Ship Resistance and Propulsion

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Lecture - 1
Syllabus and Introduction

Very good morning to all of you, see the course on ship resistance and propulsion is being now offered now. And the ship resistance and propulsion, that is resistance component and propulsion component should go hand in hand. Often it is very difficult to bifurcate these two topics for a ship, because when you says the propulsion characteristics of a ship is largely depending on the resistance offered by the ship at the decide speed or the decide point of operation, when you say it is a you know this resistance and propulsion part cannot be better not separate totally from one from the other, because the resistance of the ship, naturally increase when the propeller is put to operation, which you will be studying more when you discuss about the ship propeller interaction.

And also the resistance of the ship increases or it depends on the form of the vessel and the flow to the propeller also depends on the form of the vessel that is if you consider the fineness of the vessel, and position of the propeller and all that. So, generally these two topics the propulsion and resistance go hand in hand. So, here I will be covering the resistance part of it, and the propulsion part will be covered by professor Anantha Subramaniam, so the topics which are being covered under this topic that I mean that this course coming under ship resistance.

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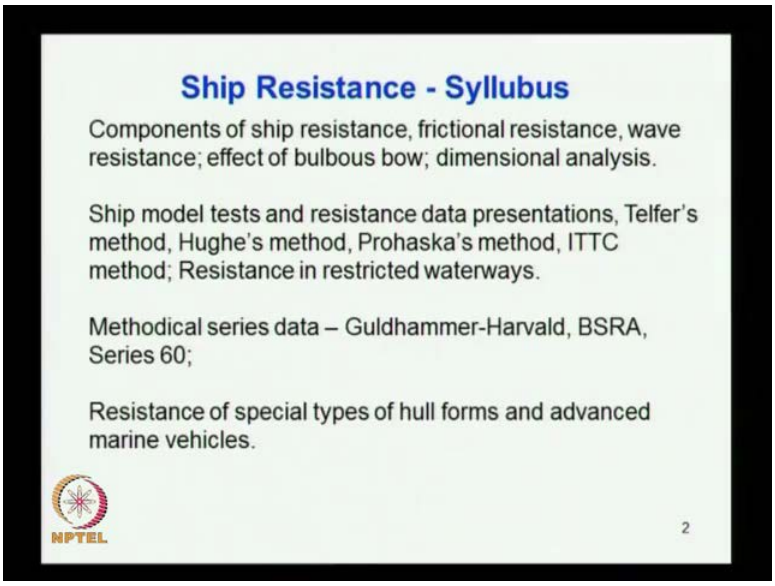

We will be dealing with the components of resistance where we will be dealing with frictional resistance, wave resistance effect of bulbous bow dimensional analysis. That is primary dealing with the model test of shapes to ((Refer Time: 02:38)) resistance characteristics of the vessel. When ship model tests and resistance data presentations that is how the model test are carried out, how the data obtained from the model test are consolidated and presented of our future design aspects.

And how do you extrapolate from the model to the ship and what are the you know discrepancies associated when with this extrapolation from model to ship. Different methods under this being covered like Telfer's method, Hughe's method, Prohaka's method, I T T C method, and naturally you have variation in resistance when the ship moves from deep water to shallow water and that to if the restriction are more in the breadth wise direction that is the case, where ship moves into a canal or a maybe into a river where you have additional restrictions coming from the breadth wise direction of the water way.

So, this increases the resistance and naturally when you discuss or when you try to find out the resistance of the vessel operating in inland water ways, there we have the three major inland water which we know inland water number 1, 2, and 3, so where a ship once a Hubli river then Brahmaputra river and other in the Kerala. So, these are three national water ways and there are lot of vessels operating in these region and whenever you design a ship or vessel which operates in this region of the water way naturally you have to consider the additional resistance or increase in the resistance due to the restriction of the water way. So that is also being looked into as part of the course.

Then this methodical series there are different resistance data, which has being evolved by performing model tests conducted systematically by different agencies and put into a ready to use format, which will be useful for a person or a designer at the at the early stages of the design. And naturally this should be a ascertain picture at a latest stage when the design is finalize, with a model tests.

Then we look into all these things, we have disused generally confining only to the conventional form namely to the displacement type of vessels, like you know general cargo ship tanclers, bulcadeous container ship all this come under this class. So, whenever you deviate from the displacement type or conventional type then then naturally you have higher or more hybrid form of shapes and also more advanced type of marine vehicles, such as planning crafts, hydrofoil crafts, then multiple vessels then all that. Then naturally that aspects that type of ships need to be delt separately you may have to perform the calculation from the basics to a ascertain the power of the vessels. These are things which are being listed under this topic.

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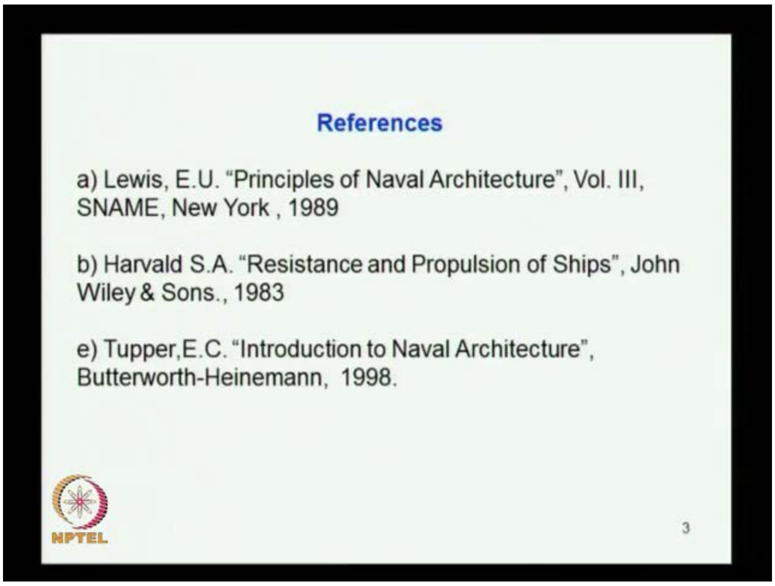

The reference put forward here are the principle of naval architecture edited by Lewis volume number three, which deals with the resistance and propulsion then resistance and propulsion ships written by Harvald then introduction to naval architecture by Tupper. So, these are the you have many other you know books, which cover the topics under a ship resistance. So, when you look to the what are the reason for what do you mean by resistance, that is the ship you know here which we deal with generally surfer ship. That is ship operating as a free surfer that is a interface between a atmosphere and water.

So, the ship which is moving at the free surface is expose to the media one is air and another is water. So, when the ship moves forward there will be a resistance opposing force, the force opposing the motion of the vessel due to radius physical reasons. So, this opposing force is named as the resistance of the ship. And as I said before there are different physical reasons for the creation of the force opposing the motion of the ship. And normally it is studied during the steady speed of the ship that is if the design the ship part for 15 knots. So, you assume that ship is not in the acceleration phase it is in the steady phase. So, the resistance is generally is dealing with steady phase steady speed conditions and the acceleration effects are generally ignored in this case.

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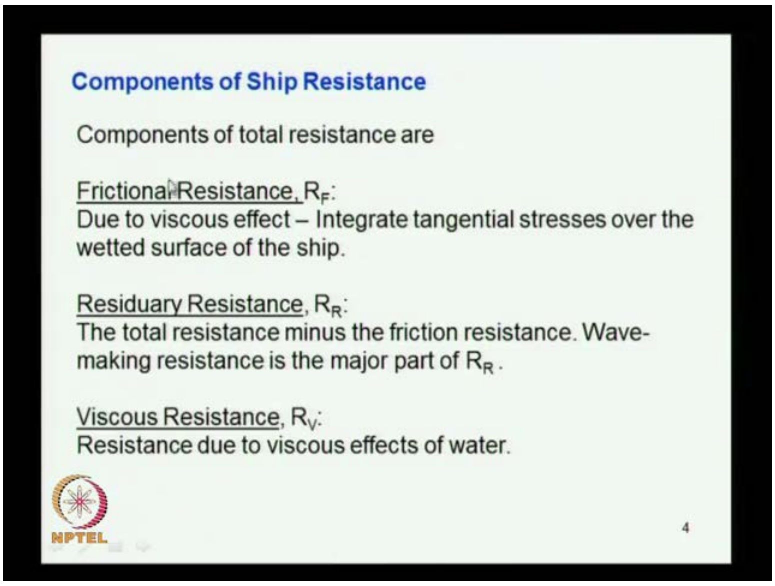

So, the first component is the you see the frictional component, you can see that frictional component friction you know it is a consequence of viscosity when the fluid friction is the basically it is the discussed property of the fluid. And due to the viscosity there will be a sharing effect between the layers of the fluid, there is a sharing effect between the body surface and the fluid, and there is a relative motion between the body surface and the fluid, when the ship is moving with the speed you say that 15 knots that means you consider the there is flow opposing it, or moving in the opposite direction with the same speed this is the relative concept which you can assume.

So, naturally there is a flow as if you can there is a ship which is stationary, and the flow is coming across it with the same speed is it not? So, instead of considering a ship to a still water you can also, there is a flow velocity of the same speed as the there as the ship. So, when it comes to the boundary of the ship naturally, there is a shearing effect. This shearing effect relates to the tangential stresses and if you integrate the tangential stresses over the wetted surface of the body, you get the total resistance force offered due to the friction. So, that is the basic reason behind it.

And here you know whenever you talk about the resistance it is associated with this loss of energy occurring to the ship mainly. So, the loss of energy here you know whenever there is a friction, there will be the energy associated with the friction is heat energy. So, due to the, is it not? Whenever there is a friction there will be a heat energy even in the fluid also you have the same thing. So, when there is a heat energy there so much energy is being lost to the ship, so which attributes to the resistances of the ship, which accounts for the frictional resistance of the ship.

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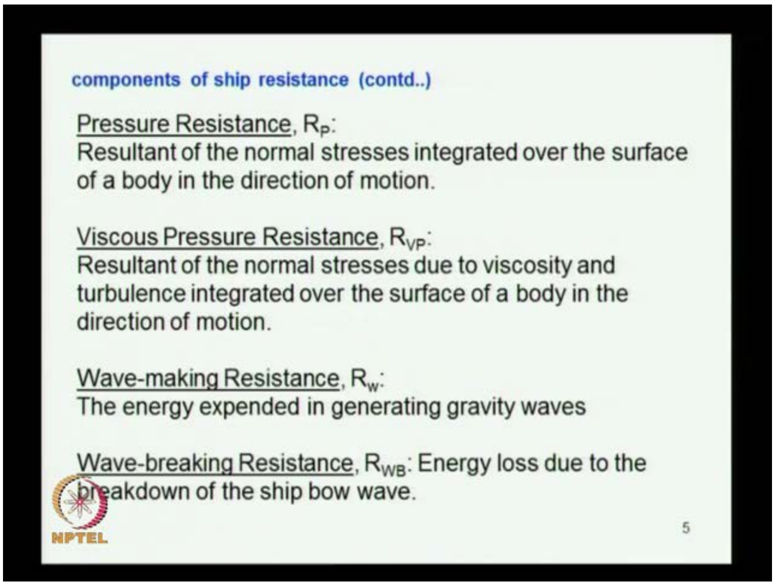

So, next component is the call it is residuary resistance there you have a residuary resistance here residuary naturally, it is a left over basically residuary, what do you mean by that that is we consider the total resistance of ship in still water here we are not dealing with ocean ways, there are just considering still water. The ship is moving through that when the ship moves through that still water first thing, what we have to discuss is it will have a frictional resistance offer to the motion of the ship.

And next thing is there will be you have noticed that waves are generated around it and plus there are the components, which we will see later. So, the total resistance minus frictional resistance component you call it residuary resistance, and in residuary resistance wave making part is the dominate one. That is the way making is the major component which contribute to the residuary resistance of the vessel.

Next, you have the viscous resistance, resistance due to viscous effects as I already said the frictional resistance is one of the components, that is discuss property of the fluid. Then we will see later there are some more components, which adds to it due to the viscous property of the fluid. So, all these components put together you call it as viscous resistance later we see in the diagram, how the components are classified.

So, the pressure resistance, resistance of the normal you know the pressure acts normal to the surface at the dynamic pressure or even hypotactic pressure that is normal to the surface of the body, and you which you can resolve that one across the direction that is in the transverse direction of the ship, another one on the launch able direction of the vessel. So, when you consider a ship surface you can let me explain using a board.

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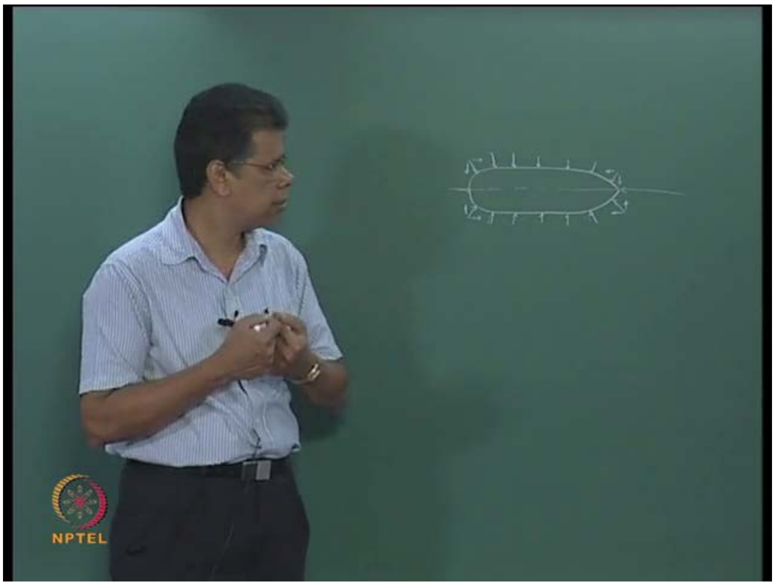

So, consider a ship moving then you know the pressure acting at this normal to the surface, see here is normal is in the direction you have pressure in this direction. Similarly, you have a pressure, so there is the pressure acting. So, if you resolve this component, ship you know it is symmetric about the centre line if you resolve this component you get two components in this way. And similarly, at the symmetric point of here you get resolved these two components. So, the pressure which acts normal to the surface of the ship and can be resolved into one component along the ship and one component without the ship are called as the transverse direction.

You can do the same to the all components here, so here you can say this point you get another component this direction you get another one here. So, here it will be in this direction and here this, now you consider the pressure what happens to the pressure this two this symmetric. So, this pressure magnitude they are same and this components these two components are same isn't it same pressure. So, these two components they are the opposite, so what happens to the resultant of these two components? They will get cancelled each other this two components get cancelled each other.

Now, you consider a point here and the point here you have a component in this direction you have a another component, so the component coming from this point in the opposing direction. These two components get cancelled each other, but these two components may not got cancelled here because these two are not symmetric above this point this.

So, that means if you do the estimation by resolving into longitudinal and transverse direction, you will find that the transverse components are estimation by resolving it into longitudinal transverse directions. You will find that the transverse components are getting cancelled each other due to the symmetric of the shape about the centre line, but the longitudinal components will not cancel each other. There will be a resultants components, which will act on the launching direction if this components is along the floor direction or opposing the ship motion ship direction, ship velocity it adds to the resistance of the vessel. So, that is what is called a pressure resistance.

So, what do you call pressure resistance is coming from that, then next component is a viscous pressure resistance, viscous pressure resistance here. So, this is due to the viscous property, when there is viscosity is there you know there will be formalization of the boundary layer around the body. And the boundary layer grow from the forward size of the shape to the end of the shape so if you consider the boundary layer.

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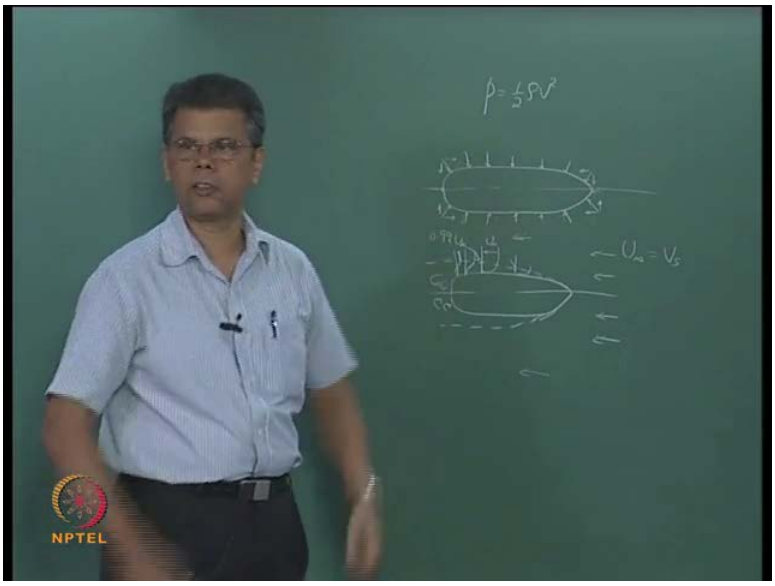

So, boundary layer its zero thickness at the point and it increases towards the up it goes like this so the boundary line opposes enlarge thickness for here. So, the boundary layer increases, so beyond a stage the boundary layer separates, boundary layer would not be able to… You know what is the definition of the boundary layer boundary layer is defined as if you take a profile here, velocity profile across this boundary see this is the profile. That is it is a actually a fictitious line which is drawn that is velocity of a consider, the vessel is such a zero speed, and you having the flow at mainstream flow of the U infinity or usually you say this is equal to the ship speed.

So, the free stream the flow velocity is same as the speed of the ship, but here we consider the ship is stationary that the flow is in this direction, the flow here will have same speed as this, but what is flow at adjacent to the body flow adjacent to the body will take the velocity of the body. Now, you are considering the body which is the shape is stationary, which fluid flowing across it.

So, naturally the flow velocity adjacent to the body will have a zero velocity that why you have a zero velocity here, but away from here will have free stream velocity and here it will have a zero velocity. So, there is a variation from zero to free stream velocity, so which is usually a parabolic distribution of velocity. So, at some point you want to identify a point where which is equal to 0.99 percent of U infinity.

You consider a point 99 percent of U infinity as per U infinity you want to identify boundary where this discuss of this is not significant. So, you consider this you do this same thing for the different region, you get the 99 percent points, then you join this 99 percent point that is called the boundary line. So, this is the boundary layer for the ship, so this boundary layer which is beyond the limit, it you know it goes like this finally, it may have a reverse gradient negative gradient. So, that is the point where the flow separates flow is not it is not following the condor of the body, it separates from that. When the flow separates what happens?

There will be formation of eddies, when flow separates eddies are formed. So, you consider this two cases, this is the case we have not considered viscosity and now this is the case where we consider viscosity, due to the flow there will be a formation of eddies. And this eddies are formed what happens to that means, the flow as attained a velocity. So, when you consider this case where you consider potential flow, potential flow means there is no viscosity, what do you call this point? These two points are called stagnation points.

Stagnation point means that a point where the velocity is zero, so that means if you look to the Bernoulli's equation the pressure is maximum, so these are the two points. The pressure is maximum and you know the stagnation pressure is given by half rho v square isn't it, that is the stagnation pressure. So, this stagnation pressure now you cancel this case with this, here velocity is zero pressure is maximum. And that means this component will have a higher value, what is this component?

This is the component which supports the ship isn't it is pushing the ship forward, and this is a component which is opposing ship. So, you prefer to have this component dominating, so the resistance will be less. Now, you consider this case where you consider boundary layer with viscous fluid, where is the flow separation the velocity of flow is not zero it is non-zero quantity. So, what happens to the pressure compare to this two, the pressure here will be less because of the flow fluid attained a velocity due to the flow separation.

So, when the velocity is there the pressure drops, when the pressure drops what happens to this component? This component reduces so that means effectively this component is more dominant it will increase the opposing force, which is the resistance increase. So, you clearly understand what is viscous pressure drag of the pressure resistance, when viscosity present the boundary layer is formed. The boundary layer builds up front of the vessel to the after the vessel boundary layer thickness is higher, and the act of the region of the vessel. And the dark region when the boundary layer increases beyond a limit naturally there will be a separation of flow, flow separates. When flow separates a eddies are formed when eddies are formed the velocity is not zero.

That means compare to the potential flow case the pressure drops, when the pressure drops the assisting force of this ship reduces. That means opposing forces coming from the foreign due to the pressure increases. So, which obviously means the resistance of the ship increases due to the viscous effect, so that is the contribution on the resistance of the ship coming from viscous property or the term which you say viscous pressure draft resistance.

Then you have the wave making resistance, well wave making resistance again here as I said before this is not dealing with any ocean wave, it is still we are considering still water. You must have noticed that ships moving to the still water, they generate waves due to tension pressure basically in it moves like we consider a pressure point moving and it has a characteristic of the wave pattern appearance and all that we will see later.

This you know wave the waves which are created, now we are talking or discussing only about surface shapes, when the waves created of a surface or in the surface of between atmosphere and water that place we call it, generally free surface waves between atmosphere and water and that is called free surface waves what we have seen motion generally the ships and all that. Free surface because they at the free surface that is the interphase between air and water. So, these are also called as gravity waves you know often the waves which appear at the free surface at the gravity waves. The reason for that is water is treated strictly as a incompressible fluid.

That means, the volume of water is not getting reduced by application of pressure that is called even if you compress it is not getting compressed. Even if you apply pressure it is not getting compressed volume remains same that is why we call is a incompressible.

Now, you consider there is a force disturbance you just consider the case of a stone being dropped. So, when you drop a stone due to the there is change in movement when it enters water and that results in the force pushing the water column down.

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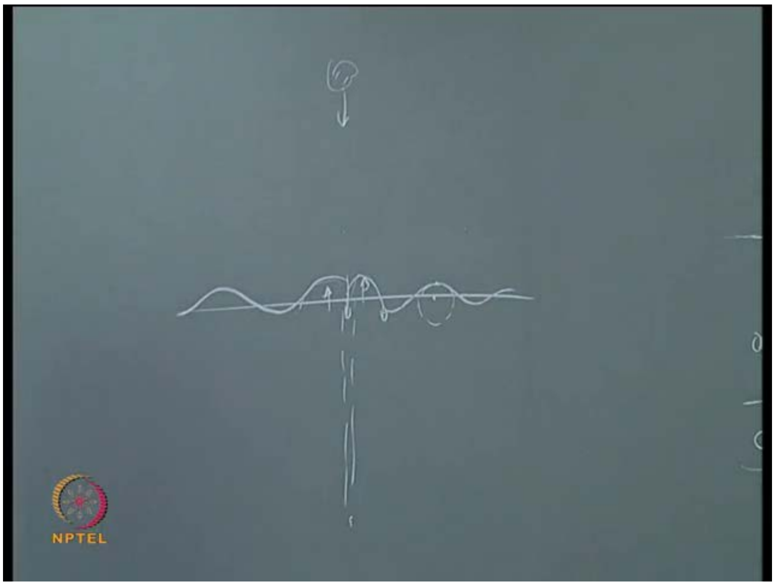

So, when you consider you consider a stone and you also the free surface, which is coming down and when it comes here you know the water column here is being pushed down. So, what happens to the adjacent water column, water is incompressible so even if you again apply a pressure its volume is not reducing. So, what happens to the adjacent layer of the fluid water? It will come up here also it will push up the water column adjacent to it. So, it moves up the water column moves up, but they cannot move up indefinitely, the reason is why the water column cannot move up?

Gravity acts because water particles possess mass, gravity acts on that because of the action gravity the water column adjacent to that which is moved up is pulled down, when it is being pulled down same thing is repeated here also the same thing is repeated it pushes the next column down. So, what happens at this column it emerges out. So, this will go on like this. So, that is how waves are created consist still water so one is drop this of the application pressure of force water column is being pushed down, water being incompressible the adjacent layer emerges out. But the gravity acts on that again its pulled down then subsequent layer moves down and this keep on repeating and to get the waves.

So, this action of gravity on the formation of wave is also called gravity feeds, so waves are generated, when the ship is moving on water and you know that compared to still water the waves. So, we consider water particles clear and water particles moved up, so water particles possess mass when that mass is lifted what happens, what type of energy is associated with that it has got potential energy isn't it. So, due to that is wave now got a potential energy and you know that water particle inside a wave will have a orbital motion that is we have circular orbit.

Again this water particle mass is moving with the main possession remains same deep water, but the water particles possess I mean the subjective of rotational motion. So, mass at this is moving constant velocity, then what happens, what is the energy associated that? Kinetic energy half m v square, so you have rho g h coming from the or m g h basically isn’t it you have the potential energy, and you then you have the kinetic. So, the wave any wave you see in a ocean in on the water surface, then it is associated with energy, which is being contribute by potential and kinetic, potential which of its movement practical possession and kinetic due to the orbital motion of water particles in the wave.

So, the total energy mean I mean the wave potential energy from where does it comes some energy ship is moving the consistent of water ship is not moving, there is no wave now still water ship is moving its creating it. And these waves possess energy and the where the law of conservation of energy applies now, isn’t it energy is not created nor destroyed. So, it is a converting from one to another isn’t it, if we take a system there should be constant energy, is it not? So, here that means the formation of wave and the wave possess energy and this energy is being supplied by the ship, which results in loss of energy to the ship. And hence that component part that component is called the wave making resistance of the ship. So, that is the wave making resistance of a ship.

So, that is one of the major components and do you know that waves size created by the vessel depends on the speed, you just on the ship low speed wave making is less at higher speed wave making beyond higher. And naturally the component wave making component of the vessel will be higher and higher speed, you see relations later how it is related to the speed of the vessel. The next one is wave breaking resistance here wave breaking resistance, when the ship is moving.

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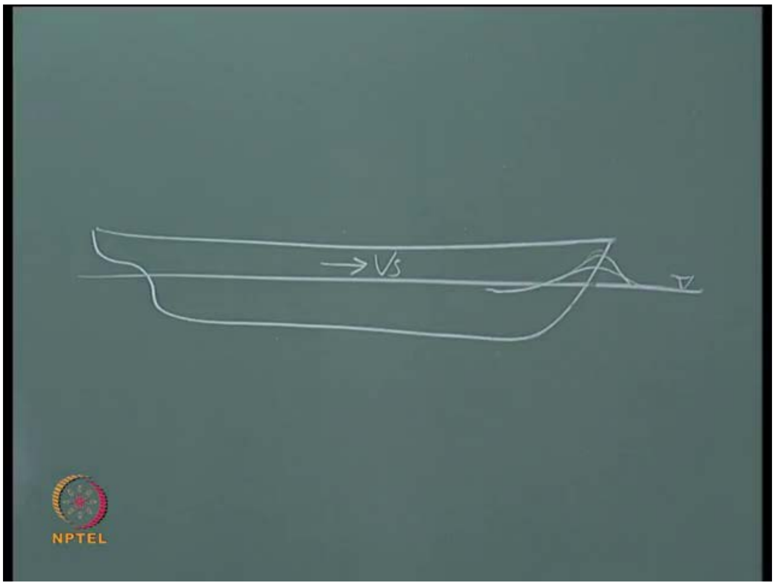

I will just draw it write here, just consider a ship moving in this direction which floating at this water line, here there will be a wave formed like this we see the components of this later, waves of components. Here what is this point, what is the velocity at this point 0, that is stagnation point what is a fresh up maximum? So, naturally there will be elevation of water due to the pressure, so bow part of the ship will have a wave crust formed that is a bow of the ship will form a wave with a crust beginning and then it propagates towards crust. So, this is called bow wave, this is bow of the ship and this is called bow wave.

And if this go beyond the limits what happens if this height increases height of the wave increases or in other terms you says steepness of the wave increases of the same length a height increases thickness increases. And if the waves steepness goes beyond the limit what happens the wave breaks, when wave breaks what happens there will be formation of a disk or breaking of the wave results in more water particle kinematics. So, that means there will be more energy associated with the breaking of the waves, and from where does this energy come from the ship.

So, breaking of wave bow wave leads to an additional resistance and naturally this component is called small compared to frictional wave making component, but still that is a increase in the resistance due to breaking of waves. So, what do you do is whenever you design a ship if you can take a breaking of waves are avoided then you are reducing the resistance that component of wave. So, care is always taken to reduce that component even a small saving in the resistance of a ship matters a lot because it is a ship is designed for the period of 25 to 35 years of operation in a small saving 2 percent, 5 person saving a resistance matters because there is so much fuel saving. And you know a fuel cost over a period of recurring expense naturally that will turn to be a advantages for the ship.

And now they m o is giving more importance for resistance a talking about green ship. So, that means when the resistance comes down the emission also comes down, so it is more it ecofriendly, and naturally the ship is called as a green ship. So, you are adopted different methods may be improving the efficiency of the engine used. Or may improving the profession of the efficiency or reducing the resistance, all these matters in the reduction of fuel consumption subsequently on the emission, which will give a much better ecofriendly ship.

So, even its a small thing even though you say it is a wave breaking resistance very small component may be 5 percent or even less does not matter, if you can save if it three or two if it, three percent from that part of if or may be five percent of that it matters it matters a lot for the whole range of the operation of the resistance.

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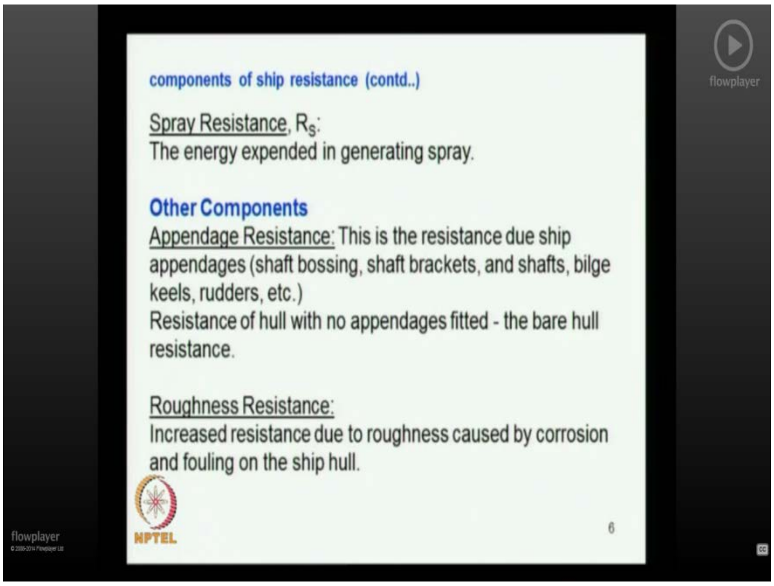

Other components spray resistance, spray resistance is the energy expended generating spray normally it occurs in planning crafts. You know when the high speed vessel you say lot of spray is coming out and spray is results in more or particles kinematic subsequently, the kinetic energy associated with the water particles kinematics and naturally that energy is being sent from the ship.

So, due to that formation spray you have more resistance is called as sprayed resistance often in high speed results in planning craft you see that the spray the big is arrested which will help in also to reduce a resistance of the vessel. So, these are general components and other components, we look into one is appendages resistance the ship normally depending on that sometimes the ship models that have done the barrel alone, without radar without the popular bose without the bracket without the bill scale.

So, all these come as appendages something external to the main wall of the ship so all these soft build radar everything can be treated as appendage. So, if it is not considered as part of the main turn, then you can give a relevance for the appendages which will increase the resistance in many counts. Naturally it will increase the wetter surface due to appendages so the frictional resistance will be higher and then it will lead, to if it close the surface of the ship it will have appendages which will again contribute, the wave making part. Then when there is due to boundary layer effect flow separation there will be a effect due to viscous pressure also can have contribution of various components.

Generally people confine the estimation only to the frictional resistance path. So, if it is a additional where the surface coming due to the appendages, and then you put a fact for that into the x factor and for the multiplies that with the friction resistance to get the increase in resistance due to the presence of appendages. Another thing is roughness resistance, roughness you know that the ship put operation in sea will be subject to corrosion, because this is steel ship generally you know this is highly sensitive to sea water resulting in corrosion, corrosion results in the roughness increases the roughness of the ship hull.

And also the ship being in marine environment, in water continuously for longer time will become a comfortable place for the many biological living beings to live on, isn’t it like weeds bionomical everything just start living on the underwater, which is always wet and comfortable things to be there. So, they get started living on the surface of the water that is why the it is become mandatory to dried of the ship that is take the ship to dried region, or shore facility. Then clean the underwater you know skip the all the growth and clean the surface underwater surface repaint it make it motor again. So, what happens is that little growth naturally the roughness increases, when the roughness increases what happens?

The frictional resistance increases, when the naturally till the ship has the more power to get this speed or the speed comes down automatically due to increase resistance. So, again it's a more fuel consumption more money for the owner and subsequent affects as i said emission takes places. So, when the ship is ship resistance is estimated, it is done using model test model is having a very smooth surface the resistance, which you measure from the model and then extrapolating the ship is not taking care of the roughness due to the corrosion and falling.

So, when you estimate the power for the ship naturally you have to give an relevance for the this two, that is for the roughness mean estimates the falling and corrosion effects. So, the roughness of an model and roughness of the ship are totally different, so the roughness increase in the case of the ship and increase the resistance estimated from the model to get an actual value for the ship, which is in operation.

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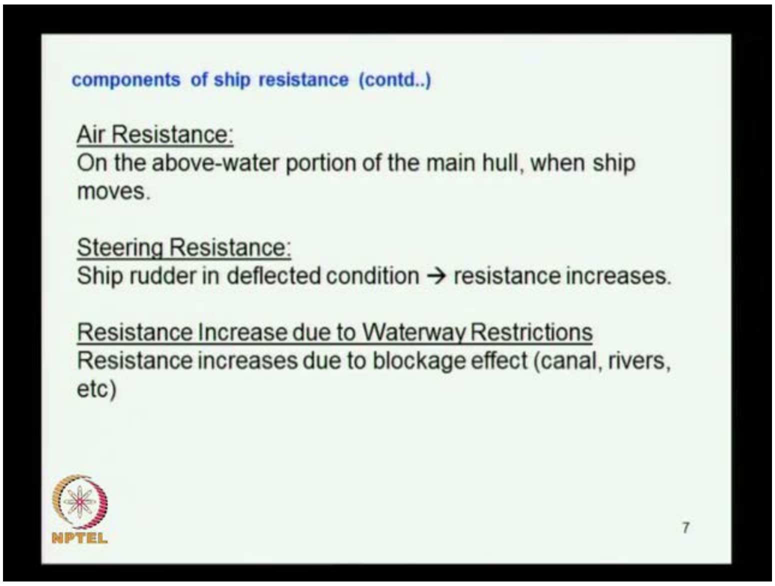

Air resistance the ship is just consists a still air is now in is not considering still air, like water a ship is moving forward. So, that means as good as above water portion the ship is having air flow opposite direction isn't, there is a air flow in the opposite direction. So, this air the structure above the water of the ship will be subject to resistance offered by the air. And that is considered as taken as the air resistance normally for conventional ships, the speed is less and air flow also is less and the, so that the component air resistance and also the density of air resistance 1800 of water.

So, the density also which is also low naturally the resistance components coming from the air resistance is small and that to for a low speed ship, which is very small. That is the reason if and the super surface of this type of the ship which is above the water is not, so steam lined for low speed ship whether when it becomes high speed vessels because the speed is high you know the force is also proportional to velocity square. So, air resistance for that is one we have to consider. Next one is a steering resistance steering resistance steering of the ship is done using rudder you know that conversion is done using rudder. So, for turning the ships are often to maintain the straight pose for the ship rudder is used, you know rudder for ship.

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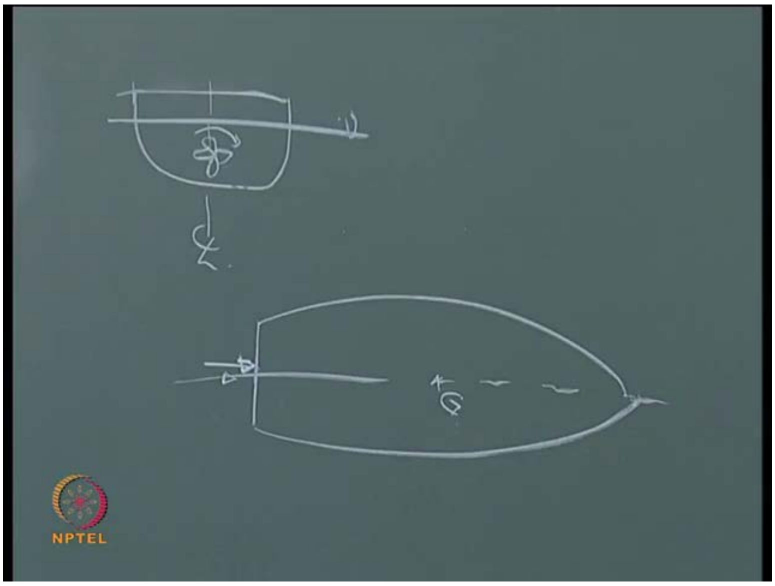

Ships with a single propeller if we consider a ship taking of a section of that view this water line, you have a propeller here. Now, it may give rotating in one direction it’s a center line. The flow kinematics around that region is not symmetric about the center line isn't it because its rotating in one direction. If it is a ten screw and they have symmetric rotation make the outward or inward rotation symmetry of kinematics, consider single screw and you know that it can rotate only in one direction. So, there is going to be an symmetry of flow kinematic with reference to the center line of the ship, Asymmetry of flow kinematic results in Asymmetry in the pressure distribution, Asymmetry in the pressure distribution results in the resultant force generated by the propellers is slightly of the central line.

Thus pressure is not same on either side if the pressure is same on either side it will act along the center line. Since, the person is not same, then there resultant force will be slightly of the center line if the resultant force is slightly of the center line, what happens? Suppose it consider this view instead of the force acting in this direction now the force is slightly of the center line, suppose this is a force coming from the propel and gravity you know it is always adjacent.

So, what happens there will be a movement isn't it, this force will result in the creation of a movement if that movement results in what? It will turn the ship, you want the ship to go straight you are not putting the rudder to any angle. If rudder is at 0 angle still the ship turns because due to the kinematic and Asymmetric of the propeller with reference to the center line of the ship. So, normally what ship does is ship, it is angle screw do is they put a small rudder angle to contact this movement. So, that the movement is contract ship will keep a straight cause, rudder you know that it is symmetric and when you deflect it is a force and movement.

When it deflects the rudder what happens resistance of the ship, due to that reflection a blocking isn’t it increase the resistance isn’t it. So, which we call is sharing resistance. So, ship is shared by rudder and rudder often is with a small angle to contract, this and symmetric generated by a single screw as ((Refer Time: 44:12)). So, this leads to additional resistance which is termed as steering resistance.

Then the last one of which is already discussed increase resistance increase due to waterway restrictions, water way restrictions leads to lots of complications when the ship move from deep to shallow water. Usually shallow water is less than two times the ship if the water depth is less than two times the craft of the ship, which is again depending of the speed conventionally say for normal ships conventional says. If the water depth is less than two times of the ship which of the shallow water, when the ship ends the shallow water what happens.

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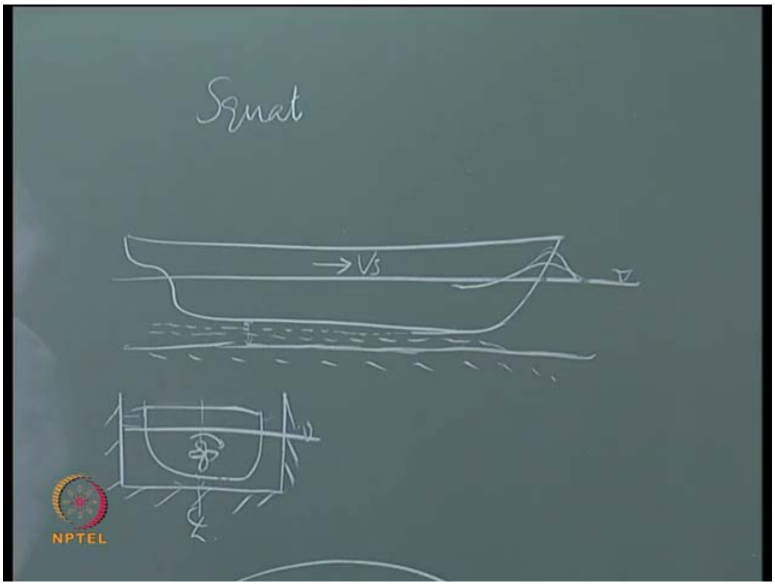

Suppose, this is a ship just say it’s a shallow water. Now the bottom is very close so this is less than so what happens the water flowing to this part. So, there will be a boundary layer formation here the bottom, you see there is a boundary layer which flows towards. The bottom which is also close to the ship will fill the flow and then it will also generate a boundary layer. So, there is a boundary layer formation coming from the bottom of the ship and also from the water wave bottom. As already said boundary layer inside boundary layer the flow velocity is less.

Now, the water here escape to this side there is no conservation of mass, it has to flow. So, the same water when its flow try to escape, so the bottom of the ship will sink due to the conviction due to the reduction water itself there will be increase in flow isn't it, the flow increases. So, velocity increases it is obviously you must have noticed that when there is a channel, when there is a reduction in the section, the flow increases. Continuity should be maintained, so the velocity increases. Same thing here the flow velocity under the ship increases, when the flow velocity increases what happens? The pressure, pressure drops when pressure drops what happens to the buoyancy, buoyancy reduces. So, to make up the buoyancy ship will sink more, when the ship sinks more what happens to wetter surface it increase.

When the surface increase resistance increases is it not? So, the resistance increases when ship will dip to its coming from the frictional resistance part, the addition to that when the boundary layers are formed, the bottom also at the bottom of the water wave that will give additional construction to the flow because inside the boundary layer flow velocity is less. So, the consistence is more so compared to the flow velocity here the flow velocity will be more, because of the boundary layer formation, because there is consistence created by the formation of the boundary layer and increases the thickness at this range.

So, the flow velocity here will be more compared to this region, so what happens a pressure compared to this two region, which region will have low pressure of the boat because the flow velocity of this side the pressure here again will be lower the lower pressure, what happens that the after enough ship will sink more than the forward region. So what happens? Which we call the ship will dip, so when the ship ends from the deep shallow water it sinks and after trims.

So, both thing are there which is the term called squat this is the term used to find this phenomena that is the shallow water effect of ship. So, due to the consistence flow consistence these things happens, then in addition to that if there is a transverse restriction, suppose we consider the ship here by putting boundary at the bottom and also at the side now the ship moving to the canal. So, we have a section here a section here and here so naturally these sections will enhance the flow velocity, and the squat effect will be more compared to the case where only the shallow water there’s shallow water in this side only the transit resistance is not considered. But if these transits resistance like canal or wave naturally this problem gets aggregated and the squat effect will be higher.