Marine Propulsion
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Lecture - 36
Waterjet Propulsion

Welcome to lecture 36 of the course Marine Propulsion. The topic in this lecture is Waterjet Propulsion.

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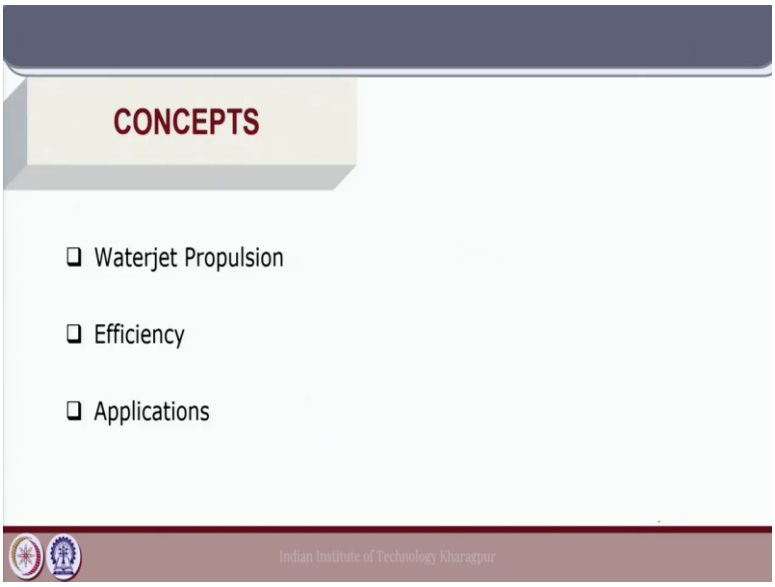

The key concepts covered in this lecture will be the different aspects of waterjet propulsion, the parts of a waterjet propulsion system and some concepts of efficiency, its advantages, disadvantages and applications.

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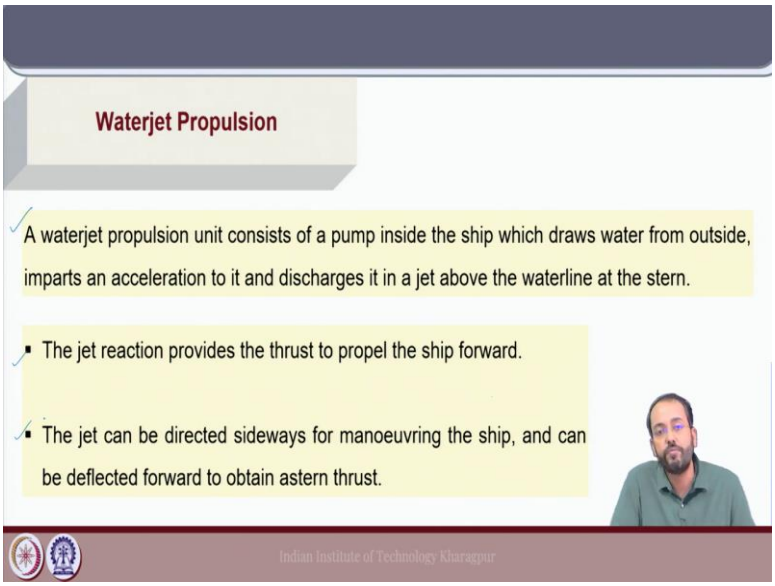

The waterjet propulsion system is one of the earliest forms of mechanical propulsion systems installed in ships. It has been used as early as in the 17th century to propel ships using different types of pumps installed at the stern of ships and they used to provide the thrust to propel the ship forward. Now the modern version of a waterjet propulsion unit consists of a pump which is housed within the ship.

And it draws water from the outside and the pump accelerates the water and discharges it in a jet form at the stern, just above the water line of the ship. So, this is the mechanism of operation of a waterjet system and in this waterjet system the jet reaction provides the thrust to propel the ship forward. We will look into the components of a waterjet system in the next slide. And a very important feature of the waterjet system is its capability to maneuver the ship by directing the jet in the sideward directions.

So, the nozzle at the exit can be directed either ways to maneuver the ship and also the jet which is coming out after acceleration can be deflected forwards to obtain astern thrust. So, this waterjet propulsion system provides excellent maneuverability to the vessel and that is one of the prime features for which waterjet propulsion system is employed on certain types of ships.

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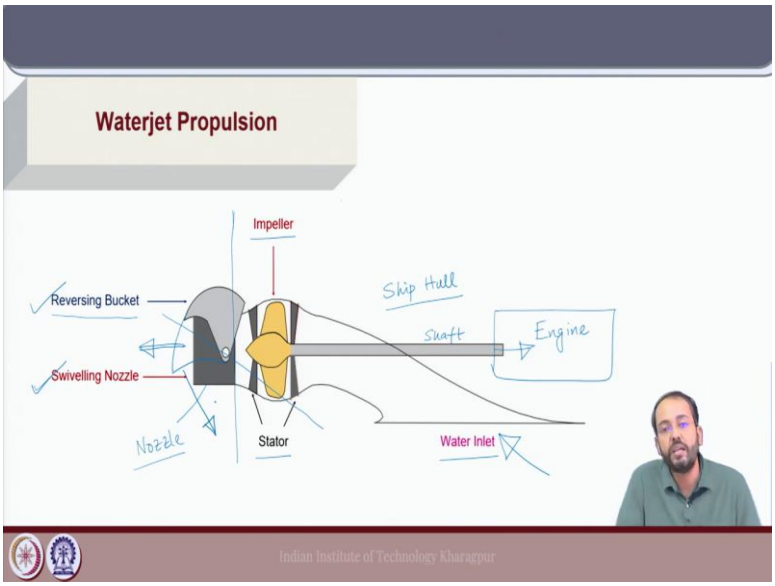

Now, let us look into the components of a waterjet propulsion system. We have the water inlet here through which the water is being drawn into the waterjet propulsion system and we have the nozzle here which is swiveling in nature. That means it can be rotated in either ways. This nozzle is throwing the water from the stern of the ship.

So, that the jet reaction creates a thrust that propels the ship forward. Now, what are the essential components of the entire waterjet system? We have an inlet and next important component here is the impeller which is housed within the waterjet propulsion system in the ship hull.

So, this entire propulsion system is housed within the ship hull and that is one of the critical characteristics of a waterjet propulsion system is that the entire propulsion system including the impeller which is the pump producing acceleration to the water is housed within the hull of the ship at the stern and hence it takes up a huge volume within the ship.

And this impeller is driven by this shaft connected to the engine here which provides the necessary RPM for the impeller to provide the axial thrust and on two sides of the impeller these stators are used. These stators are nothing but vanes which are static and they reduce the rotational losses in the flow. And finally, at the outlet where we have the nozzle the two critical characteristics of the waterjet system are shown here; the swiveling nature of the nozzle and a bucket which is reversing in nature.

Let us look into these things one by one. First this nozzle can be rotated on either ways about a vertical axis. That means, the nozzle through which the waterjet is coming out, the exit of the waterjet can be rotated on either ways about a vertical axis at the stern of the ship and by that feature the thrust can be directed in such a way that the ship can be maneuvered without the use of any added feature like rudders which are not used in waterjet propulsion system.

So, this swiveling nozzle can be used for maneuvering the ship towards the port or starboard directions. Now, the other characteristic feature of the waterjet propulsion system is the reversing bucket which can be operated above a horizontal axis. So, this reversing bucket can be operated about a horizontal axis either in the open condition or it can be closed in such a way that when the bucket is open in the normal ship operation condition the jet of water is coming out at the stern and the reaction force will push the vessel forward.

Now, during astern operation of the ship when the ship needs to move in the astern direction this reversing bucket can be used to reverse the thrust that is why it is known as the reversing bucket. So, about the horizontal axis this bucket can be turned in such a way that the jet is deflected in a direction which is forward and downwards such that the effective force applied on the vessel is in the reverse direction and the ship can move astern.

So, this is a very simplistic diagram of the waterjet propulsion system which is installed on vessels to provide thrust in both forward and astern directions and also maneuvering capabilities.

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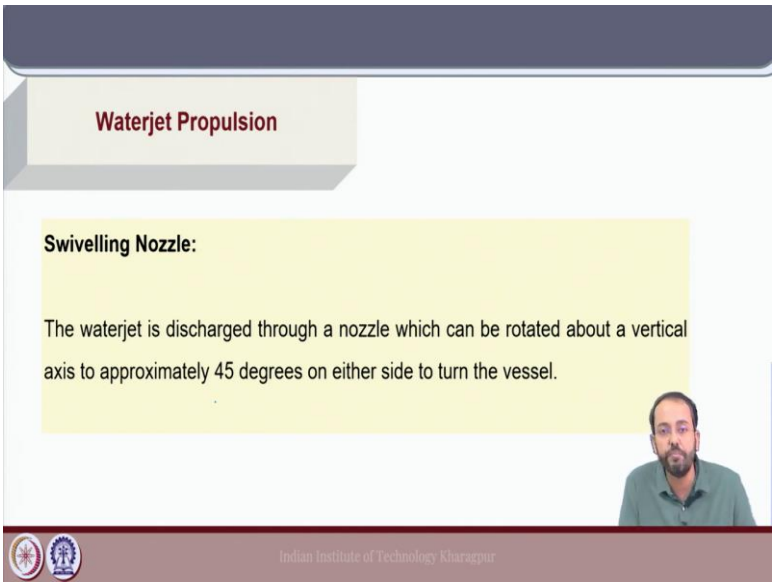

The swiveling nozzle which is present at the exit of a waterjet system can be rotated about a vertical axis to approximately 45 degrees on either sides to turn the vessel and that is how the jet is deflected on the port and starboard sides and the vessel can be maneuvered accordingly.

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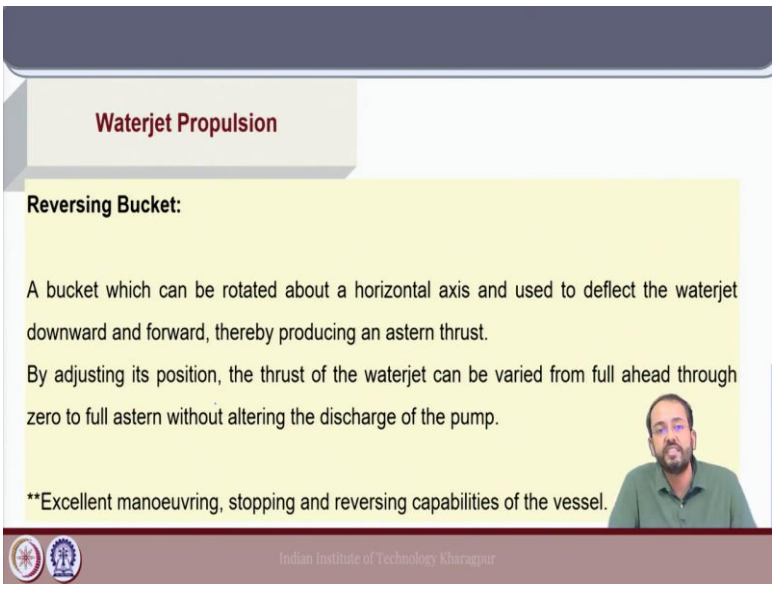

And the reversing bucket as just discussed can be rotated about a horizontal axis to deflect the waterjet so that astern thrust is produced. Now by adjusting the position of this reversing bucket, the waterjet can be varied from full ahead through zero to full

astern without altering the discharge of the pump. This is a very important feature of a waterjet propulsion system. For normal screw propellers the astern motion requires the engine to be reversed or for controllable pitch propellers the pitch can be reversed.

Now, here in a waterjet propulsion system just by operating the reversing bucket the thrust can be directed in such a way that the full ahead to zero to full astern conditions can be encountered without altering the discharge of the pump; that means, without changing the rpm of the impeller. Hence vessels having waterjet propulsion systems have excellent maneuvering stopping as well as reversing capabilities.

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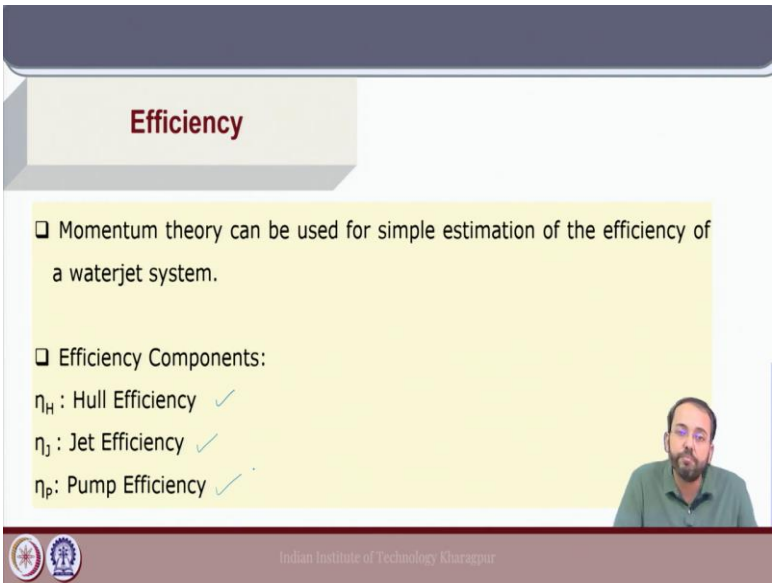

Regarding the efficiency under normal thrust loading conditions a waterjet propulsion system will have in general a lower efficiency as compared to a conventional propeller. So, these are used for vessels where the speed is generally quite high typically above 30 knots and it is fitted specially in ferries and naval vessels, where the requirement of thrust is high and maneuverability is very good.

Now, momentum theory can be used to estimate the efficiency of a waterjet system in a very simple way. So, by axial momentum theory we can get the efficiency of a waterjet system by using the momentum of the fluid or the water in this case which is coming in and the momentum that is imparted to the waterjet at the exit.

So, this can be used to have a basic estimation of the waterjet propulsion efficiency. Now what are the critical components of efficiency for a waterjet system? We have the hull efficiency which is very similar to the concept as for the conventional propulsion which depends on the shape of the stern and the interaction between the hull and the propulsion system. And we have the jet efficiency which is the efficiency of the waterjet.

It will include the momentum losses through the system as well as some factors which will be included in the calculation of jet efficiency regarding the inlet loss, the outlet efficiency and the rise of water head through the waterjet system. Next we have the pump efficiency.

Now, the pump is the impeller which is housed within the ship hull which forms the integral part of the waterjet system and the efficiency of the pump is very important in defining the efficiency of the entire waterjet system. So, these are the important efficiency components for a waterjet system.

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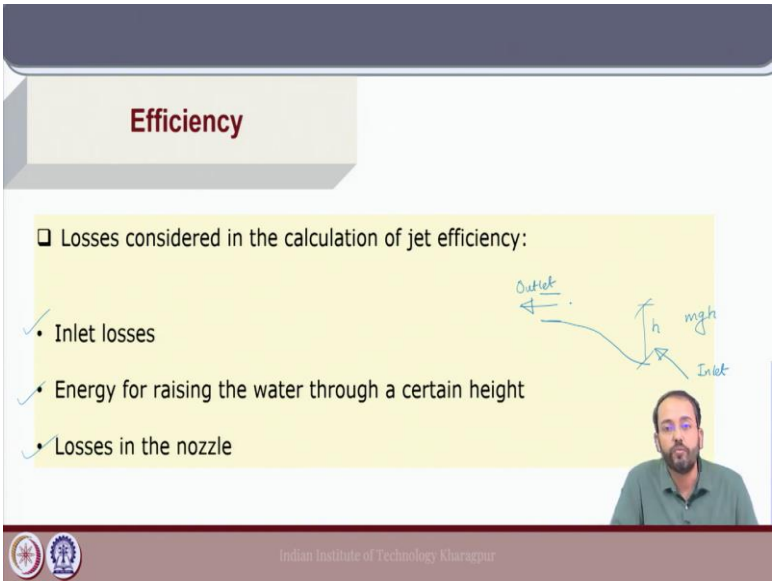

Now what are the losses that needs to be considered while calculation of the jet efficiency; that means, the efficiency of the waterjet between the outlet and the inlet. The inlet losses will depend on the shape of the inlet through which the water is being taken in the ship hull through the waterjet propulsion system. So, the location of the inlet at the particular region of the ship hull below it is very important in defining the losses that will incur in a waterjet system which are the inlet losses.

And the boundary layer on the ship hull at the location of the inlet will play an important role in the inlet losses which will impact the waterjet efficiency. The energy required for raising the water through a certain height should be included in the losses of a waterjet system. So, for a waterjet system the inlet is located in a region which is at a lower height as compared to the outlet. So, inlet is at the bottom region of the ship here and from the stern we have the outlet.

So, between the inlet and the outlet the height of water is being raised by an amount h and energy is required to raise the water through this particular height which is mgh and this should be included in the losses while calculating the efficiency and finally, the losses in the nozzle. The nozzle is located here in the waterjet system at the exit and the nozzle losses play an important role in the efficiency of the waterjet system.

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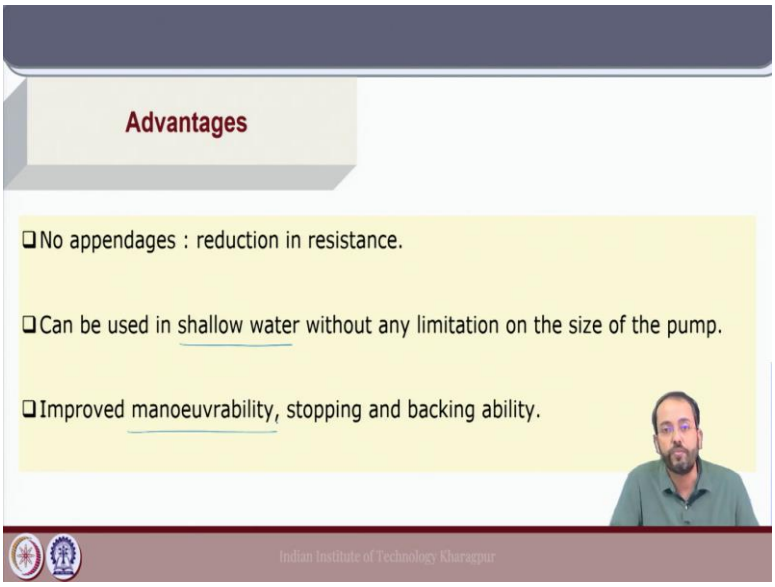

Now, if we look at the advantages the first advantage mentioned here is we do not require any appendage because the entire waterjet system is housed within the stern of the ship. So, there are no appendages like brackets or other structures which are otherwise required for conventional propellers.

So, if there are no appendages that reduces the resistance as appendage resistance plays an important role in the total resistance of the ship. Next waterjets can be used in shallow water without any limitation to the size of the pump. In shallow water conditions conventional propellers suffer from submergence problems and the thrust and torque

characteristics are not proper, but in waterjet propulsion system shallow water operation is not a problem.

So, waterjets can be used for ships which are typically operating in inland and coastal waters especially at high speeds, where shallow water can be encountered. Improved maneuverability this point we have already covered stopping and backing ability because the waterjet consists of the swiveling nozzle as well as the reversing bucket by which both port and starboard maneuvering as well as astern motion can be performed.

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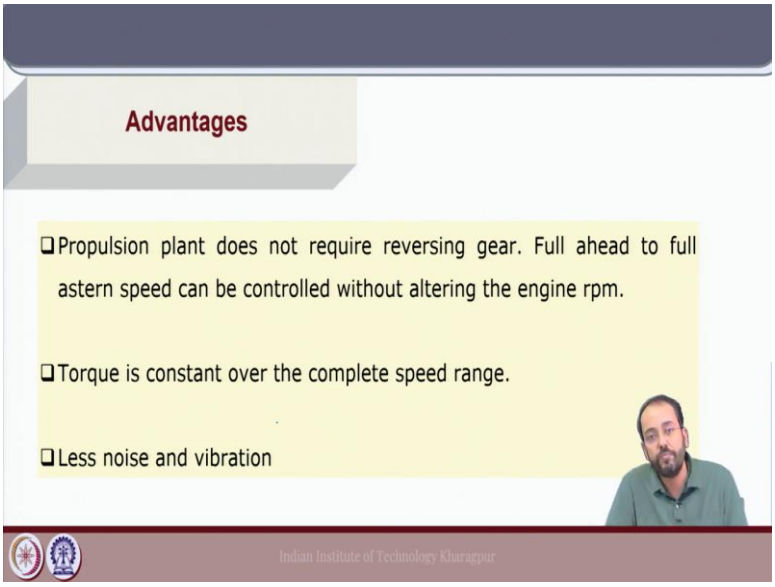

In waterjet systems there is no reversal gear required due to that the full ahead to full astern speed can be controlled without operating the engine rpm. Torque is constant over the entire speed range because we are not changing the engine rpm and this leads to optimal performance in terms of the specific fuel consumption and less noise and vibration because the impeller is working within the hull enclosed in the waterjet system. So, the noise and vibration levels are lower.

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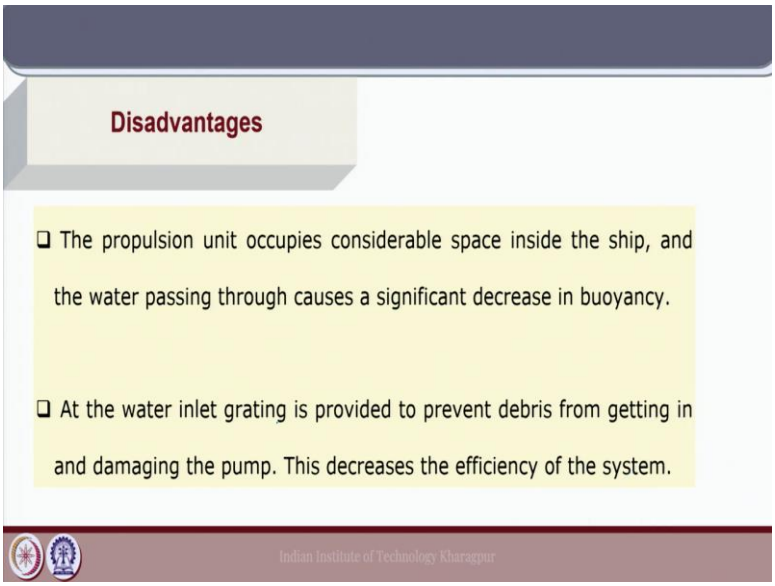

If we look at the main disadvantages of a waterjet system, the propulsion unit between the inlet and the outlet the entire waterjet propulsion unit is present within the stern region of the ship. And hence that occupies a large space in the ship which is not possible for cargo vessels where space is a very important characteristics in terms of the vessel operation that is why waterjet propelled vessels are typically ferries and naval vessels where the advantages are very important in the operation of those ships.

On the other hand the water passing through the waterjet system will also significantly decrease the buoyancy of the ship because this entire waterjet system is housed within the stern of the ship. And another disadvantage is that because the waterjet system takes in a huge volume of water and throws it from the stern of the ship it should also be critical that if there are debris in the water that might get into the waterjet system and damage the impeller.

So, we have to use grating which is put at the inlet of the waterjet system. So, that these debris or other floating objects do not enter the waterjet system. Now because of providing this grating the efficiency of the waterjet system is slightly affected, but this is an essential component in the waterjet system to prevent the impeller from being damaged due to these debris or other particles going inside the waterjet system.

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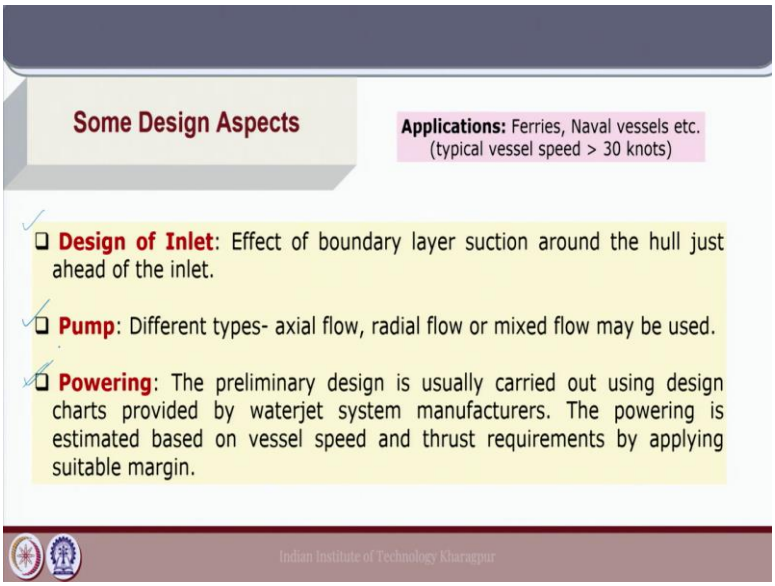

In terms of application, waterjet propulsion systems are used in ferries and naval vessels typically fast attack crafts, where the vessel speed is higher than 30 knots and waterjets give very good performance in terms of maneuverability and other operation conditions for these ships. Now, we will briefly look into some design aspects which are critical for waterjets.

First the design of the inlet because the water will enter the waterjet system through the inlet, the location as well as the design in terms of the area and positioning in the ship is very important and the effect of boundary layer suction around the hull at that point will play a role in the performance and efficiency of a waterjet system.

Next the choice of the pump is very important in the waterjet propulsion system, different types of pump like axial flow radial flow or mixed flow type can be used based on the requirements for the propulsion system as well as the vessel on which it is fitted. Finally, the powering performance is important for which a preliminary design is done using design charts which are provided by waterjet system manufacturers.

Now, these charts are used to have a preliminary basic design and the powering is estimated based on the vessel speed and thrust requirements also depending on the operation characteristics of the ship suitable margin is to be provided to calculate the engine power for a waterjet propulsion system. This will be all for the discussions on waterjet propulsion.

Thank you.