Marine Propulsion
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Lecture - 01
Introduction

Welcome to the 1st lecture on the NPEL course on Marine Propulsion. I am Anirban Bhattacharyya, Assistant Professor at the Department of Ocean Engineering and Naval Architecture at IIT Kharagpur. So, this lecture is the first of the series of lectures on marine propulsion and here we will give a brief introduction to marine propulsion in general.

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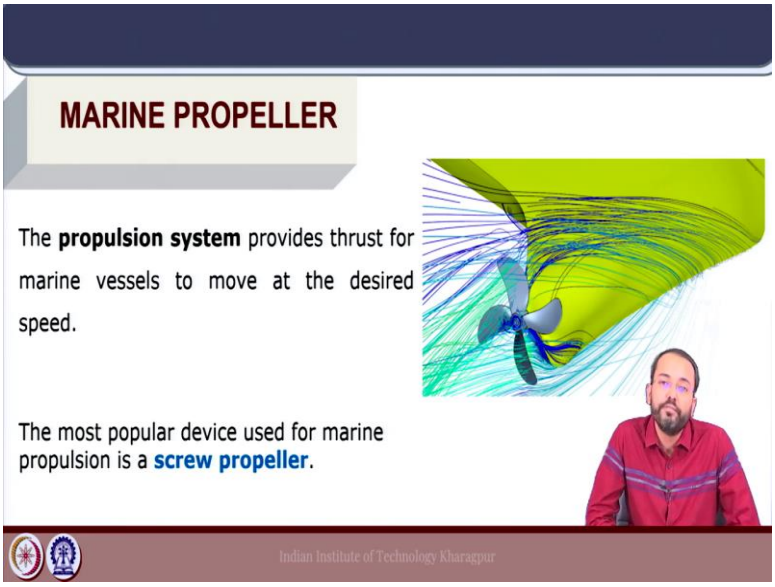

Any ship or marine vessel when it operates in the ocean, it is subjected to forces and due to wind and waves, it has a resistance which it needs to overcome when it operates in the ocean. So, this resistance needs to be overcome by a thrust force and it is the propulsion system of a ship or a marine vessel which provides the thrust for the vessel to move forward and the most popular device for marine propulsion is the screw propeller. Most of the ships all over the world this is the main device used for marine propulsion.

And different varieties of propellers depending on the exact application have been designed and also there are other propulsion devices which are used. So, in this particular course we will focus our attention towards screw propeller and the hydrodynamics of

propellers and then move on to other aspects of propulsion and also cover other propulsion devices. So, historically if we look at ships the earliest forms of ships were typically made of woods and the propel propulsion mechanism was human-powered.

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So, in that sense the earliest ships were propelled by oars where the oar using the oar momentum was given to the water around the ship and that provided the thrust force for the vessel to move forward. Now the other form of propulsion which also came into practice was the use of sails in sails the wind energy was used and that was converted into a thrust force which moved the marine vessel forward.

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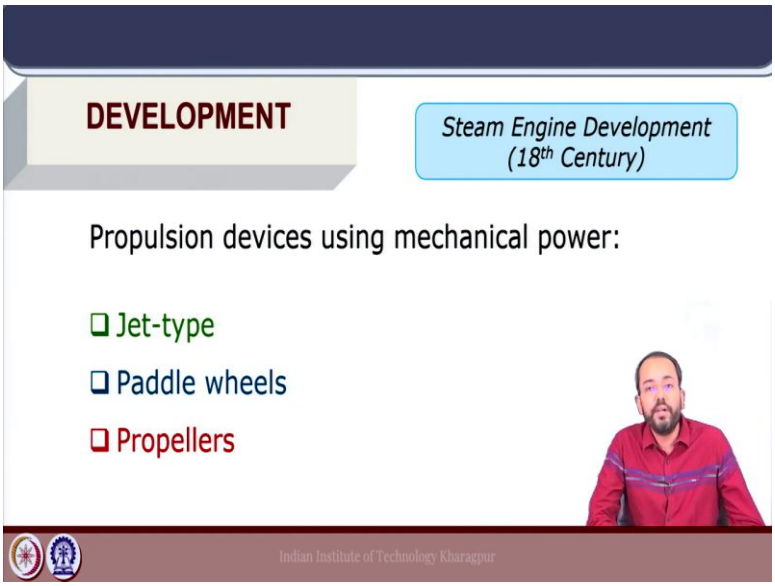

Now, with the industrial revolution, there were different propulsion machineries which were developed one of the starting points of that was the development of the steam engine in the 18th century then different propulsion mechanisms were developed and they used to be applied on the different types of ships that gradually began to operate. So, the propulsion devices during that time were basically using the mechanical power from the engine.

So, the types were typically jet-type this is basically based on the pump which was fitted a pump-type propulsor which is fitted towards the end or the aft end of the ship and it provided a thrust force for the ship to be propelled forward. Then there were paddle wheels large wheels fitted with paddles on both sides of the vessel and a mechanical power was used to rotate the wheels and these paddles because of the rotation provided a forward thrust for the vessel to move forward.

And then came propellers and it took many decades of designing and continuous applications of two different types of bearing vessels to gradually design the marine propeller to get the present design that we have as of today.

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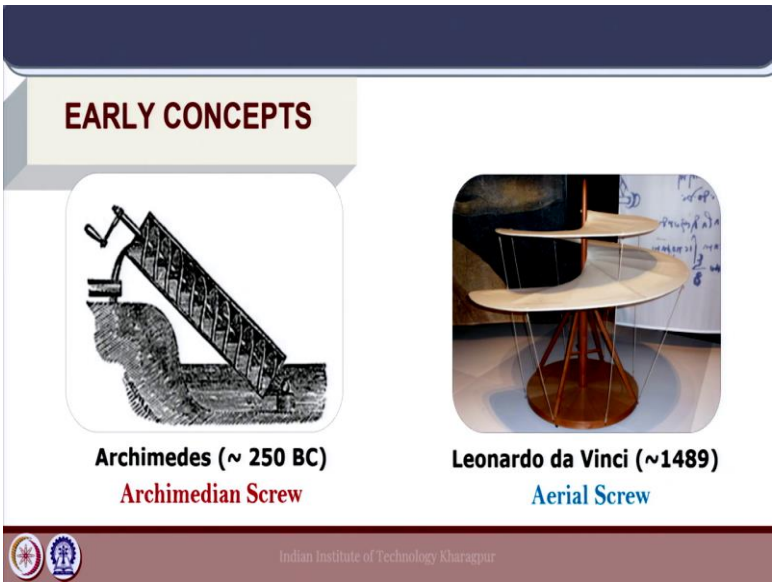

So, if we talk about marine propellers specifically screw propellers, the earliest concept of a screw propeller can be visualized from the Archimedian screw. So, this was devised by Archimedes as early as 250 BC.

So, the idea of an Archimedian screw was by use of a screw action water could be lifted from a location at a lower height to an upper elevation by rotating the screw and this has been used for irrigation over many centuries ok. And another concept which also was a precursor of the present marine screw propeller that we can say was the aerial screw which was devised by Leonardo da Vinci in his drawings ok.

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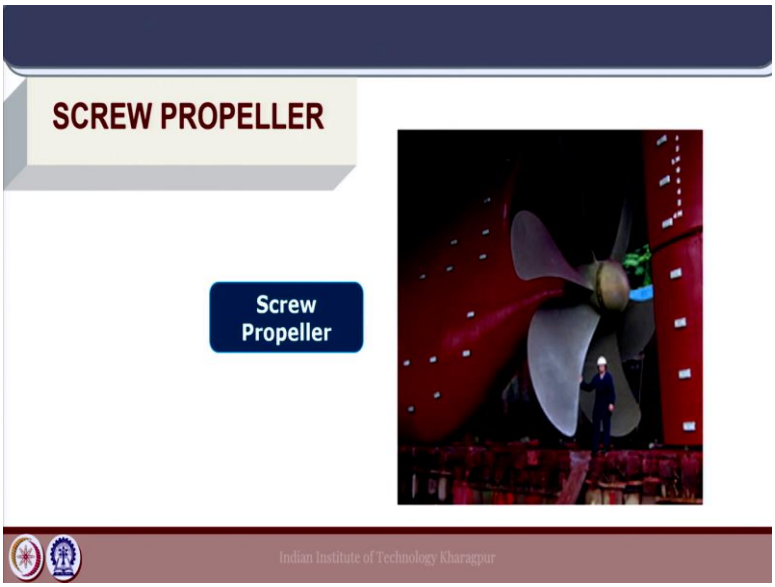

And from these screw concepts to the modern screw propeller that we have today it took more than a century of innovations and involved many engineers and scientists and notable researchers like Robert Hook and Bernoulli who were all involved in different ways to the development of this marine screw propeller. This picture shows the present version a standard version of the marine screw propeller which is fitted behind the ship.

The propeller as you can see consists of a central part which is the hub here and a number of blades are fitted over the central part ok and these propeller as it the blades as they rotate they provide thrust for the ship to move ahead and the propeller is connected by a shaft to the marine engine which provides the delivered power to the propeller so, that it can rotate at the desired rpm ok.

Now again in this particular course, we will mainly go through the hydrodynamic aspects of the screw propeller and then try to go forward and look into other propulsion concepts which is prevalent in the marine domain in general.

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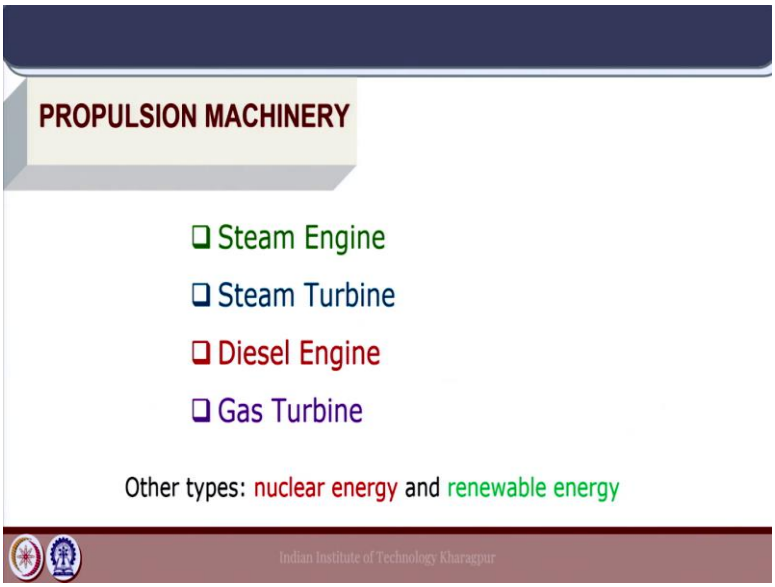

Now, if we look on the other part the development of propulsion also worked along in lines with the development of the marine machinery because from the engine part, the engine which is supplying the delivered power to the propeller the development of the engine over the history of ship propulsion or the our naval architecture, in general, is also very important towards the development of ship propulsion in general.

So, the earliest form of propulsion machinery which was used was the steam engine followed by steam turbine and then diesel engine came into practice and now diesel engines are the most widely used forms of propulsion machinery in modern ships, and gas turbines are also used for specific ships typically for high-speed applications. Now if we consider other types nuclear energy is also used, but it is restricted to submarines which typically cater to the global navies of different nations.

And renewable energy is also being explored as an alternative. So, we can talk about solar energy wind energy and energy harvested from the waves are also being used and many devices concepts are being used so, that they can cater to a part of the powering demand for a ship. In some cases, solar-powered ferries boats are in practice, and also some other as we see the other forms of energy like wind and waves can are also being

used these concepts to provide some powering demand for the marine vessels in addition to the main sources of power.

And also one must take this into account that a combination of different machineries are also being used in addition to electric drives for propelling modern ships.

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So, next if we look take our attention to a completely different thing from marine vessels if we look into nature in general what is the mode of propulsion which is prevalent in nature. So, if we ask this question to ourselves how does a fish propel itself ok. So, this is the picture of a fish ok moving through the water and we can see that a body of a fish consists of small fins on different parts of the body ok. So, a fish propels itself by flapping a part of its body.

So, a part of its body is flexible depending again on the type of the fish, and the tail fin that is behind this fish it provides the propelling force for the fish to move forward. As the fish flaps its tail along with a part of a of its body the tail fin provides the thrust that allows the fish to move forward and also a combination of other fins provides force to the fish in different directions required for both horizontal as well as vertical movement and stability.

So, if we look towards the fish movement, it is a very complex locomotion depending on the motion synchronized motion of a set of fins along with a part of the body.So, over the

last few decades attempts have been made to develop many underwater vehicle concepts mainly autonomous underwater vehicles which are mimicked from the concept of fish locomotion.

So, these vehicles or as we call AUVs they have flapping fin devices which can be used to generate thrust and for the devices to move forward without the use of any propellers or other propulsion methods that we are used that are being used for ships ok.

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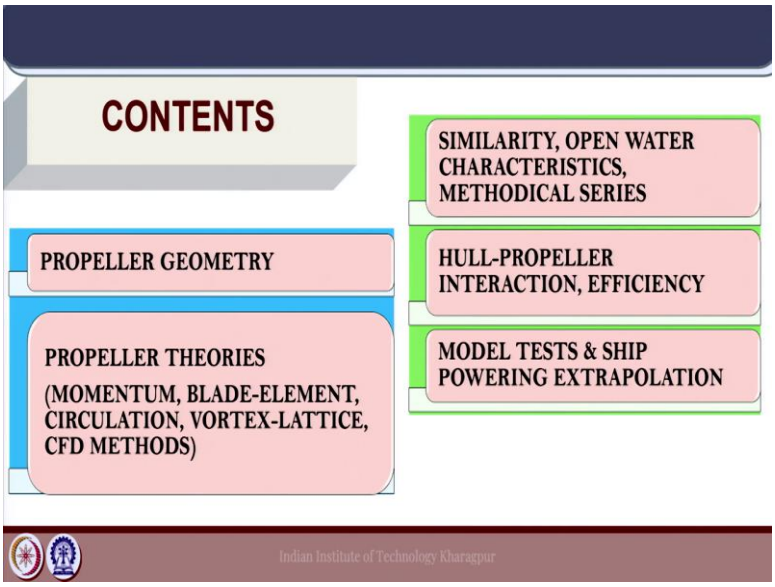

So, next if we now go to the contents of this course here we will look into the contents of the course the different parts of the screw propeller its geometry hydrodynamics as we move forward towards the different aspects of the course. So, we will start with propeller geometry, now the geometry of a screw propeller is very important to understand its characteristics. So, there are different aspects of geometry which define its performance.

A propeller is highly three-dimensional in nature. So, the different geometrical aspects, for example, the number of blades of a propeller the pitch of the propeller blade, and also other blade sections play a very important role in the performance of a marine propeller. So, this will be the starting point of our propulsion course next we will move to propeller theories. Now propeller theories basically mean the different theories which explain the action of a marine propeller.

So, basically how the geometry of the propeller relates to the characteristics of a propeller this will be understood through the use of propeller theories. So, we start with a very simple axial momentum theory which assumes the propeller to be like a simple momentum disc and then we develop it towards slightly more complex theories which take into account more aspects of the propeller geometry and define its characteristics.

So, for example, the blade element theory considers different elements across different radial sections of the propeller blade and how they are related to the development of the thrust and torque forces on the propeller blade ok. So, next circulation. So, we see that the circulation of each of these blade sections is related to the force developed at these propeller sections.

Typically, if we talk about airfoil sections which is the general section used for propeller blades. There are also other types of sections, but airfoil sections are the most standard sections used for propellers in general. So, the circulation around the foil is related to the lift force which it generates and a component of which is visualized as the thrust that is the final output that we require from the propeller. So, we will also cover glimpses of other theories, for example, vortex lattice theories and other methods.

And also CFD methods computational fluid dynamics approach which is used to calculate the hydrodynamic performance of marine propellers once the ah design of the propeller is known. Now if we see naval architecture in general we will have ships and propellers which are built in the full scale and its performance have to be tested using model experiments. So, it is not possible to directly get the performance of a ship or a propeller in the full scale from practical point of view ok.

So, a ship or a propeller will only be built once. So, we can always run numerical simulations, but also we need to understand its properties using some testing methods. So, for naval architecture, there are standard methods where we scale down the ship and propeller to a smaller scale depending on the available testing facility as well as the size of the ship or in this case the propeller involved.

So, when we do that how do we maintain the similarity of forces ok. How do we maintain, the required velocity and rotational rates between the model and full scale? So, this these aspects will be touched under similarity and next in open water characteristics

we will look into the aspects of open water performance of marine propellers; that means, we do not have the ship, in this case, we have only the propeller ok.

So, if we have only the propeller then we have a pure uniform inflow into the propeller and the propeller is run at different conditions which is defined by advanced coefficient and we try to understand the characteristics of the propeller without the ship also in this connection it will be ah important for you to know that a propeller performs differently when it is behind the ship and that again will be covered in this course and also depending on the ship design the performance on the of the propeller will also change.

So, in open water characteristics what we do is we study the performance of the propeller only without the presence of any ship hull ok. So, based on these open water performances different methodical series propellers are developed. So, these methodical series propellers have a set of predefined geometrical characteristics and it can be used to design a propeller according to the given requirement ok. So, the next part after the open water performance will be to study hull propeller interaction.

This is again extremely important and will form the basics of ship powering. So, how the ship hull and propeller interact and results in a set of efficiency terms which explain the ship powering calculations. For example, what is the input power to the system the input power to the ship propulsion system is the delivered power to the propeller again which comes from the brake power of the installed engine ok.

So, from the engine power, it is delivered to the propeller and then the output is the effective power from the system which is calculated from the resistance of the ship and the speed of the ship. Now how are these input and output powers related with respect to the ship propeller interaction? This will be discussed in this particular section as well as the efficiency components involved in the calculation of ship propulsion ok.

So, the next set of topics will include model tests and ship powering extrapolation. now as discussed model tests form an extremely important part of naval architecture because we need to understand the performance of a ship and propeller as well as a combination of ship and propeller before we finally, build the vessel. So, to understand that we make models based on similarities and we test those models in facilities typically which we call as towing tank.

So, under resistance as we see that we have ship resistance experiments similarly under marine propulsion we have two specific experiments that will be covered in this particular course. One will be the open water test where only the ship propeller is tested without any ship model in front of it. So, we have the only propeller which will be towed in open water condition and the next one is a self-propulsion test where we have the ship model as well as the propeller behind it rotating at the required rpm as per our requirement for that specific vessel.

So, these two tests will be discussed under model tests, and some videos from actual tests being done in the towing tank facility at our department in IIT Kharagpur will be shown and based on these tests an idea of ship powering extrapolation will be provided and we will do a practical ship powering extrapolation problem which will give a clear concept of how model tests are used to calculate the ship powering ok.

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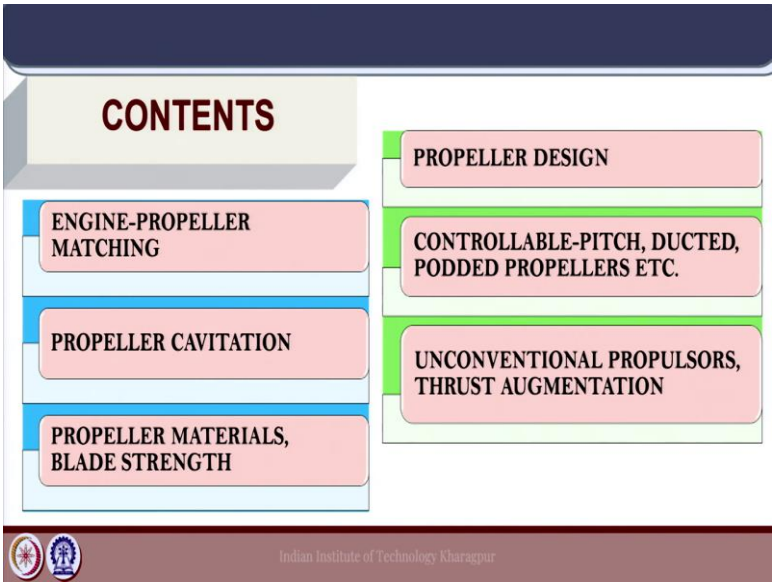

Next engine propeller matching which is quite important from the point of view of ship powering because the choice of the engine is related to the propeller performance and the rpm that we need for a specific case. So, because the engine and propeller will be connected by a shaft and they work together as a propulsion machinery of the ship. So, matching of the engine and propeller is extremely important from the context of ship powering.

And we will see that there are certain margins that needs to be provided in this regard for efficient powering performance for a ship in the given operation conditions. Propeller cavitation is important because cavitation is what when we have a fluid in this case water which is being converted into vapor without any change of temperature; that means, because of a reduction in pressure which happens why because in marine propulsion high velocities are involved on different parts of the propeller blade.

Because of the rpm or the rotational speed of the marine propeller it can happen that some part of the propeller blade can cavitate; that means, the pressure around that part can fall below vapor pressure and cavitation may occur in those points on the propeller blade. Now depending on the type of cavitation and on the domain of occurrence it can be very critical at certain points. So, in those cases we have to take care right from the propeller designing process so, that cavitation occurrence can be minimized and neglected if possible.

So, propeller cavitation is very important from the point of view and also if the propeller cavitates, it leads to vibrations it leads to structural damage of the propeller and that creates noise in the stern of the ship and reduces the passenger comfort especially in the sterned part of the ship where there is a lot of vibration and noise. So, we have to look into propeller cavitation aspect both from the point of view of design as well as its occurrence in general.

Next any structure whether it is a ship or a propeller requires to have a particular strength depending on the forces that are acting on it. So, for the marine propeller we have the propeller forces like thrust and torque which are acting at different sections of the propeller blade depending again on the operation condition and on top of that because if its rotation there is a centrifugal force acting on the propeller blade.

Now, because of these things, the propeller blade will be subjected to a mixture of different forces depending again on the flow condition on the velocity or the speed of the ship and also the propeller rpm. Now these have to be taken care of in designing the propeller blade. So, the blade strength have to be considered in designing the propeller and the material of the propeller is also important from this point of view.

So, propeller blade strength will be basically a structures part of this particular course where we look into the aspect of the forces on the propeller blade and the materials

which are used for propellers and how they are used in simple design calculations. Next we will look into propeller design basically cover the different aspects of propeller design mainly in this particular course the focus will be on design using methodical series data and also a bit on the basic tenets of circulation theory design along with the properties of the propeller which impact propeller design in general.

And some other variants of the screw propeller like controllable pitch propeller ducted and podded propellers etcetera will be covered as necessary in this course and these will give a general application point to the aspect of the course. So, in general the these other propellers also are used for specific kinds of vessels depending on the performance aspect. And finally, unconventional propulsors like water jets will be covered and thrust augmentation devices.

This means basically these devices are energy saving devices which are placed in and around the marine propeller whether in front or at the aft of the marine propeller around the propulsion part of the ship; that means, towards the aft end of the ship and they improve the propulsion efficiency using different ways of energy savings they will be covered towards the end of this course.

And also they are becoming quite important considering the requirements of reduced fuel consumption and better energy efficiency from the point of view of marine propulsion.

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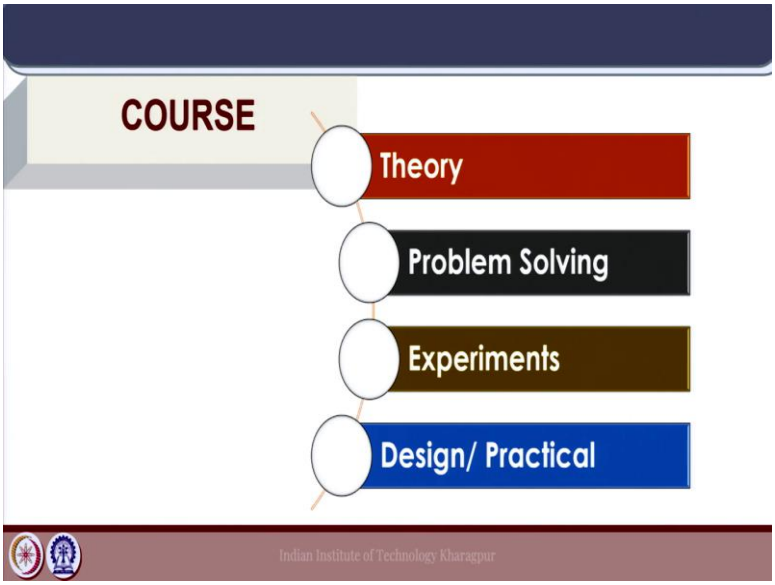

So, if we look in general to the different aspects of the course we will see that there will be a theory component which will cover propeller hydrodynamics in general and also other topics like structures cavitation ah engine propeller matching and all. So, this will form the background framework based on which we will do extensive problem solving on different aspects of the course mostly on all the lectures that topics that we have discussed in the contents.

Next there will be experiments. So, as it is mentioned ah propeller open water test and self-propulsion tests and how these experimental results are used to get the full scale ship powering that will be discussed in detail.

And finally, we will look into aspects of popular design and also on the practical application of different propulsion types for example, from basic screw propellers to other propellers like ducted podded propel propellers and also unconventional propulsion devices how the practical scenario looks like and how these propulsion devices are applied to different kinds of ships and with some examples these aspects will be discussed in this particular course.

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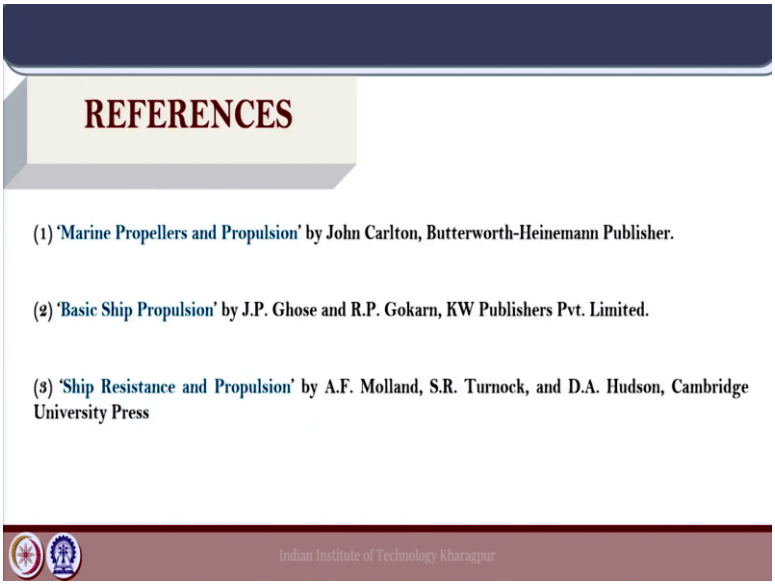

So, in general if we look at the references these books can be used as reference material to read through different parts of the course on marine propulsion.

Thank you.