**Marine Propulsion**
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**Lecture - 35**
**Surface Piercing Propeller, Podded Propeller, Thruster**

Welcome to lecture 35 of the course Marine Propulsion. We will discuss some different propulsion types like Surface Piercing Propeller, Podded Propeller and Thruster in this lecture.

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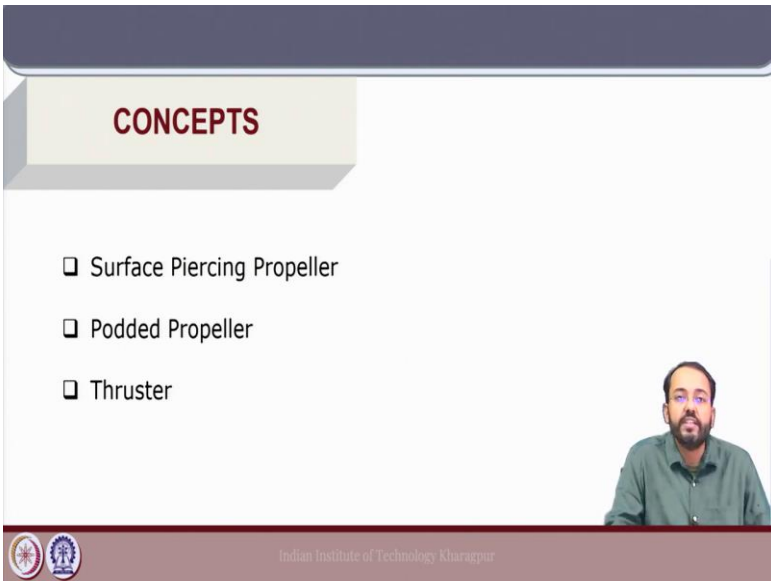


The key elements of this lecture will be the three different propeller types – the surface piercing propeller, podded propeller and thrusters, and their basic concepts, design types and application for different vessel types.

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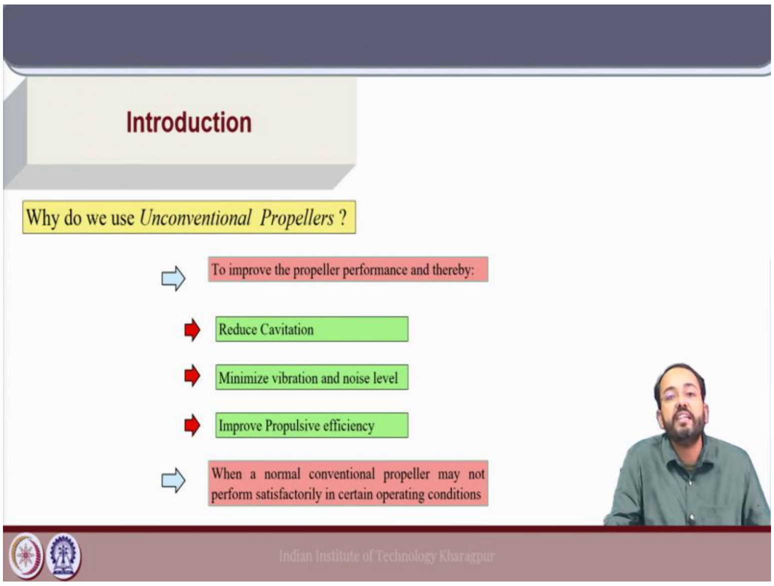


These propellers are sometimes referred to as unconventional propellers. Now, unconventional propellers can be both screw propellers with different variants, which are not the conventional design or some totally different concepts of marine propulsion like water jets, paddle wheel propulsion, vertical axis propellers, etcetera.

Now, this unconventional propellers find application in vessels where special requirements are there depending on their operation conditions. So, they are used to reduce cavitation, minimize vibration or noise and to improve propulsive efficiency for specific operation conditions and particular vessel designs and where they have certain improvements in the propeller performance in these regards.

And, also on the other hand, in these particular cases it is observed that conventional propellers may not perform satisfactorily for the specific operation conditions and due to the additional requirements unconventional propellers provide certain benefits over the conventional design.

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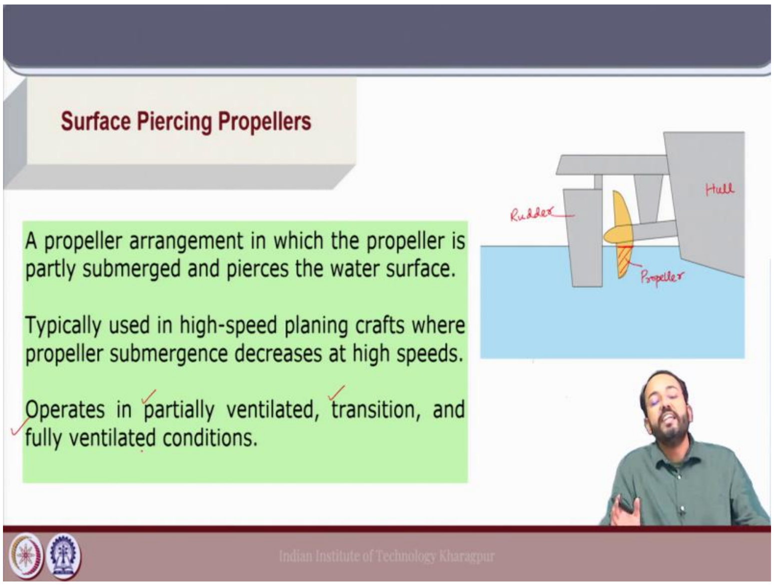


So, we will look into each of these types and start with the surface piercing propeller. Here as the name suggests the propeller arrangement is such that the propeller is partially submerged during it is operation. And because of that it pierces the free surface at different propeller operation conditions and the submergence will depend on the vessel speed. Here we have the propeller behind the hull and we can see that the propeller is partially submerged and behind the propeller we have the rudder.

These surface piercing propellers find applications typically in high speed planing crafts where the Froude number is very high and the cracks operate in the semi-planing and planing range; that means, during the high speed operations the trim as well as the immersion of the craft changes and that changes the propeller submergence especially at high speeds.

So, normally for a displacement vessel during its operation what we have the weight of the vessel is supported by the buoyancy and that is why for standard ships they are mentioned as displacement vessels. For these high speed planing crafts during their operation at high speeds the hydrodynamic lift provided by the craft itself at the high speed operation conditions balances a part of the weight. And hence the draft will decrease in the planing modes and that changes the propeller submergence.

So, for these specific kinds of vessels the use of surface piercing propellers become important. Now, as the crafts moves and gradually increases the speed the submergence of the propeller will change. And, especially at very high speeds where the hydrodynamic lift is very high when the craft is operating in the planing mode, then the propeller submergence will decrease and the propeller will come out of water depending on the final balance between the different forces, which are the hydrodynamic lift the weight.

And, the buoyancy of the craft and the final propeller submergence will decide the operation characteristics of the propeller in the surface piercing mode. So, during any specific operation condition for a surface piercing propeller only a small part of the propeller is immersed and the rest of the part is out of water.

Now, if we consider a blade for a full revolution, it passes through both the air and water. So, there will be a condition when the blade enters the water and there will be a condition when the blade leaves the water during one entire revolution and because of that ventilation will occur for surface piercing propellers. And hence they operate in different conditions during one entire revolution.

So, partially ventilated transition and fully ventilated conditions, will be encountered during the revolution of a surface piercing propeller. Now, ventilation means drawing of air by the propeller blade during it is operation. When we discussed propeller model tests a minimum immersion of the propeller below the water surface was recommended by ITTC because we want to avoid ventilation for normal propeller model testing.

If the propeller blades operates very close to the free surface, then it may draw in air and that will lead to ventilation and change in the propeller performance characteristics. But, for a surface piercing propeller which operates in partially submerged mode the ventilation mechanism will be an important part of the propeller performance.

And, it operates in partially ventilated when a part of the propeller blade is engulfed in the air and in transition condition where the air will be formed and, on certain parts on the propeller leading edge and, in fully ventilated condition where the propeller blade will be covered entirely by an air film.

And, hence the thrust and torque characteristics of the propeller will fluctuate when it operates in these different conditions and during one entire evolution the thrust and torque characteristics of the propeller will vary on the instantaneous location of the propeller blade.

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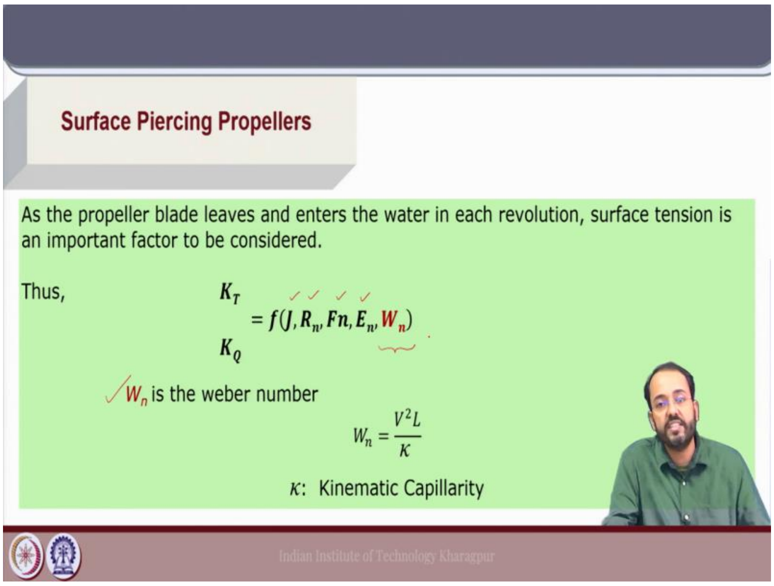


Now, for surface piercing propellers because the propeller leaves and enters the water in each revolution as we have just discussed, the surface tension of the fluid will also be an important factor in governing the thrust and torque performance of a surface piercing propeller.

And hence we have the additional term which is the Weber number apart from the standard non-dimensional coefficients that we have already seen for conventional propellers. This Weber number also plays an important role in the performance of a surface piercing propeller because the Weber number is related to the surface tension force.

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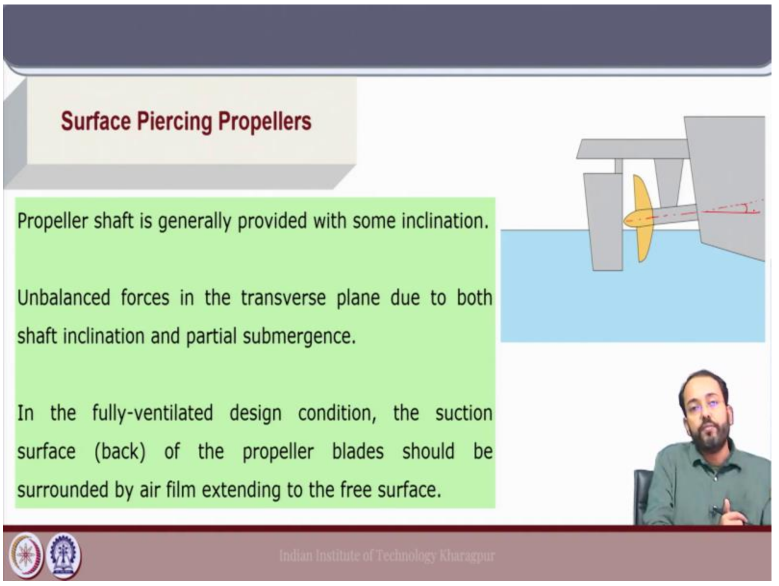


For surface piercing propellers, in order to achieve the propeller immersion during different operation conditions for a high speed craft, normally a shaft inclination is provided in the design, which means if this is the propeller shaft here and we draw the center line and this is the horizontal line there will be a small angle by which the shaft is inclined.

And, due to this shaft inclination there will be additional transverse forces in the propeller plane for surface piercing propellers and also because the propeller enters and leaves the water surface during each revolution, there will be additional transverse forces which are unbalanced and these have to be taken care of in the design of surface piercing propellers.

Now, in the fully ventilated design condition which is the optimum condition for a surface piercing propeller the suction side which is the back of the propeller blade should be surrounded by air film which extends to the free surface; that means, the back of the propeller blade which is the suction side will be entirely covered with an air film for the fully ventilated condition.

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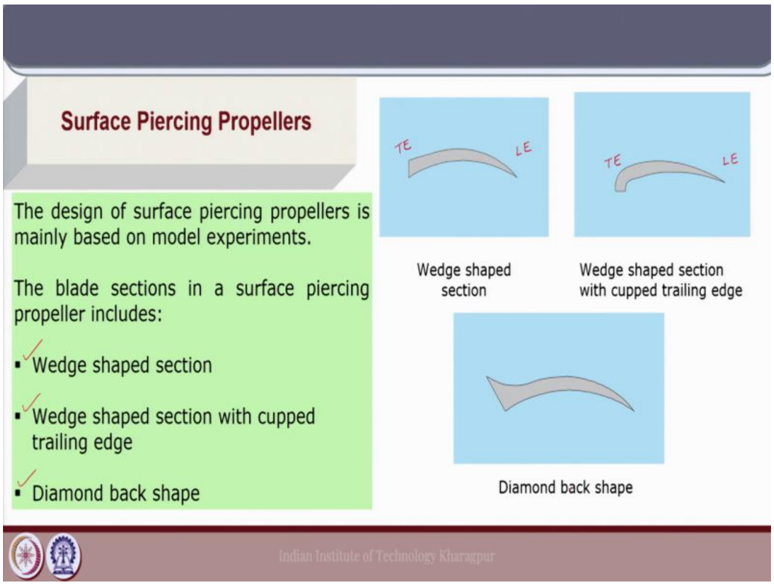


Regarding the design of surface piercing propellers, it is essential to conduct model tests for different immersion conditions and assess the thrust and torque performance of the surface piercing propeller. Now, the blade sections which are used to design a surface piercing propeller are very much different from the blade sections which are used for conventional propellers.

And, here the typical sections which are used to design surface piercing propeller blade sections are shown. We have the wedge shaped section which is in the shape of a wedge and the same section with a cupped trailing edge is shown here. In these sections, we want the entire suction side to be covered by air film in the fully ventilated design condition and hence we have the leading edge here and the trailing edge which is in the shape of a wedge.

Similar way we have the leading edge and the trailing edge here and this particular design helps in the development of the air film in the fully ventilated condition and another shape which is the diamond back shape used for surface piercing propellers is shown here. Now, these shapes are very different from the conventional propeller blade sections and they are specifically designed to achieve the thrust and torque performance in different surface piercing conditions.

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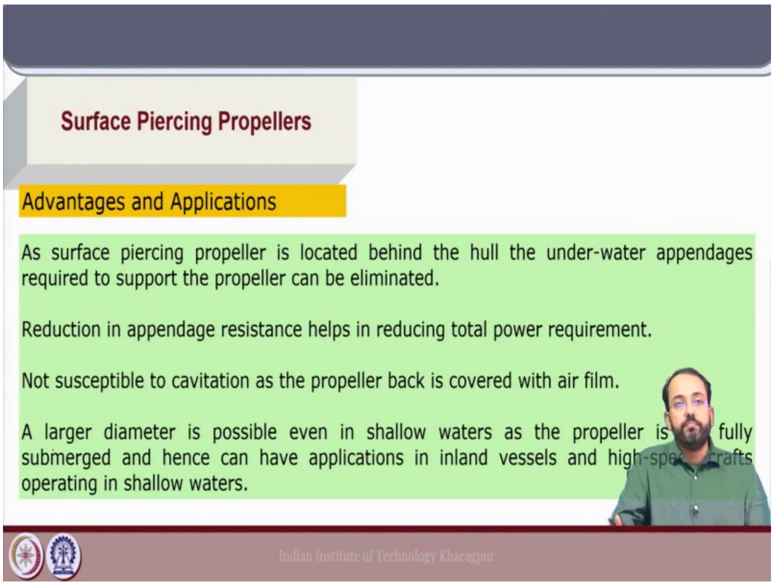


Next, we will look into the advantages and applications of surface piercing propellers. Now, typically the surface piercing propeller is located behind the hull where a part of the propeller is above the water surface. And hence the support structure which is used for the propeller the appendages are above water.

And here we can reduce the requirement of the underwater appendage which creates additional drag and because of that the appendage resistance is reduced which can help in the reduction of the power requirement at very high speed operation. Now, these surface piercing propellers are not susceptible to cavitation because the propeller back in the design condition is already covered with air film for the fully ventilated condition.

And, for surface piercing propellers even in shallow waters a large diameter is possible because the propeller is only partially submerged and this allows surface piercing propellers to be applicable for inland vessels and high speed crafts operating in shallow waters, where we can have a higher diameter for shallow condition by designing surface piercing propellers.

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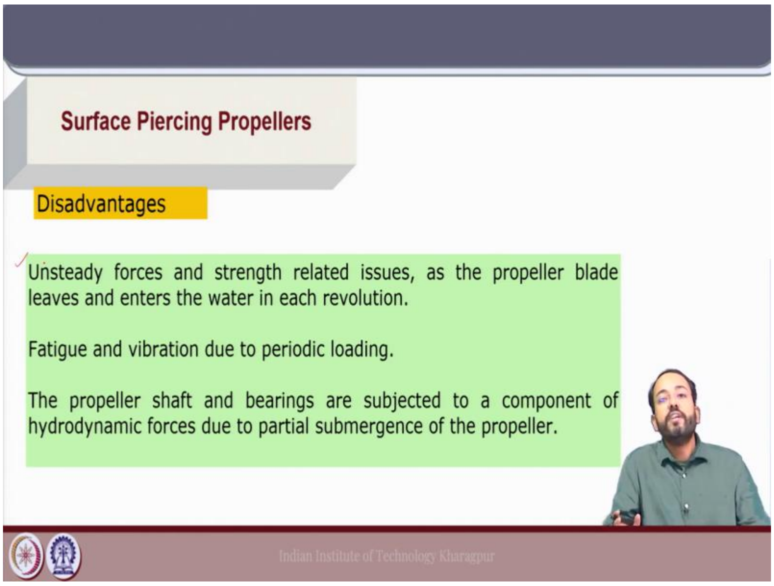


Next, there are some disadvantages that the propeller designer should also be aware of while using surface piercing propellers for specific applications. The first one is the generation of unsteady forces during its rotation as the propeller blade continuously pierces the water surface and this leads to strength related issues that needs to be taken care of in the design.

Fatigue and vibration will be problems because of the periodic loading of the propeller. And, the propeller shaft and bearings are subjected to hydrodynamic forces due to continuous operation in and out of the water surface.

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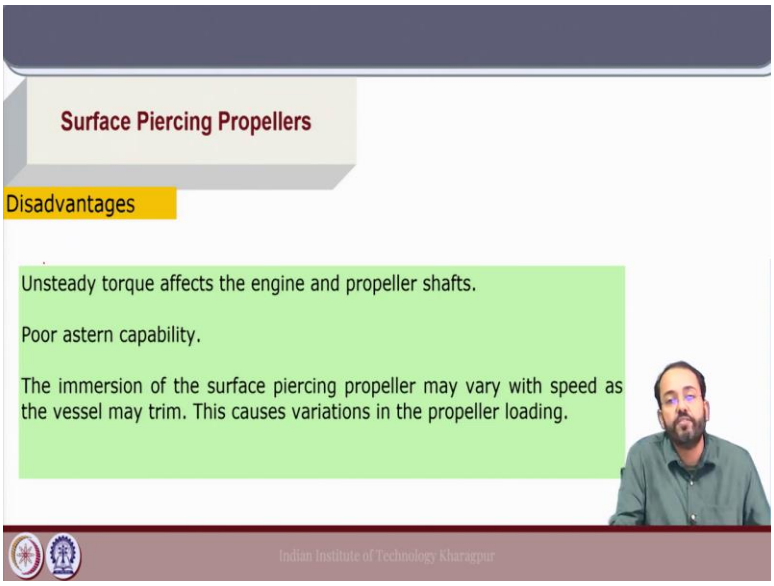


So, because of that there will also be unsteady torques which affects the engine and propeller shafts. So, all these disadvantages are mainly related to the partial submergence during its operation, and hence these factors needs to be looked into in the design of the propeller blades so that the thrust and torque and also the vibration characteristics of the propeller are properly estimated.

The poor astern capability is an important factor for surface piercing propellers because the blades are designed in such a way that the leading and trailing edges are very much different. The immersion of the surface piercing propeller will also vary with the vessel speed and this is a very important factor for very high speed planing crafts as the speed increases the vessel immersion will be different because the draft will also change and hence the propeller immersion will change with speed.

And, hence the performance of a surface piercing propeller will also change with the vessel speed and hence the design condition should be properly looked into when the fully ventilated design condition is defined for the surface piercing propeller.

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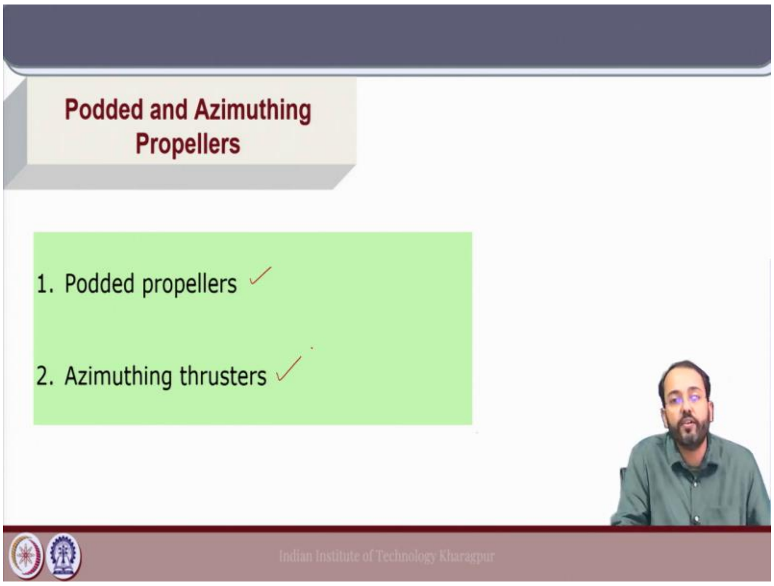


Next we will look into two specific design types the podded propellers and azimuthing thrusters which are used for specific vessels depending on their requirements for operations.

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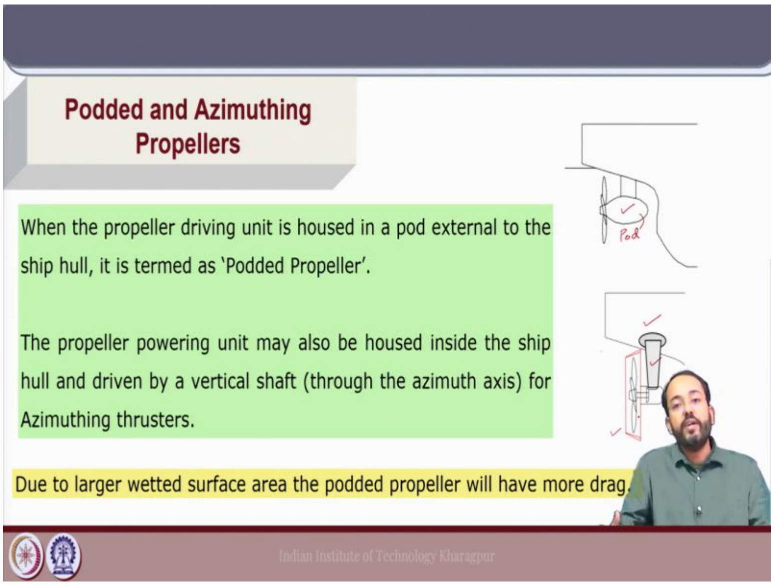


Now, the podded propeller is a type, where the propeller driving unit is housed in a pod which is external to the ship hull. For a conventional propeller we have seen that the propeller is connected directly to the engine using a shaft where there might be reduction gears which are used depending on the ratio of the engine speed and the propeller speeds.

Now, for podded propellers these propellers are mounted externally on the ship hull at the stern and the driving unit is housed in the pod. This is the pod and if the powering unit is housed inside the ship hull and the propeller is driven by a vertical shaft here, then it is called an azimuthing thrusters.

Now, these azimuthing thrusters can be rotated to different azimuthing angles and they can provide excellent manoeuvrability for different operation conditions. So, in these designs the powering unit is housed here and it is driven by a shaft through the azimuth axis about which the thruster can be rotated and in this particular design the thruster has a duct. So, there can be other designs where the thruster is without the duct. So, this is a ducted azimuthing thrusters.

Now, these cases of podded propellers and azimuthing thrusters they require additional pods or structures behind the ship hull and that will lead to drag and to estimate the performance of these propulsion types the drag of the pod or housing needs to be estimated properly for proper calculation of the propulsion performance.

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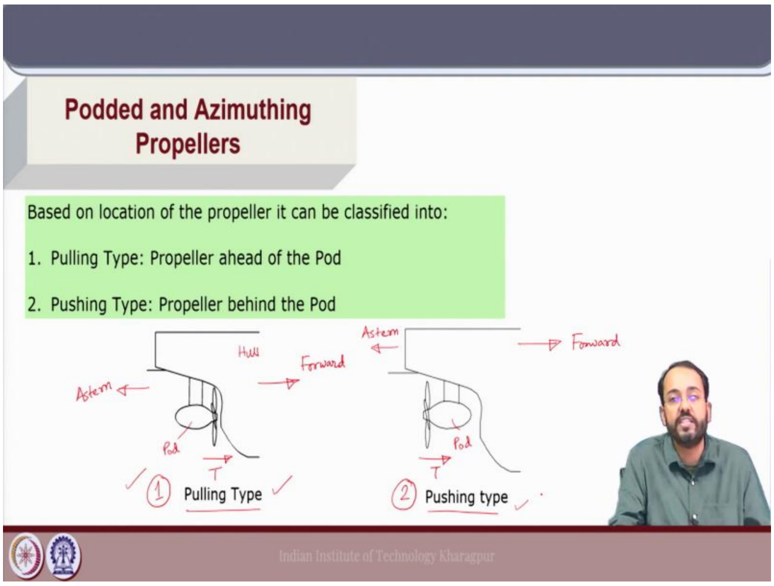


Depending on the location of the propeller with respect to the pod, podded propellers can be classified into pulling type and pushing type. Now, for the pulling type podded propeller which is shown in this figure 1, we have the pod which is behind the propeller. So, this is the ship hull and the direction of forward motion is shown towards the right and we have the astern direction here towards the left.

And, the propeller is generating a thrust in the forward direction. So, that thrust is pulling the pod because the pod is behind the propeller and for the type 2 which is the pushing podded propeller, the propeller is fitted behind the pod. Again, we have the forward direction and astern direction of thrust and this thrust generated by the propeller is pushing the pod ahead because the pod is located forward of the propeller.

Now, these two types have certain advantages and disadvantages depending on the operation condition. For example, the pulling type podded propeller has a more uniform inflow into the propeller because the propeller is ahead of the pod. So, the inflow into the propeller is not disturbed by the pod here in this pulling type, and hence it has better vibration and noise characteristics because of a more uniform inflow. Hence this pulling type podded propeller is used for passenger and cruise vessels where noise and vibration requirements are critical due to passenger comfort.

Now, on the other hand, if we look into the pushing type podded propeller the propeller is located behind the pod and hence the pod is ahead of the propeller. So, the flow into the propeller is disturbed by the presence of the pod. But, on the other hand for the pulling type the pod is behind the propeller slip stream. So, the pod drag will be higher as compared to the pushing type.

Because the flow is accelerated behind the propeller due to its rotation the pulling type podded propeller will have a higher pod drag as compared to the pushing type. So, these factors needs to be taken care of while designing these pulling and pushing type podded propeller and their application on specific vessel types.

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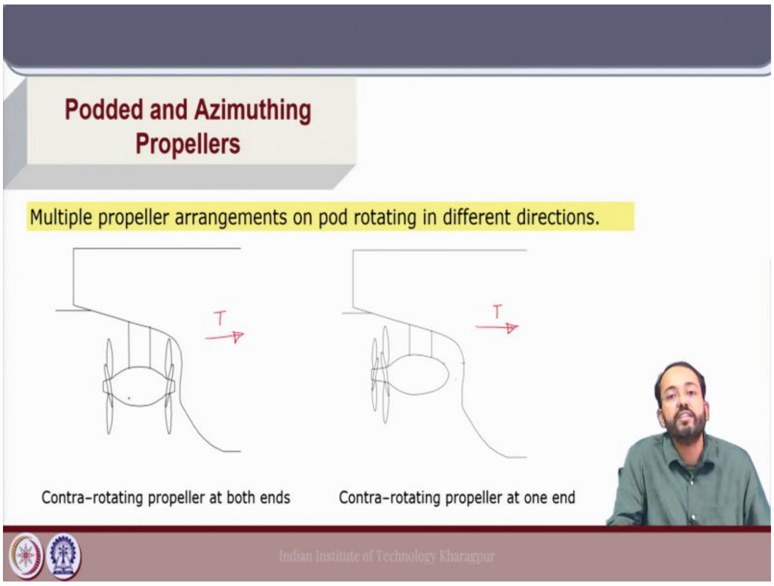


Additionally, we can have multiple propeller arrangements on a pod in this slide two different designs are shown for contra rotating propellers on a pod. Here contra rotating means the two propellers are rotating in two different directions and hence the pitch of the propeller blades should also be in different directions so that they provide thrust in the forward direction.

Now, details on multiple propeller configurations including contra rotating and tandem propellers will be discussed later in the course. Here the concept of multiple propellers on a pod is shown in the respect of podded propellers; that means, we can have a pod designed in such a way that it can accommodate two propellers either at one end or at the two ends providing thrust and this can be used for providing high efficiency for certain operation conditions.

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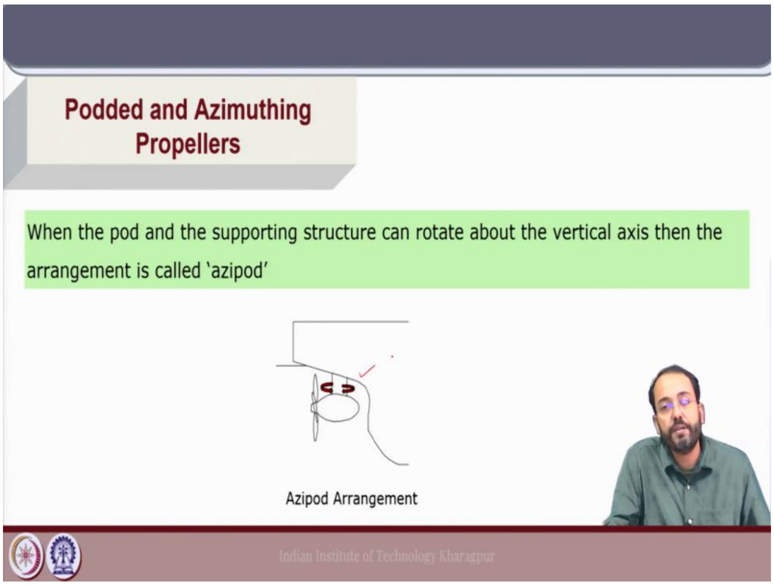


There is another specific design where the pod and the supporting structure can be rotated about a vertical axis as shown here and this can provide thrust in different azimuthing directions. And, hence this particular design is called azimuthing propeller or azipod and these are used for vessels where the manoeuvring requirements are very high, and they help in dynamic positioning as well as slow speed manoeuvring of vessels.

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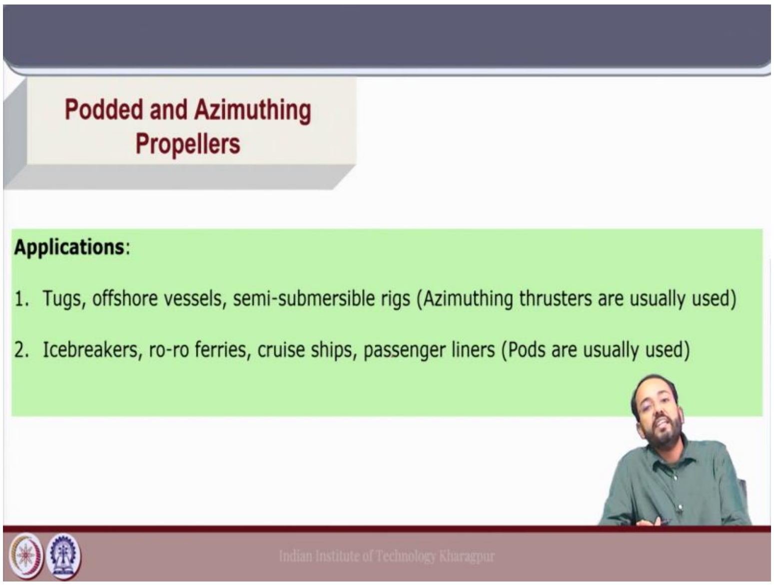


Now, regarding applications, the azimuthing thrusters are used for tugs offshore vessels semi submersible rigs where requirements of low speed manoeuvring is very high. These azipods provide an excellent option for propulsion in these cases. And podded propellers are usually used in cruise, ships, ferries passenger liners, icebreakers where typically diesel electric propulsion systems are used and podded propellers can be a very good alternative either as the main propulsion or as additional propulsion systems in addition to the screw propellers, which are already implemented in the ship design.

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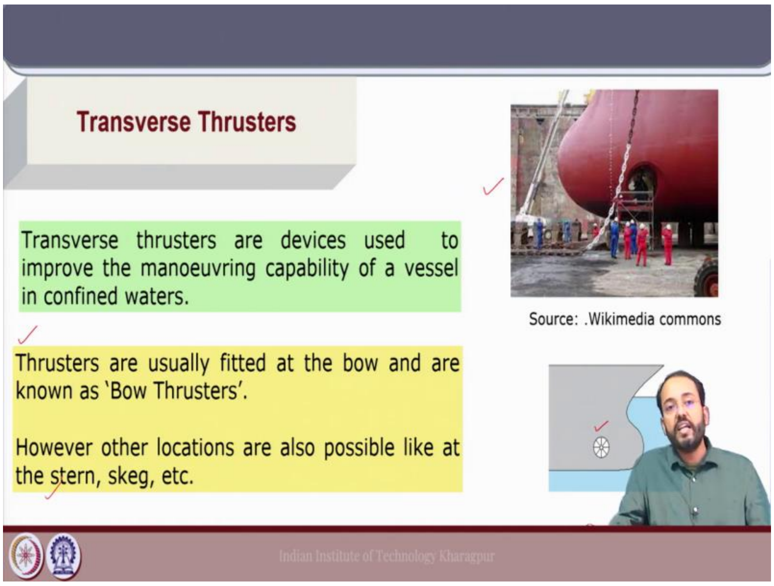


Next, we will discuss transverse thrusters which are used to provide transverse thrust and this is important for manoeuvring of the vessel in confined waters. Now, these transverse thrusters are typically fitted at the bow of the ship as shown in this particular picture and a tunnel is provided from the port to starboard in the bow region of the ship and a propeller is installed there.

And, they are providing thrust in the transverse direction as opposed to a conventional propeller which provides thrust in the direction of the ship motion in the longitudinal direction. So, these are called transverse thrusters and these thrusters are used for manoeuvring. When the vessel moves at low forward speeds typically in confined waters near the port then the flow velocity into the rudder is very low. And hence the rudder cannot generate enough lift force for the vessel to be manoeuvred properly.

In these particular cases transverse thrusters are very useful to provide thrust in the transverse direction and they can be effectively used for manoeuvring the vessel in confined waters. Now, in general these transverse thrusters are located at the bow region of the ship as far ahead possible so that the thrust provided can be easily used to generate a high amount of moment to turn the ship. However, other locations are also possible like at the stern or skeg, also multiple thruster configurations may be used both at the forward as well as the stern or multiple at the forward as shown here.

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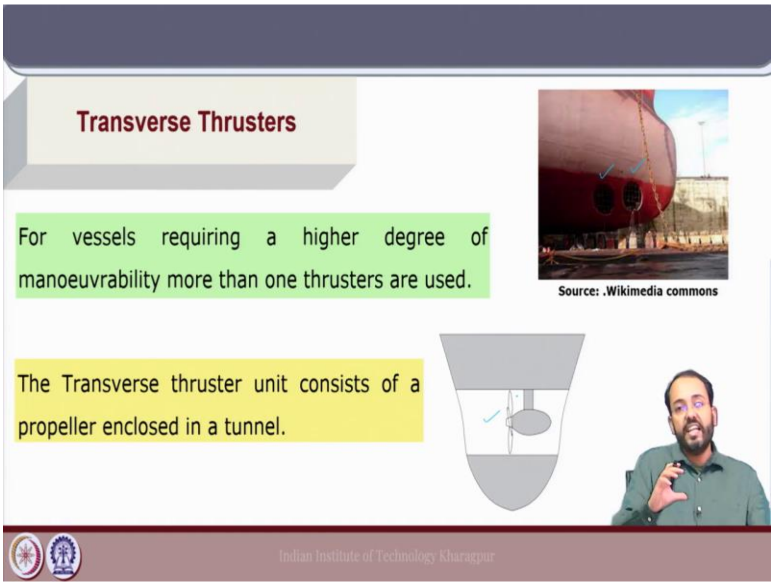


So, for vessels which require high degree of manoeuvrability as shown in this figure there are two bow thrusters which are used and two tunnels are created in the design of the ship near the bow such that in each of them a thruster can be housed. And these thrusters provide transverse thrust for the ship to be manoeuvred in cases where the forward speed is very low especially in confined waters. Now, a transverse thruster consists of a propeller which is housed in the tunnel and this propeller provides the thrust in the transverse direction.

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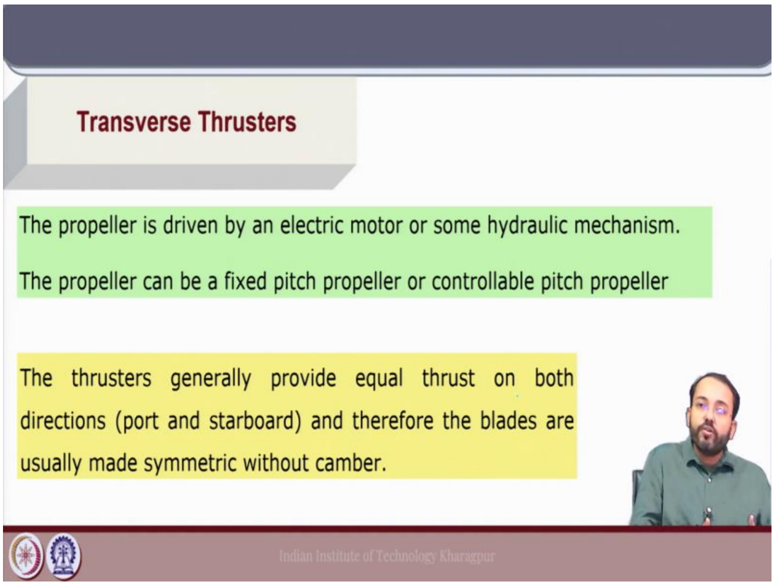


Now, the propeller is driven by an electric motor or by a hydraulic mechanism and both fixed pitch propeller or controllable pitch propellers can be used, but the main criteria of design is that we need equal thrust characteristics in the port and starboard. And hence the propeller blades are designed using symmetric sections without camber, so that the blade can provide similar thrust characteristics in both the port and starboard directions.

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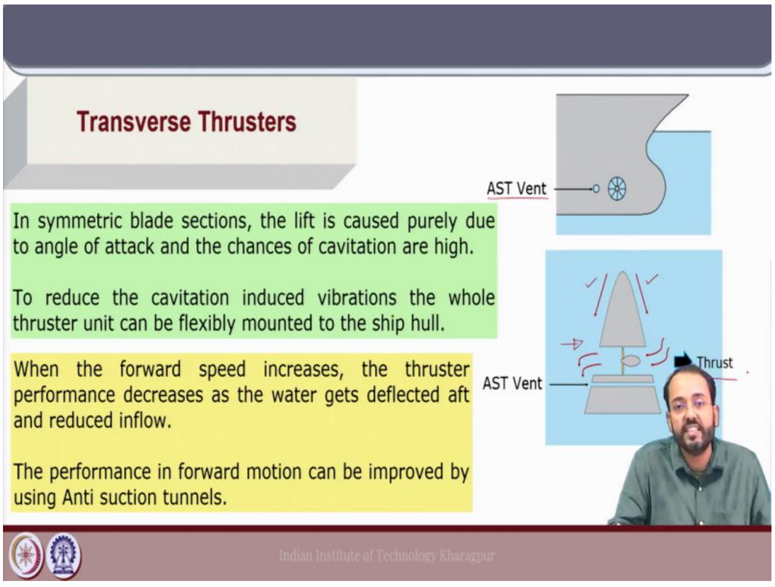


Now, for symmetric blade sections the lift that is generated is purely based on the angle of attack. We have seen that aerofoil generate lift based on both the angle of attack and camber, but for symmetric sections there is no camber and hence the lift is entirely from angle of attack. And, that causes suction peaks and cavitation problems which needs to be taken care of in the design because these cavitation induced vibration of the thruster unit can be transferred to the hull, and that is one of the reasons why flexible mounts are used in order to reduce these vibrations.

Now, as the forward speed of the vessel increases the thruster performance in terms of the thrust generation will decrease, because at high forward speeds the flow past the two sides of the hull will have higher velocities here and that will deflect the flow along the thruster in the transverse direction. So, the high forward speed of the vessel will deflect the water afterwards which is caused by the thruster action and that will lead to worsening of the thruster performance in the high forward speed conditions.

And, hence these AST vents which are called anti suction tunnels are provided just behind the thruster, and by providing that the thruster performance in larger forward speeds can be improved. And, in this particular diagram the thruster is generating a flow and it is providing a thrust in the starboard direction.

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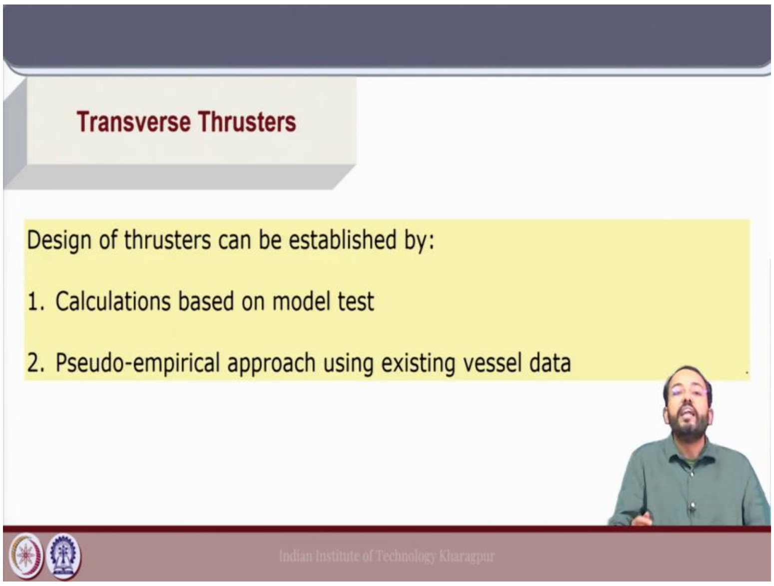


Now, the design of these transverse thrusters can be done based on calculations from the model test results and also some empirical approaches may be applied based on existing vessel data. So, a combination of empirical approaches based on the thruster configuration and data from existing vessel operations can be used to design the transverse thrusters. This will be all for today’s class.

Thank you.