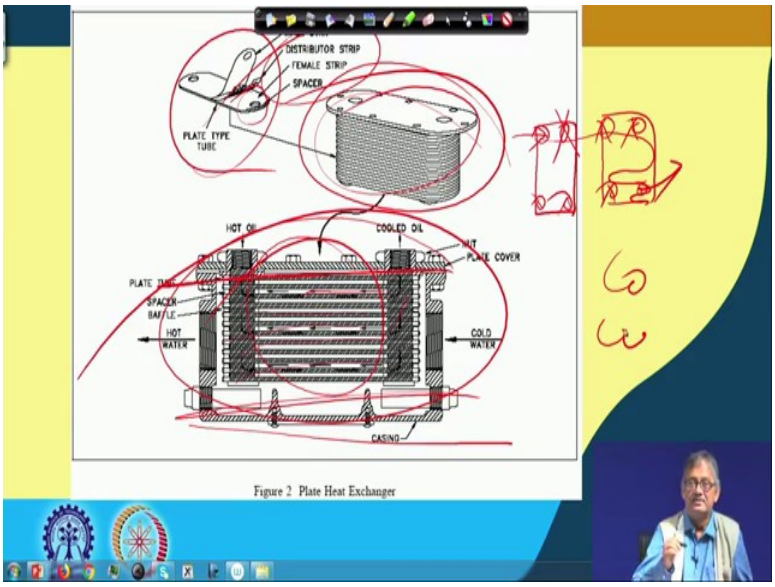

This is a we can say little, we get a heat plate heat exchangers. Similarly, this is another one as we said. There are some big bolts, 'right' so which are mounting the plates, 'right'; so which are mounting the plates and big bolts nuts and bolts are required for the, and these plate heat exchangers are like that say, this is a elaborated one, 'right'. So, this is a flow, this is another flow, this is another flow, 'right'. So, flow directions will be also directive to the type of this, 'right'. This is a plate type tube, distribution strip etcetera, etcetera. These are some holes, 'right'.

So, you will see in a plate typically if this is a plate there are four holes, ‘right’ and depending on which hole when closed the flow that direction of the flow of the fluid may be coming from here and in another plate that may, these all this is coming from there and these are all closed. So, in another plate these may be all closed and may be going out from there, ‘right’. So, all along it will move through that and then come out of that. That is how it will exchange the heat, and also direct whether it is co or counter current, ‘right’. So, this is a typical example of that.

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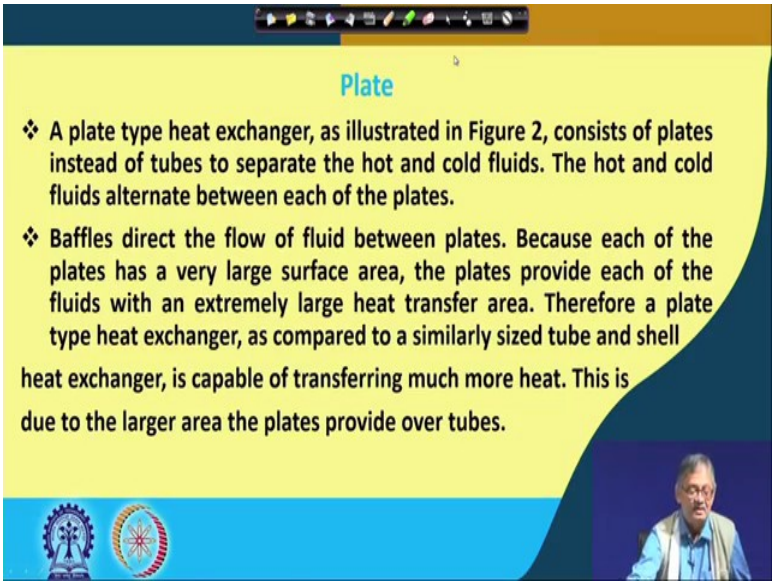

So, if we look at that plates that; so, there as it has been illustrated it consists of plates instead of tubes to separate the hot and cold fluids. Hot and cold fluids alternate between each of the plates and baffles direct the flow of fluid between the plates because of each of the plates has a very large surface area. The plates provide each of the fluids with an extremely large heat transfer area.

Therefore, a plate type heat exchanger as compared to a similar sized tube and shell heat exchanger is capable of transferring much more heat. This is due to the larger area of the plates provide more surface area over that of the tubes, ‘right’. So, these are some of the what we see, the some of the typical features of the plate type heat exchangers, ‘right’.

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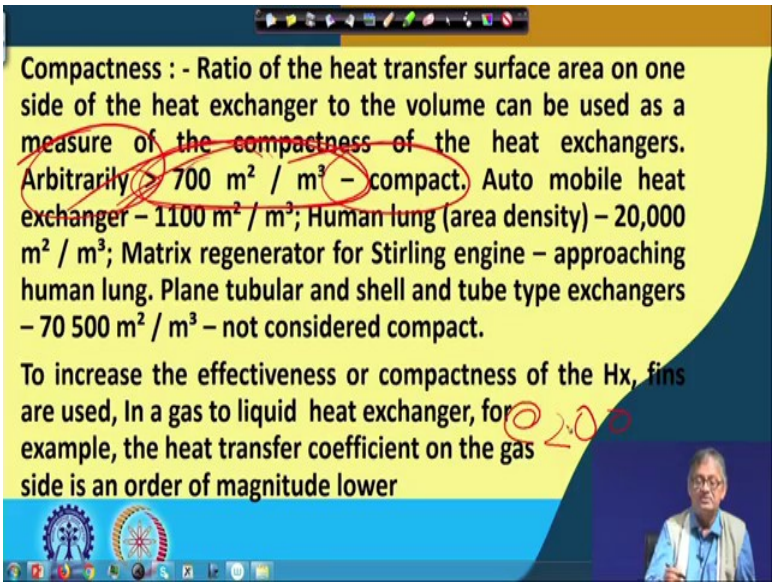

Then compactness, if you look at the compactness of heat exchangers which means ratio of the heat transfer surface area on one side of the heat exchanger to the volume that can be used as a measure of the compactness of the heat exchangers. So, meter square per meter cube is the compactness of the heat exchangers, 'right'.

Arbitrarily more than 700 m^2/m^3 compact is taken as, 'right', arbitrarily greater than 700 m^2/m^3 is taken to be a compact, less than that are less compact which we have shown that in tabular type heat exchanger it is somewhere around 200 [FL], so which is not compact at all, 'right'. So, arbitrarily this number of 700 or greater than 700 m^2/m^3 is taken to be a compact heat exchanger.

Automobile heat exchanger is around 1100 m^2/m^3 area volume, m^2 area /m^3 volume 1100 human lung that is area density is around 20,000 m^2/m^3; see 1100 and 20,000, 'right', 20,000 m^2/m^3. This you remember because that throughout your life it may carry with you, that 20,000 m^2/m^3 is the human heart normal compactness.

Matrix regenerator for Stirling engine, which this Stirling engine is an engine by which that cryogenic fluids are being produced. So, that approaches human lung. And plane tubular and shell and tube type heat exchangers as around 70 500 m^2/m^3, but not considered to be compact, 'right'. Though, plane tubular and shell and tube type heat exchangers they can have around, oh not 70 500, there is a gap, 'right' 70 to 500 m^2/m^3 it is not considered to be compact type heat exchanger.

To increase the effectiveness or compactness of the heat exchanger fins are used in many cases, 'right'. Because as we said earlier, fins to increase the surface area or heat transfer area are used in many types of heat exchangers.

In a gas to liquid heat exchanger for example, the heat transfer coefficient on the gas side is on the order of magnitude lower than this is what, that in a gas type gas to liquid type heat exchanger the heat transfer coefficient on the gas side is in the order of lower than that for the liquid side. Gas side obviously, has much lower heat transfer coefficient than that of the liquid side.

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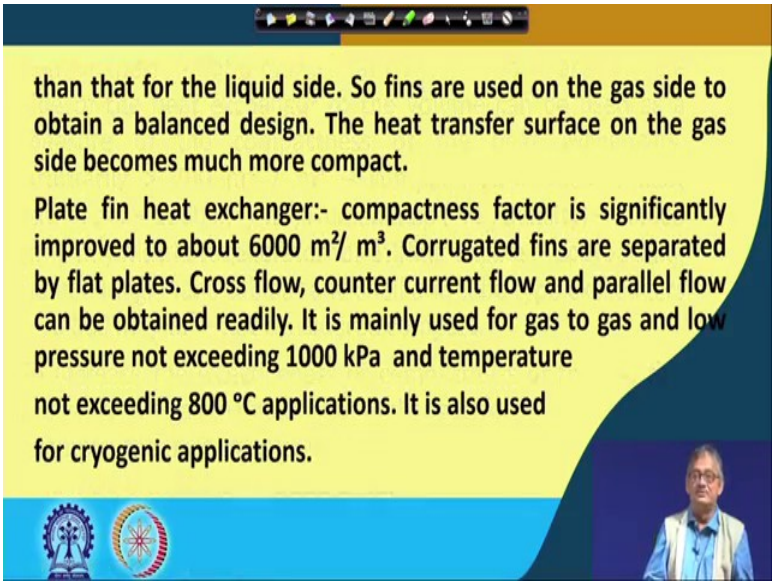

So, fins are used on the gas side to increase the heat transfer area, 'right' and that is how a balanced design is obtained. The heat transfer surface on the gas side becomes much more compact; compared to that of the liquid side because liquid side heat transfer coefficient is much high. So, compactness could be less required, but gas side heat transfer coefficient is much lower. So, the compactness required is very high.

Plate fin heat exchangers, there are another where the compactness factor is significantly improved to about 6000 m^2/m^3. In that corrugated fins are separated by flat plates. Cross flow, counter current flow and parallel flow can be obtained readily with those type of heat exchangers. It is mainly used for gas to gas and low pressure not exceeding 1000 kPa and temperature not exceeding 800 °C applications. It is also used for cryogenic applications. That is all these three cross, co and counter current heat exchangers, 'right'.

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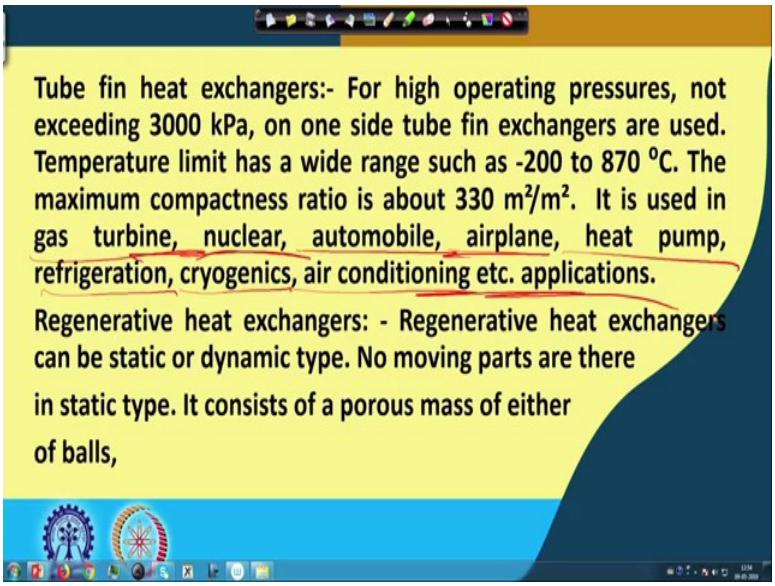

Again, do you feel heat exchangers are those where for high operation or operating pressures not exceeding 3000 kPa, on one side of the tube fin exchangers are used, 'right'. For high operating pressures of course, not exceeding 3000 kPa, one side of the tube is used for fins and they are fin type heat exchangers.

Temperature limit has a wide range around -200 to +870 °C for fin type heat exchangers. The maximum compactness ratio is about 330 m^2/m^3. It is used in gas turbine, nuclear, automobile, airplane, heat pump, refrigeration, cryogenics, air conditioning, etcetera applications; pin type heat exchangers are used in many many areas wherever you have heat transfer coefficient less.

So, to increase the heat transfer coefficient you cannot increase the heat transfer coefficient. So, for that to have the more heat transfer you increase the surface area, 'right' because q is u or h A ΔT. So, if h you cannot increase then it is better you increase A, 'right' it is better you increase A, 'right'. And in that case if you are increasing A, so you are in turn increasing q, 'right'. These are the ideas where they are used.

Then, regenerative heat exchangers; this is a relatively recent. I do not say recent means in this century, yeah in the last century only, but relatively recent. That regeneration, in earlier days that after heat exchange some heat was not utilized, whether it is hot or cold whatever we were not properly utilized. So, that time scientist and engineers they did

found out that if this unutilized heat or cold can be reused then the cost will be much much lower.

So, that is why in the regenerative type of heat exchangers where you are gaining the lost heat or the heat which we are not utilizing or cold either heat or a cold which you are not utilizing, ‘right’ or being wasted that is utilized in regenerative type of heat exchangers, ‘right’. That it can be for the gas side, it can be for the liquid side or for both depending on again the application, depending on again how much heat is being lost, it depending on if the recovery is beneficial or cost economic, ‘right’.

So, it can be that you are losing say 10° to the, I mean that is being (Refer Time: 28:08). But to recover this 10°, if you have to use the price or that regeneration whatever you name, if your price going up to compensate this 10° some price which will produce you 15° or even equivalent, so then that cannot be compared. So, it has to be also looked into that, the price of this regeneration has to be remunerative then only it will be applicable, ‘right’, ok.

We have come to the end of the class. Time is up. So, we will continue that heat exchangers in subsequent classes also.

Thank you.