Fluid Machines.
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Lecture-26.
Axial Flow Pump.

Good morning and welcome you all to this course on fluid machines. Now in this class before discussion on axial flow machines, a very brief introduction of the axial flow pump, I will 1st discuss the characteristics of pump in series and parallel, which I left earlier, we had discussed the head discharge characteristics of a pump, how this can be, how the head discharge characteristic at one speed and diameter, from one speed in diameter we can generate head discharge characteristics at different speeds, pump speed and diameter.

And at the same time we have recognised the operating as the intersection of the system characteristics and the high discharge characteristics of the pump. So all these things we have discussed, now 1st we will discuss the operations of pumps in series and parallel. Sometimes the multiple pumps, more than 1 pumps are required depending upon the requirement and use. Where a very high head is required to be generated, which cannot be met by a single pump, we use more than 1 pumps, 2 or more pumps in series.

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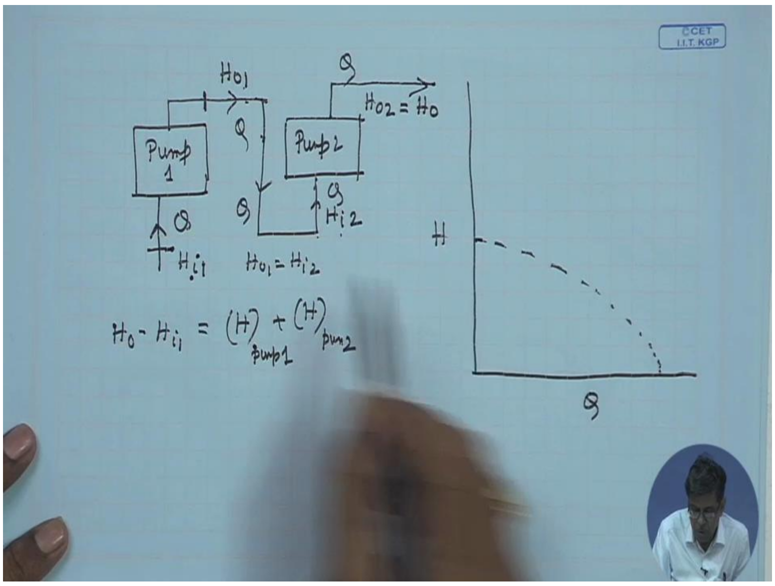

Series means the discharge of 1 pump attached to the inlet of the other pump and so on. By which what happens is the head developed of each pump is being added together to find out the total head developed of the system of pumps in series. So let us 1st see the pumps in series. If we have 2 pumps in series, okay. That means the inlet of 1 pump, that means let us now show by a box only, that pump 1. Everything you know, the impeller, diffuser, so unnecessarily am not drawing that, this is the inlet of pump 1.

And the outlet of pump 1 goes to the, this way, to the inlet of pump 2, pump 2, the inlet of pump 2 and ultimately the outlet of pump, let us consider 2 pumps as a final discharge. So therefore you see the head developed by pump 1 is the difference of head at inlet and outlet, this is the head developed. Let this head in let us is HI and let this is the outlet head. This is the outlet head of pump 1 and let this is the inlet head of pump 1, this is the inlet head of pump 2 and this is the outlet head of some 2 which is equal to the head delivered.

Now it is common sense that you see that the head developed by the pump 1 is H1 minus HI1 and this H1 is equal to HI 2 because they are connected in series. So the loss through this pipeline connecting this is very small, this is very short pipe, they are just connected, coupled. So HI 2, and this H O2 minus H I 2 is the head developed by the pump 2. So therefore the total head developed his HO minus H I 1 is the head developed by pump 1, head developed by pump 1, this is the head developed H + head developed by pump. Whereas the same flow is going, Q, Q remains same, this is a serious connection, most simple thing.

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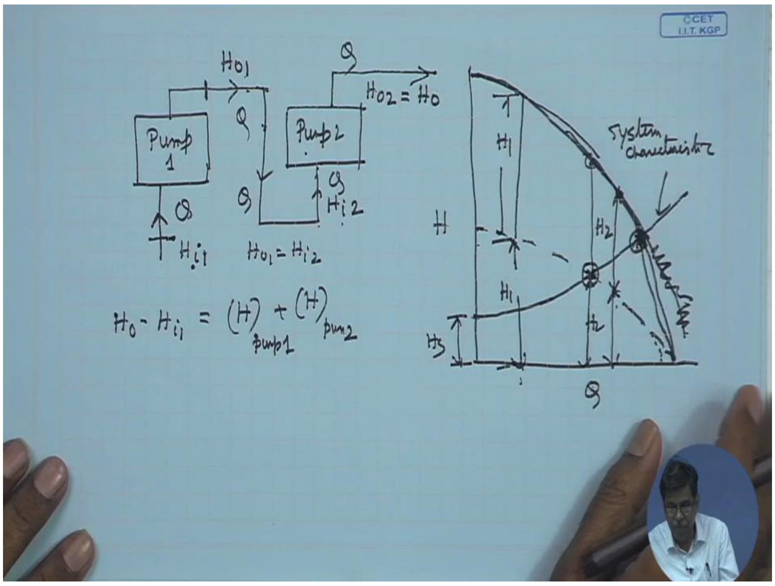

If we now draw the characteristic curve, we will see that, now these 2 pumps may be identical ones, be different ones also. Let us consider the identical pumps, it will begin to draw the diagram. So let the single, for the single pump this is the head discharge characteristic for the single pump. So the head discharge characteristic of the combined pump is very simple. For each and every discharge we just add the head and we get the head discharge characteristics of the, sorry.

Head discharge characteristics of the, this is the curve, this is the curve, this ends here at the same point where it is 0. That means that any point Q, if this be the head developed H1 by this, this is H1 by this pump 1 pump. Then this will be also H1, that is twice H1, this will be H1. That means twice of this H. Similarly here also at any other point, if this is H2, then this will also be H2 because heads are added. Therefore for any Q, the head of the combined pump in series is double that of the single pump since the pumps are identical.

But the interesting thing is that if we draw the system characteristics, this is HS, the system characteristics, this is system characteristics, this is system characteristic, system characteristics, then you see this was the operating point for the single pump and this will be the operating point for the combined pump where this is not double. For example here, if this be the head of the single pump, the operating pump head here which is doubled.

That means though the discharge characteristics for the identical pump in series, so the head to be doubled at a given discharge but the operating point, this is the head discharge characteristic, the operating point, the head is increased. That means in actual operation, there is an increase in the head but it is not doubled in case of a typical pump. So therefore increase in head is same, that this head is higher than this, so this depends upon the system characteristic curve.

Okay. So therefore the operating point shows like that but the head discharge curve is like this. Head discharge curve is generated like that. If the pumps are different, so we have to add the, we have to draw the 2 had discharge curves and the heads have to be added and to be drawn like that. This is the head discharge curve for pumps in series.

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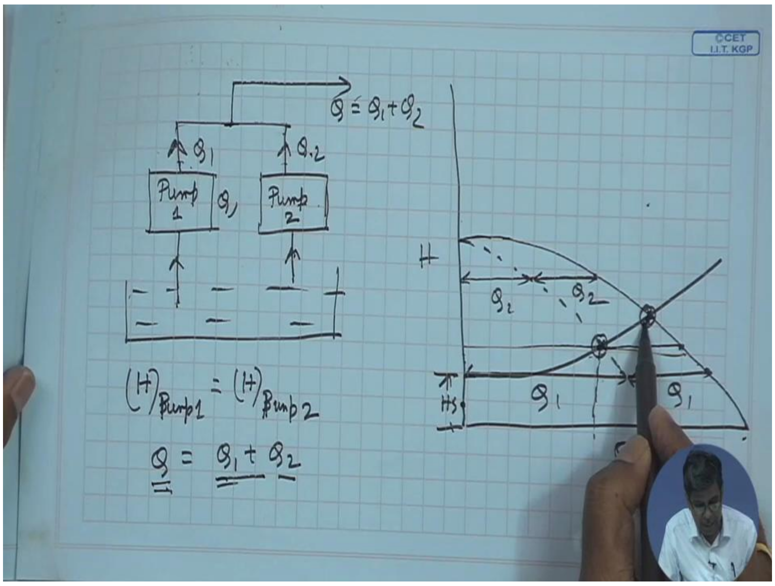

Similarly for pumps in parallel where the requirements of discharges more which cannot be met by single pump, individual pump, there the pumps are connected in parallel. That means pump 1 and pump 2 are connected in parallel. Pump 2, that is pump 1 and pump 2 are connected in parallel. So they take for example the same source, same sump or something like that but the, they are discharged in the same line and from where the final discharge is there.

That means here what happens that Q1 and Q2 of the 2 pumps is being added to, just like the parallel connection, what happens is, but the head developed by the pump 1 and pump 2 will be same because they are connected to the same mainline. So the head here is the same for both the pump. So this is the head, final head available. So H of pump 1, head developed by pump 1 equal to head developed by pump 2, head developed by pump 2, pump 2. But the flow rate is added, the discharge is added for pump 1 and pump 2 to give the final discharge.

That is the pump in series, here also we can draw the discharge characteristics. If we consider the 2 identical pumps pump 1 and pump 2 identical and we have a head discharge curve like this for the 1 pump here what happens, the discharge is added, the flow rates are added. So therefore for any head, given head, the flow rate will be added, it starts from here and ultimately show like this.

That means this is not correct in the scale because this discharge and this has to be same, however this is little awkward but you just take it that this is Q at any head and this is also Q, this should be same. However my drawing in the scale, the space is limited, so this is not correct, so this Q has to be same here you can better represent, Q1, Q1, here Q2 and this is the same Q2. Okay. That means queues are added at a particular H.

So this way we can generate and in the same way we can tell that if we have the resistance, system resistance like this, this is the HS for example, the static lift, then the operating point is here and operating point is here. So here the operating point, the discharge is increased from that of the operating point with the individual pump. But not it is doubled, but here it is doubled. The discharge what was here is doubled here. So it cuts here, this looks like this, this is a parabola, okay.

So therefore the operating point here also gives a higher discharge which is the objective of pumps in parallel but this is not the double in case of 2 identical pumps. That means this is not the addition of the 2 flow rates. That means this is the addition of the 2 flow rates is the final flow rate we tell, not in case of operation. That is when we find out the characteristic things. But in actual operation, when it is added or when it is integrated with the system, then the flow rates addiction will not be the final flow rate, it will be different.

In the similar way as we saw that this thing for a series, pump in series also, it is different, though we told that the head developed is head developed by the pump 1, pump 2, that is when we think of the discharge characteristics. But actual head developed in case of operations with a system, that is pipes, valves, everything, the transmission pipes, so that system characteristics is added with the pump, then the operation point will give a head higher than this head developed by pump 1 or head developed by pump 2 in case of identical pump or it will be less than the sum of these 2, double of that for sum of these 2.

Okay. It will be higher than the individual head developed but less than the sum of these 2. Similar is the case. This is because of the fact that operating point is the point of intersection of the system characteristics and the HQ or head discharge characteristics of the pump. So this way we have an idea that how we can get the head discharge characteristics of pumps in series and pumps in parallel and the requirement for that where the pumps in series is required or the pumps in parallel is required.

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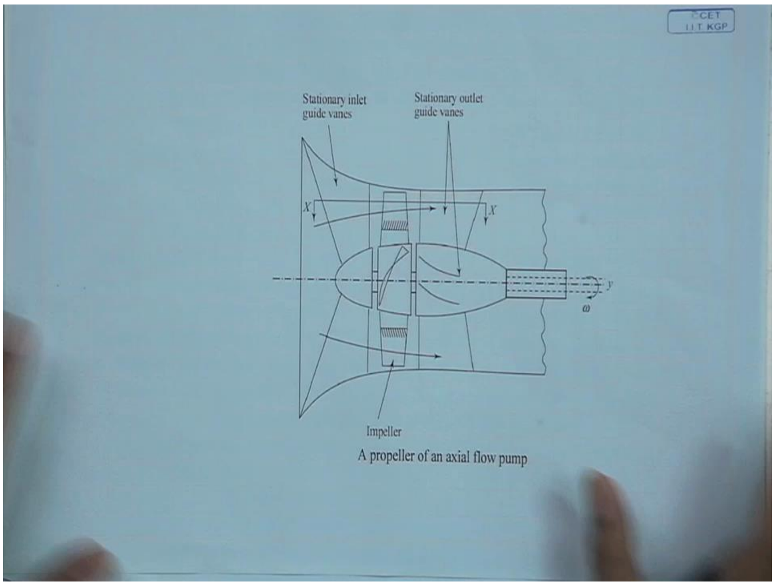

Now we will discuss an axial flow pump. The 1st of all I tell you that axial flow pump is just the converse of an axial flow turbine. If you recollect that axial flow turbine came to give a higher efficiency and to give a high-power developed by the turbine when the head is very low. Substantial amount of flow has to take place through the runner for which the demand in the axial flow turbine came. Similarly axial flow pumps also comes into picture when we have to deliver a higher flow rate, okay.

And a relatively lower head and so the concept of axial flow pump comes into picture. Now the axial flow pump looks like this, basically I just explain you that this basically looks like the converse of a axial flow reaction turbine. It consists of a central boss which, this is the central boss or hub on which the rotor discs are mounted and this is a cylindrical casing. And there is clearance between this rotor and the casing, this clearance should be made as less as possible to avoid leakage.

And this is rotated, this rotates and these blades are mounted in a way that the fluid comes axially, the flows, the water flows axially through these blades and there are inlet guide vanes, you see these are fixed, this is fixed to the stationary inlet guide vanes to the casing. This we see a frontal view. So there are stationary guide vanes. And the purpose of these guide vanes is to direct the water or the liquid properly to the rotating blades, rotating blades of the axial pump in the proper angle to the rotating blades without shock.

That means matching the inlet angle of the blades, this is a function of the inlet guide vanes. Now there are also at the outlet some stationary vanes are there which are also guide vanes, fixed to that, the purpose of this is to reduce the swirl. That means when the liquid comes, the water comes out of these blades, this has got a substantial swirling component of velocity along with the axial component of velocity. And this swirling component of velocity is being reduced while flowing through this stationary blade and finally it goes out of these blades and out of the machine.

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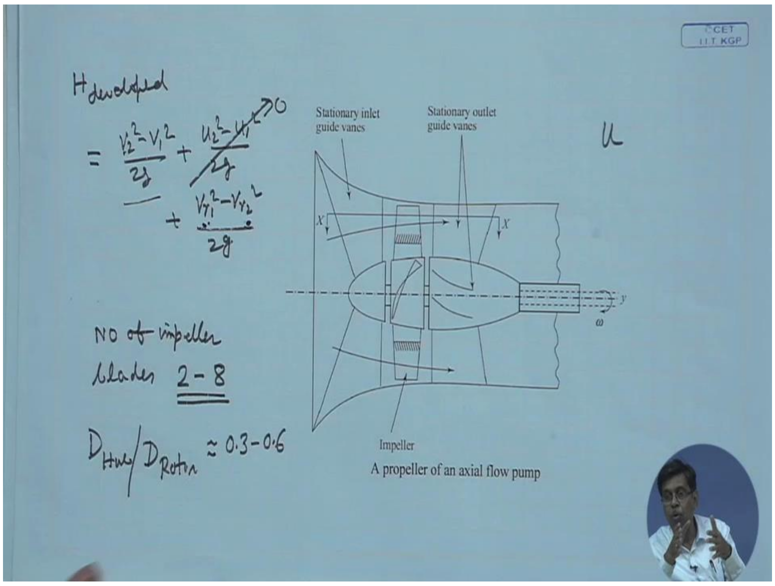

This is overall a picture of this axial flow pump and here 2 information you can take that the number of impeller blades or the rotor blades, number of impeller blades, impeller blades rotor blades usually varies from 2 to 8. And the ratio of hub diameter to the rotor diameter, to the rotor diameter is equal to 0.3 to 0.6. It is almost similar to the axial flow turbine, that is the Kaplan turbine, it looks like that, the blades are like that but here the axial flow is similar to the turbine.

So at entry, at all inlet, the radial locations vary, all outlet, the radial locations vary. So the radial location at inlet and outlet do not change, that way there is no change in the U component of velocities that inlet and outlet. So at all radial locations, inlet is there and all radial locations, you see here, all radial locations the inlet is there, all radial locations. So here the blade velocity U is usually defined in this type of axial flow machines at a main radius.

So therefore if we write the head developed part of the pump, head developed, that is equal to V2 square minus V1 square by 2G + U 2 square minus U1 square by 2G + VR1 square minus VR2 square by 2G. Just the minus sign for that of the turbine. Now here U2 U1 is same. So one is the increase in its kinetic energy or the velocity and another is the increase in static head because of the increase in radial velocity, rather decrease in the radial velocity from that at the inlet so that these blades accidents are diverging types. In case of a, of axial flow turbine, it was converging and diverging types of that the VR1, that is the, that VR2 that is the relative velocity with respect to the blade at the outlet is less than that at the inlet.

So that this becomes positive and this is manifested in terms of the rise in pressure. So this is a function of any axial flow machine in case of pump this is like this, in case of turbine the sign changes. So therefore it is only the change in the relative velocity that the flow passage is accordingly designed. It is converging in case of a turbine and it is diverging in case of a pump. Flow is mainly in the axial direction, it has both axial and tangential components of velocity but the swirling tangential component of velocity coming out of the blades is being reduced I will flowing through the static guide vanes at the outlet.

So these all are the main part and this is in brief the axial flow pump. So with this I will end the lecture on Rotodynamic machines. The machines which functions on the change of angular momentum of the fluid in course of a continuous flow of fluid through the machines having a relative motion between the rotor of the machine and the fluid. And we have discussed turbines, impulse, reactions and also the centrifugal pump and the axial flow pump. Next I will discuss the positive displacement type of pumps, machines, mainly the positive displacement pump, reciprocating pump in the next class. So for today, thank you.