Ship Resistance and Propulsion
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Lecture - 2
Seaway Effects on Resistance

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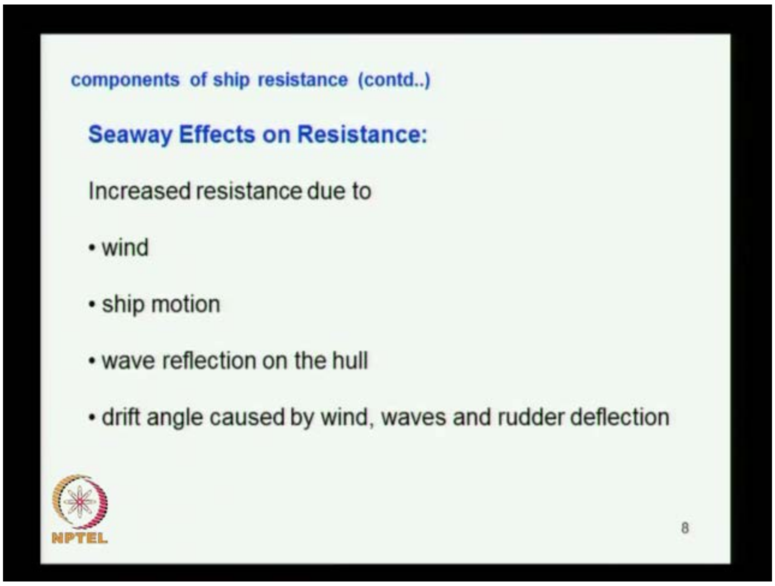

Good morning to you, we have been discussing about ship resistance and the ship resistance, we have seen the calm water resistance that is the ship is moving calm water, why calm water is considered that even though you know often the ship cannot be operating in calm water in sea, it is going to operate in a wave condition. And the ship operating in calm water conditions very rare unless it get in to a harbor region or may be in shelter waterways or may be in land waterways where the waves are not present.

And also we consider the previous class the resistance without the wind condition, this environmental affects have been not considered in the cases, and one of the reason for that been model test are performed in toying tanks, where the water is still. And you are estimating the model resistance from the in that condition, in the calm water condition then you extra plate in to the proton type actual shall ship.

And then you add the other environmental effects such as the increasing resistance due to waves, and wind and other reference. So, that is what we have discussing it here, you can say that the seaway affects on resistance. So, in a real sea condition, what would be the additional affects running to the or additional affects coming to the resistance of the ship due the environmental affect.

So, one of the aspects we have here we consider is a wind, we have already discussed about air resistance for ship, air resistance which it is pertaining to the resistance offered to the most of the ship, where we consider still layer. So, when the ship is moving forward there is a flow of the same speed of air in the opposite direction. So, there is a air resistance, but in the case of a ship operating in open sea an opened an atmosphere there will be a wind, natural wind acting against a ship, ship motion. So, this wind is principally treated as the air resistance, air resistance is along the longitudinal direction of the ship, whereas wind can come from any direction.

So, the component of the wind which opposes the motion of the ship will be treated as the wind resistance often this two components are club together because principally they are same air resistance and wind resistance are, so depending on the sea condition and weather condition, the air resistance or the wind resistance changes. So, you have to have an idea about them direction of wind, velocity of wind to consider to estimate the wind force opposing the motion of the resistance, which we called as a wind resistance.

Often you know either wind strictly speaking not a study state you if you take a record time record of the wind, it is going to be unsteady one it is not a having a uniform velocity throughout, but often we treat the wind as having uniform velocity. So, the wind resistance become predominant or do not considerable when you consider a far ship when they I am not strictly with that they gets a just telling about the air resistances. But the far ship, we discussed last class the their resistance depends on the wind ship speed, but wind resistance depends on the winds landed direction, as I said before and also the velocity of the wind.

The next aspect is a ship motion, if you consider the ship motion that is you know which is not considered in calm water resistance estimation, the ship which is now expose to as sea environment you will be subject to motion in or all the six degrees of motion. And the motion will generate waves, we just consider still water air ship is floating, and now the ship subject to any motion they will just puts it is down specific motion, specific motion you push it down you see that waves are generated it is not having speed, it is stationery the ship is subject to if motion.

As we discuss in the previous class these waves possess energy we have already discussed that and that is a loss of energy to the ship speeds. So, the ship which is prone to all the six degrees of motion will generate waves for an each component, or each mode of motion. And the result in effect is here result wave they will be formation of wave this possess energy and loss of energy to the ship an hence adding to the resistance of the ship.

A ship is moving forward and subject to motion will have this affect, and the motion effect obviously it depends on the roughness of the sea the sea is rough. Naturally the motion will be more and that is the size of the generated by the ship motion will be more, and when the size of the wave increases the energy associated with the wave also increases energy is proportional to square of wave amplitude, so size increases then energy also increases, so that means the resistance part coming from the ship motion also increases.

So, the ship experience more resistance in a seaway compare to stilled water. So, there are two options in this case, so when the resistance increases, what happens? The speed comes down voluntarily mean, involuntarily automatically the speed comes down because a resistances gone up. If you want to maintain the same speed in the same in a necessary condition then you have to have a vessel, which is powered to overcome the resistance powered and with we should have profession system which generates the required thrust to attend the or to maintain the speed. So, that is a ship motion effect.

Then the next component is wave reflection on the hull, you know that when the wave is progressing against the direction of the ship, it is blocking the propagation as a wave. So, it is a hitting a boundary which get reflected back, part of the wave get reflected back. So, which doe to the changing momentum there will be a opposing force to the direction of the ship. So, this imparts another component of resistance. So, this is usually felt in ships which are more full in form, like if is the tanker ship the effect will be more were as for a container ship, which is more fine the effect will be less. So, there is the another aspect of the seaway on resistance.

The last component that is a drift angle caused by wind waves and rudder deflection the ship in seaway due to the action of wind and waves will changes is direction, may not be able to able for the ship to retain it is straight direction. So, because of the external disturbance caused by wind or wave and also by the rudder because you may put the rudder, which will give drift to the ship. So, this are the effects which causes the drift to ship that is changing the direction may be slide, change thoroughly.

So, this will increase the resistance of the that is instead of the ship moving in this direction with the drift it will move in this way. So, there is a increase substantial increasing resistance due to the drift tanker. So, this things are not considered when you perform a model test in a toying tank, this are the additional affects on resistance occurring to a ship when it is put to operation in a seaway condition. So, that is what we discussed as the seaway effects on resistance.

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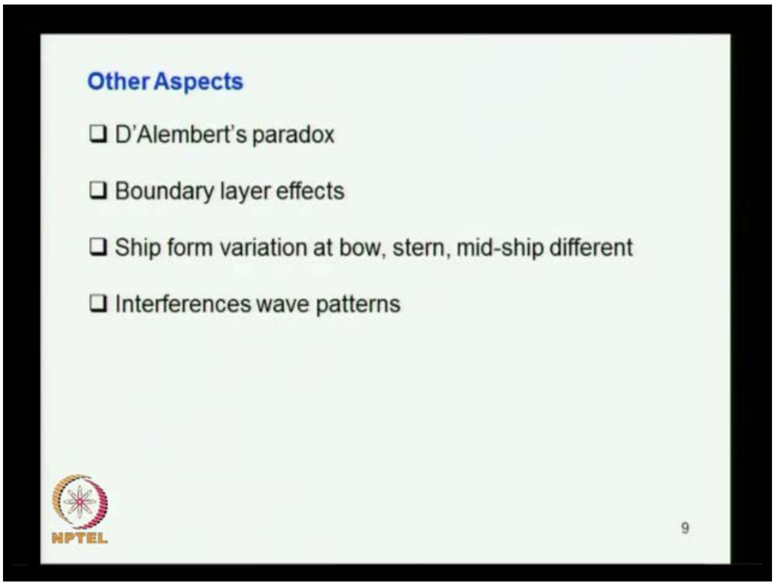

Some other aspects we considers, we should be considered in resistance are this one that is the D' Alembert's we will just discuss what are the effects of this D' Alembert's paradox we will see may be in the next slide, what does it. That means here the major components of resistance generally consider the fractional resistance due to the viscous property of fluid, and the wave making resistance of the fray surface due to the presser disturbance. So, when you consider the body is deeply submerge will that be a wave making, no there is no wave making. So, for a deeply so in case of sub marine, submarine is operating you do not see any waves at the surface of water.

So, when the body is deeply some there is no wave formation. Now, we consider the body is deeply so much the water is idol you say perfect, fluid there is no viscosity. So, which no viscosity means no fractional resistance, no open viscous drag nothing and body is replace some were we making wave making nothing is present. So, no resistance for a body, which is submerge deeply submerge in an idol fluid. So, the body will move without a force, so it is only paradox which never exist, and which is the one put forwarded D' Alemberts which is called the Alemberts paradox.

So, next is a boundary layer effects, boundary layer effects, it differs from model to ship we have already discussed boundary layer effect and we discuss about the viscous version drag, boundary layer formation is ((Refer Time: 12:21)) viscous property of fluid water. And when and also the boundary layer you know the thickness increases from the forward side of the ship towards the aft of the ship, the maximum thickness come in draft region and when the thickness go beyond a limit, the flow brakes.

So, this boundary layer formation the type of boundary layer it is a laminar boundary layer or a turbulent bound layer, or transition boundary layer all depends on the Reynolds number. Reynolds number of the model and ship are different we will see later when we discuss about the model test, how they are different what is a problem and how it is tackled.

So, the boundary layer effects actually what do you predict from model test cannot be extra piloted to a proto type actual ship case, then we have against the ship form variation at bow, stern a mid-ship. So, the form the ship we know that influences the flow pattern around it, and the underwater surface area determines are resistance component. So, this the form matters and you know that fars ships generally are fine an shape where the wave make resistance is reduced due to the fans in the form of the ship.

And next is the interference wave pattern, that is ship if you consider again we will see in the next it generates waves from different discontinuities in form or may be where are from where are this abet change in the form. So, when where basic ray some recreation of wave is the pressure disturbance. So, whenever there is a abrupt change in the form of ship, there will be a sudden change in the flow and flush. And whenever there is a sudden change in pressure or flow a waves system is generated from that reason. So, when you consider idol is form of the ship we will see later, it will generate waves from four points from the bow from two shoulders and from the stern.

So, these wave systems when they inferior constructively that is the result and wave size increases. Then the wave making resistance increases, so that is why often many ships you find that a ((Refer Time: 15:11)) is provided, a bulb I heard of the bow, in front of the bow. So, which will generate a wave system the bulb is descending such a way to generate a wave system which will distractively inferior with the ship wave system and this bringing, bringing down the size of the wave and hence the wave make an resistance.

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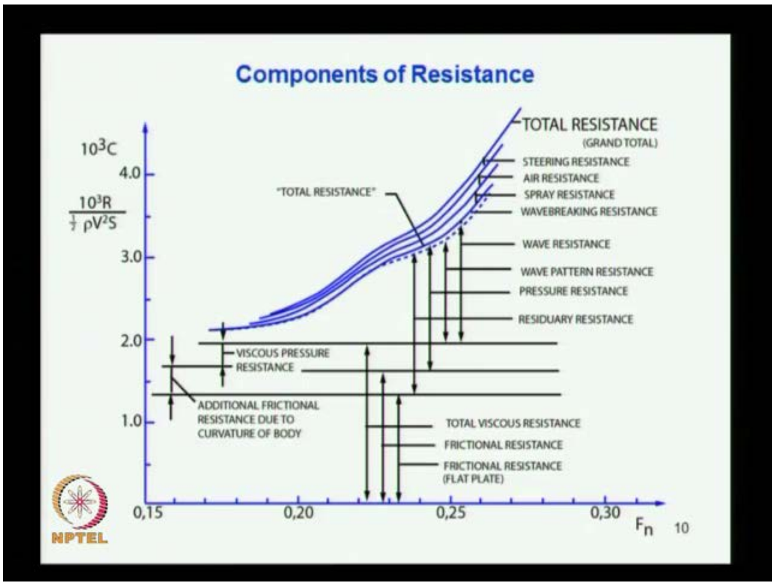

So, we this is a consolidation of the total resistance what we discussed you can see that I think this is a mistake over here this is basically C t and here you see that the total resistance non dimensional resistance is given by R by half row viscadass, V is ship velocity as I say vidor surface it is under water surface of the ship surface area. So, here I plotted against the float number, float number I know that V by root g L.

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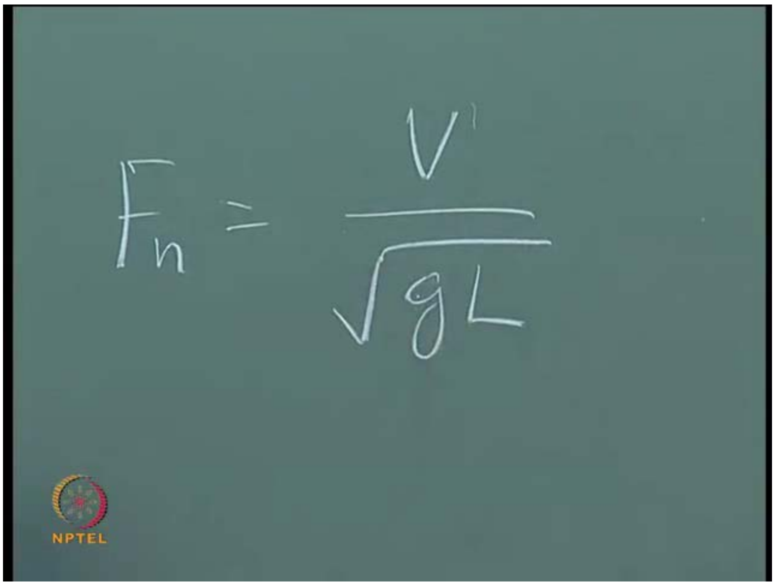

So, where V is the ship speed and the L is the ship length the acceleration due to gravities. So, it upper since a non dimensional a ships speed. So, if you look to that you can see the will resistance components, what we discuss so far put in a diagonal form inside the total resistance, this is this dotted line here that shows the total resistance from a model and you can see that the components here are this line the bottom line which shows here which is a frictional resistance flat plate, frictional resistance of a flat plate. We see why a flat plate is considered we will see it later.

Here we consider you consider a flat plate, which is being towed through a tank are the particular spate, when you measure the resistance of that plate the surface area of that plate that is two surfaces put together it is equal to the metal surface of the shape, and the length also preferably to that of the model. So, it is a model metal surface area putting to the two sides of the plate and length of the plate is equal to that of the model which is been towed at a submerge level. So, that wave disturbance also there and you measure the drag offered by the plate when it is moving at that velocity, and from which the resistance is obtained for the plate.

So, the tests have been done by you know century old a results are available, where people have done experiments with using the flat plate. And the flat plate resistance are put forward by using some empirical relations, which are been obtained results obtained from model test. So, we see the reason why that is used here later, when we discuss about the model test, and exploration.

Then we have the frictional resistance here this component this line overseas is called a frictional resistance. Frictional resistance depends on the flow velocity square, we say that the order of the velocity based on which the frictional resistance depends later. So, friction velocity the that is here the plate is moving, we are considering a plate and comparing with the ship frictional resistance. But the natural case the ship is having a three d form plate is at 2 D point.

So, when there is a 3 D form the flow velocity passing the sides of the model or shape due it is curvature attain a higher velocity, that velocity increase adds to the resistance of the frictional resistance. So, it is not considered in the flat plate. So, we get a extra count which generally says a form resistance, that is the form of the ship contributing to a additional resistance that also we see later, how that extra term is being estimated.

Then you have here wave of discussed the viscous pressure drag in the last class, where we said the viscous pressure drag is due to the viscous property where boundary layer is formed due to separation draft region, and eddie is of formed and this head is results in reduction in pressure. And then the supporting force reduce, which wants to increase an resistance due to the viscous property of fluid.

So, all these three components that is the flat plate one, this line which is the flat plate and then you have this one coming from the form then this difference coming from the viscous pressure drag. All these are due to the viscous effect, so the total thing you just put it as from here to here, this is the total viscous resistance. So, the total viscous resistance got three components now one is the flat plate resistance, formed resistance and viscous pressure tanker all due to the viscous effect.

When you consider ah the total resistance here, what is shown here we have that is I can say this I row over here, so this is also total resistance that caught under small component also the breaking resistance. We see here this resistance to the dotted line which shows that total resistance without the wave breaking, it is a from here to here is a total resistance that is from the base line. So, minus the flat plate resistance, which we get some empirical relation that is called the residuary resistance. The total resistance measured from a model minus the frictional resistance of a equivalent plate, that is a plate. So, that difference is called a residuary resistance.

So, after residuary resistance, if you look you can see that one of the major component coming here is the pressure resistance. Pressure resistance we have all ready discussed pressure resistance may be due to wave making you can see that pressure resistance again divided into this pressure resistance is divided into here, wave pattern resistance that is a wave making resistance. And where we have all ready discussed of the is this a pressure resistance here, which is another component. So, only I have given a class we can discuss pressure drag also here using that along with the wave resistance. So, it is a pressure resistance.

Then you we have additionally we discussed about the wave breaking resistance, wave breaking resistance we have said a even ship moves the forint of the ship is having a stagnation point a stagnation point through, the pressure is maximum the pressure is maximum there generates a wave crust. So, both part of the ship goes by the buildup of wave I will just say may be one or two slides, that I have put here.

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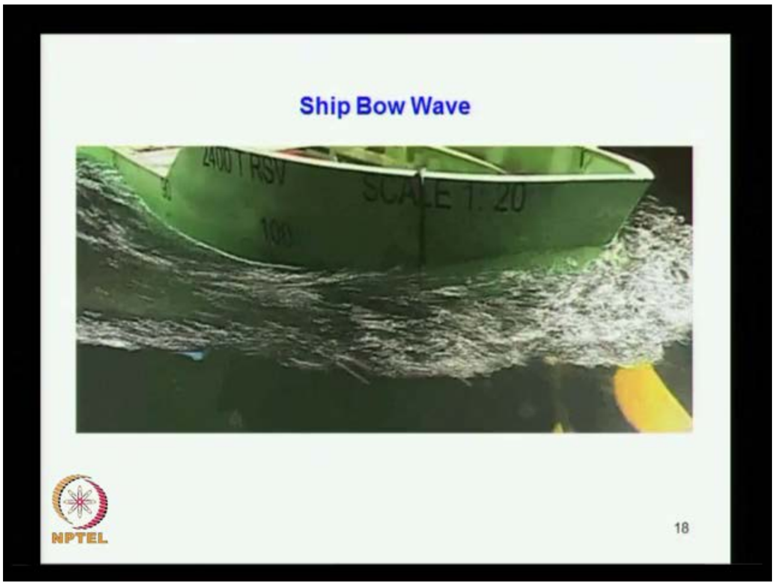

I can see in this slide, see the it is the model test which is been carried out here in the institute. You can see that the wave elevation at the bow part here I can say the height is more compared to other region. So, that is called the bow way, the wave formed at this part. So, when this wave go beyond the height the wave would not be able to retain its form, that is when the steepness go beyond the limit the wave breaks. When the wave breaks there will be more water particle kinematics because of breaking the wave. So, this water particles kinematics now also say that with kinetic energy is a loss of energy to the ship system, which amounts to increasing resistance of the ship and that system does the wave breaking resistance.

So, if we can bring down the height of the wave and thus avoiding breaking of wave, you can save some part of energy or the resistance. Coming back to the previous slide here we can say this is a wave breaking so the ((Refer Time: 24:25)) now because the building of wave at the bow region and the basic reason is that it is a stagnation point where the pressure is high, and water level builds up. Then the spray resistance which also we discussed that is usually present in faster ships, like plain ((Refer Time: 24:46)) and all that due to the spray formation there will be again more water particle kinematics and that is the energy losses will be more, which adds to the resistance.

Next, component is the air resistance, which we again we discussed we consider still air either the ship is moving. So, there is a flow of air across it which offers a resistance, so the ship to the portion above water. So, that is a air resistance. Next component is the steering resistance, which also we have discussed in the last class steering that is whenever the ship is the we know the direction of the ship is controlled by the application of radar. And whenever you put the radar and also we have seen that even for a straight course often for a single score ship due to the flow kinematic unsymmetrical above the central line you may have to put a small angle for the radar, for the ship to get a straight course.

So, in such cases when the radar is put to a small angle, the resistance of the ship increases. So, this increase in resistance due to application of radar is termed as a steering resistance. So, all this components all these thing we have discussed in the previous class also, all these things put together if it gets a total resistance. So, normally from this resistance, air resistance, spray resistance steering resistance etcetera are not estimated from the model test.

So, that is why you have the total resistance is somewhere below and other things are given additional to that. So, in addition to this, all this we have the effects of let us see again as we discussed before due to went to action due to the ship motion, there will be increasing resistance. And also we said due to the environmental of that there will be a drift there will be an effect, so we discussed the very other components which adds to that. So, the seaway effects on resistance or estimated depending on the root of operation of the ship, the sea condition varies over the period of the year.

And also it varies from region to region over the globe, so whenever ship is designed one should have the designer should have an idea, where the ship is going to put to operation. So, if it is a that means, you will have the data of the sea state, where the ship is expected to operate and based on the sea state you will be able to estimate or determine, the motion characteristics of the vessel. And from which you will be able to access the resistance additional resistance coming to the ship.

And based on which you can found find out what is the power requirement for the managing and subsequently, what is a propeller to be designed of proportion system to be designed for that condition. So, the environmental data is also important include in the wind direction, wind, velocity everything is required to be known to design up to make a proper design of the vessel.

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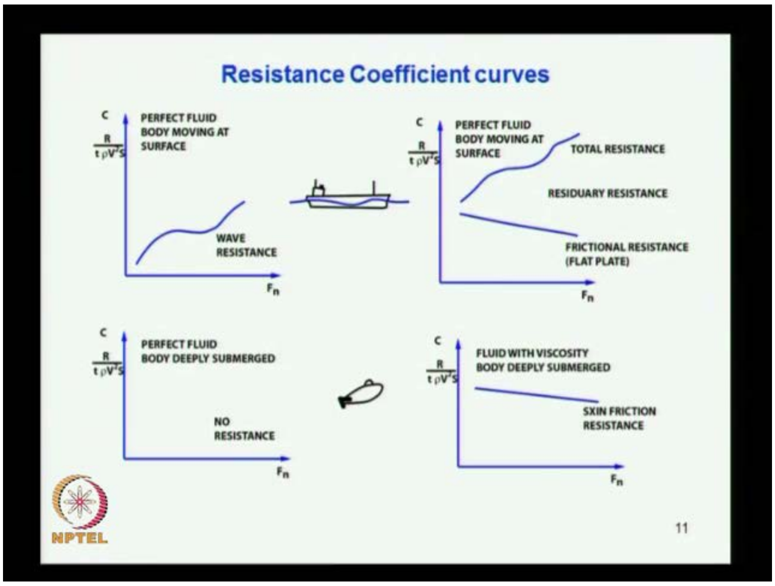

So, this are representation of a resistance coefficient we say different you know cases when you can say that fluid, here you consider perfect fluid body moving at surface. So, you consider a perfect fluid means there is no viscosity and the body is at surface. So, there is no frictional resistance, only the wave making component. So, you can say that there is no friction only the wave making component is present you consider a vessel at surface.

Now, you consider perfect fluid body moving at surface side I think there is mistake here, it is not a perfect it is a real fluid might be because you have the frictional resistance coming here at you have the frictional resistance, and also the wave making resistance. So, this is the case with a real fluid, so that is the viscous fluid.

Now, you consider here same thing here is a real fluid, fluid with viscosity certain this is the correct one, and body deeply submerged. When the body is deeply submerged there is no way making only right components of the case of deep summarized. So, here we the friction line, which is skin friction and only the friction is there, that is what will deeply submerged.

But now you consider this case of a at the element paradox, you say perfect fluid body deeply submerged, no viscosity body deeply submerged so no resistance isn't it this is case, this is a case for the D' Alembert's paradox that is perfect fluid, no viscosity. And hence no frictional resistance and now body is deeply submerged no wave making, so no resistance the ship which is in study motion or the submerged body which is in study motion will continue to keep the speed without a problem because there is no resistance offered to that.

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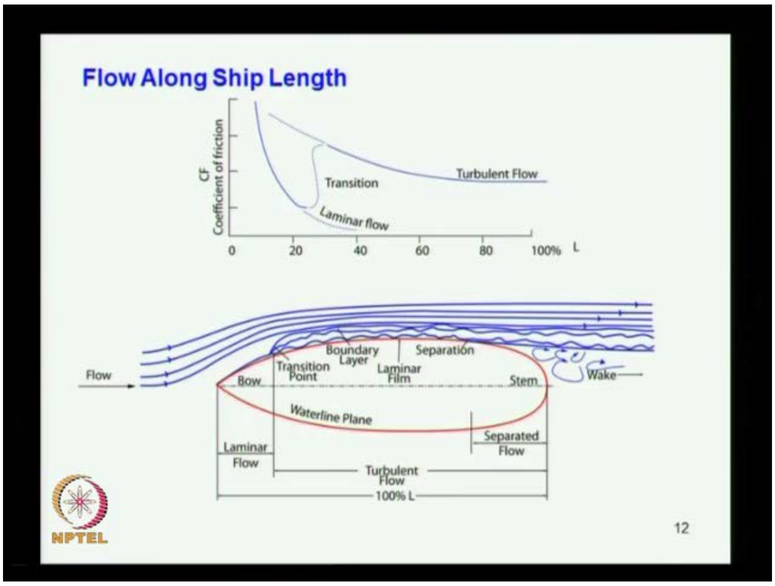

So, if you look to the flow along the ship the flow the boundary layer around the ship. The nature of the boundary layer is determined by the local Reynolds number, you know that when the Reynolds number is slow the flow is laminar, when the Reynolds number is high it is turbulent. And in between these two a small region we call that transition region. So, when you consider the ship moving through water you can see the bow part the bow region of the ship the local Reynolds number is small isn't it. So, that means the Reynolds number is given as by given by the expression.

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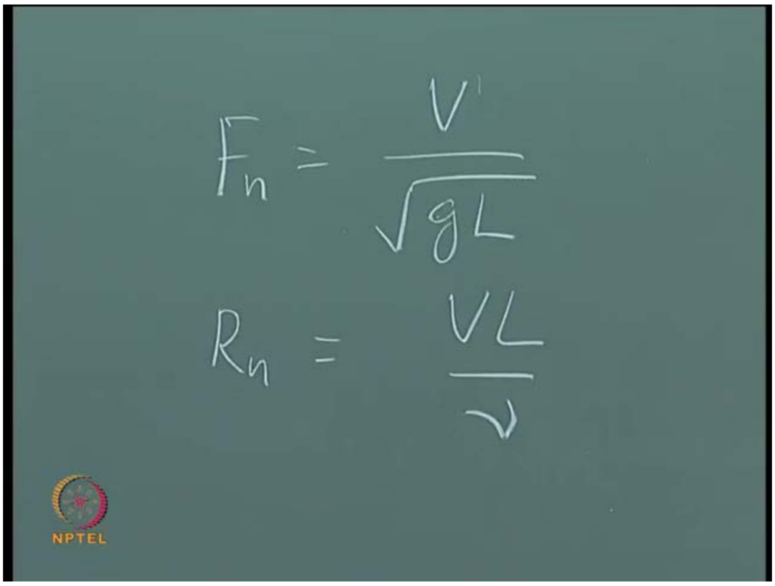

V L by mu is a Reynolds expression, where V is the flow velocity L is the characteristic length dimension of the body and mu is the kinematic viscosity of the fluid. So, if you consider the bow part of the ship alone, the bow part is having a small length. So, V L by mu L is a small length speed remains same if you can consider mu also remains same. So, that means the local Reynolds number is less, so low Reynolds number naturally will have laminar flow.

So, the forward region of the ship you say that the flow is laminar there is no disturbance, the forward side of the ship. So, after that the local length increases so Reynolds number increases the flow changes a transition region and then to turbulent region. And then the boundary layer thickness increases when it goes to after the ship stem part of the ship and beyond the limit as, we discussed in the last class the velocity gradient changes. So, when the velocity gradient is 0 with its shows a initiation of turbulence and when it goes to negative the flow separates and even that 0 it is itself.

So, beginning of flow separation and the flow separates when the flow separates, when the flow separates head is formed, so you can ah the breaks the flow breaks and head is a formed here. So, here like these are there you can say that the flow that the coefficient of friction against a length you can say the this the coefficient is high, then it comes to a transition region and then there is a turbulent flow region.

So, this is how coefficient of friction changes you see details about the coefficient friction later, how it is going to have a such a trait the coefficient of friction coming down. So, this just to give an idea what is the flow around the vessel? The flow will be laminar in the forward small region, then enters the transition region then enters to turbulent region for the boundary layer. And finally, the flows up rights towards the half side of the ship that is the reason what we said, the ((Refer Time: 34:12)) track is created.

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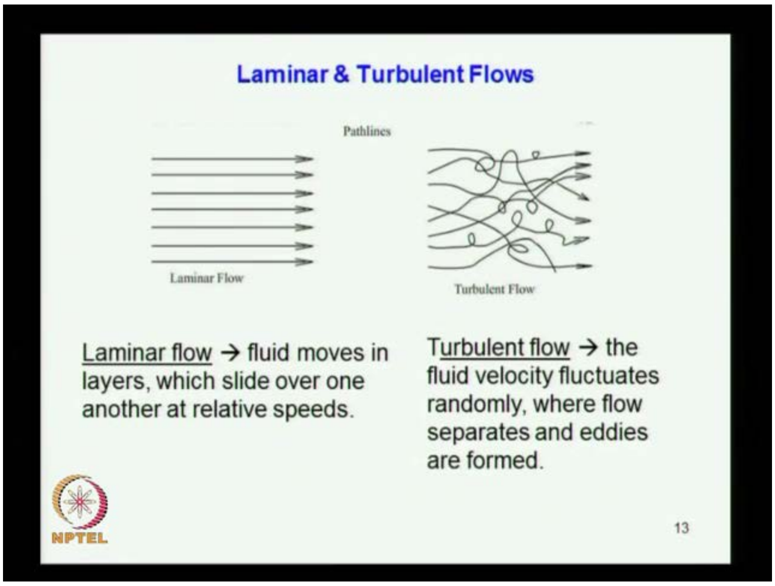

So, this is the difference how you distinguish between laminar, turbulent flow the systematical representation of that in laminar flow means, going layers the flow going layers where the orderly flow going layers. Whereas, when it comes to turbulent flow so that 's what we say that laminar flow they move in orderly layer wise in we will see slide over one another at relative speed. So, there will be a shading affect effect each layer will have different speed. So, that is why you have a velocity gradient, velocity gradient velocity of each layer is different. So, that is a velocity variation which results in friction between layers, the friction between layers results in shear force between layers and when it comes to the body surface the adjacent flow here there is a shear force, along the surface of the also which you call it is a tangential force, tangential stress due to the viscous effect.

Then you integrate the tangential stress over the wet surface it get the total frictional force. So, here this turbulent flow it is more random in nature fluid particles they are not in orderly form they move randomly, the fluctuations are very random and that is how the turbulent flow is observed or defined. You say you they are eddies are formed and you say flows up rise and eddies are formed. So, that is a region where is provatic and you get lot of random behavior for their fluid particle motion.

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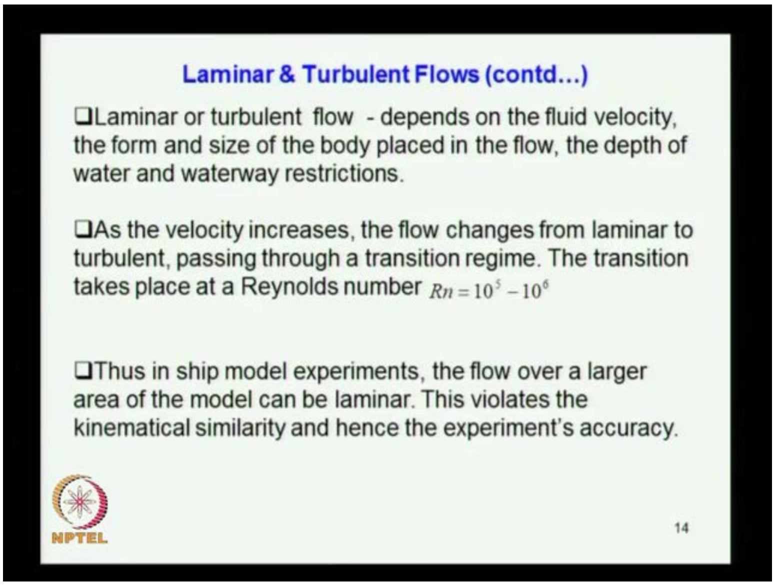

We looked to the laminar and turbulent flows mode and they say laminar that depends on the flow pattern laminar or turbulent flow depends on the fluid velocity because you know that Reynolds number is a factor yours a number, which are gives an indication for the type of flow. If is low you have laminar if it is high, then it serve turbulent and as I said before in between you have a transition region, so this velocity so it depends on Reynolds number, if the velocity is high Reynolds number is high flow become turbulent same body high velocity the same ship if it operates a low speed the flow is more laminar the same ship if it operates in a high speed, it become the boundary layer to the turbulent.

Then that is why it is a it is a dependant on the flow velocity then it depends on the form that is with the form is very smooth stream lined, then they boundary level will be more laminar in nature or more orderly in nature. But if we say there is a sudden change in curvature of the body when flows up rise the turbulent layer become mean, the boundary layer become turbulent. So, that is a different, so form is another parameter then size of the body, size of the body placed in the flow size of the body you see that the here you have the length, which has representing the size of the body.

So, when you can long body, then naturally the Reynolds number will be high for the same velocity, and same fluid and for such a body the boundary layer will be turbulent that is what you have seen in the previous case also, and we discuss about the ship locally. The initial characters recline the lower bow part is smaller. So, the size of that ranging is less and you have lower Reynolds number and laminar flow. So, when go towards shaft the length increases Reynolds number increases, the flow changes transition and then to turbulent region.

Then it depends on the depth of the water and also it depends depth of water, and what are the restrictions. Whenever there is a depth of water means, the water the water will become shallow which also we discuss the previous class, some effect of the shallow water. The water belongs shallow there be a concession at the bottom, the flow at a higher velocity, the higher velocity results again to turbulent.

Similarly, when you have a concessions that is like water way restriction the breadth is canal or river or anything a naturally, you have you will have more constriction for the flow and the velocity of flow further increases. And thus the Reynolds number increases and flow become chance of the flow bound to lay between more turbulent. So, this are the major parameters when we consider the you know laminar or turbulent flow what type of flow what are the parameters, which determine whether the flow round the vessel is going to be laminar turbulent or transition that is if you have to look into what is the velocity of flow. You have to look into the form of the where is stream line, which is form or maybe it is uprightly changing a form, or because a thing will be different for container shape or fast shape which is very fine in shape or triangle shape, which is more full in form.

Then size of the body length of the body in relation to the flow that matters here and water way restrictions where shallow water are you know restrictions, the sideways. All these are determine the type of flow, whether it is laminar or a turbulent. As the velocity increases the flow changes from laminar to turbulent, which I already said when the velocity increases Reynolds number increases. So, Reynolds number from the small value it increases to the higher value and the velocity increases. So, the flow change from laminar to turbulent.

And also there is a small transition period called transition regime, the transition here for a shake generally the transition region is Reynolds number, the order of 10 rise to 5 to 10 rise to 6 is only general guideline it is not strictly for all type of velocity, because we have seen that many other parameters influence the type of flow, as we discussed the previous point.

So, any if it is a Reynolds number is less than 10 rise to 5 you say the flow is generally laminar region, if the Reynolds number is more than 10 rise to 6 then you say is laminar flow is turbulent. So, between 10 rise to 5 and 10 rise to 6 it is going to be a transition region, which is basically a mix of laminar and turbulent it is called as the transition. So, thus in ship model experiments, the flow over a large area of the model can be a laminar as we discussed before because we have seen that the forward side of the forward region the local Reynolds number is less, and flow is laminar. And in the towards the shaft the Reynolds number become higher, and flow become turbulent.

So, this you see the model experiments in case now it is a case of model experiments, the ship models ship model is quiet small may be you have two hundred meter ship gauge model as may be four meter. So, the ship model length if we look to the Reynolds number of the model and ship, the Reynolds number of the ship order comes in the order 10 rise 8, 10 rise 9, whereas the Reynolds number model is equally less and 10 rise to 5 around laminar region.

So, whenever you perform a model test one of the criteria it will be met between the ship and model is a kinematically similarity, that is the flow condition around the ship should be similar, not same should be similar, in the case of a flow around the model. So, that flow condition again depends on the Reynolds number, if you are not able to match the Reynolds number between ship and model the flow kinematics differs. So, the flow kinematical similarity is not achievable between ship and model, because you will not have the same Reynolds number, behind this might small velocity will say that it is also going to be small.

But whereas, in new is almost same why the ship operates in water only difference is sea water model is tested in water it is in fresh water. So, both cases its water kinematical viscous kinematic viscosity remains almost same. So, the denominator remains almost same, we see discuss more about this when we come to the model test and the dimension and all that. So, similarity is difficult to be achieved from the kinematical aspect between the ship and model.

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Similarly, you can see the boundary layer turbulence of a vessel you see the forward side is very almost smooth flow, and when it comes towards the way from the forward we say that it becomes foaming. Hence you always note that the foam region represents the turbulence, in the flow. So, the forward region you can say the local length is small Reynolds number is less and the flow is laminar. So, when it goes towards raft the length increases Reynolds number increases, flow become turbulence.

The turbulence the one which gives the foam affect because the flows up region and there is a random movement. So, this gives the foam generates so it is visible from the operating vessel itself, how it differs from region or forward part of half part of the ship. And also you see that the boundary layer, boundary layer thickness you can see that increases towards the raft, so and the flows up rise. So, this is the you know Reynolds number affect on the flow characteristics around a vessel. The same thing which we observed before we can say that this diagram, we are in his diagram we have seen that this is a laminar flow region thus forward region you have laminar. And then you have the turbulent flow region, so same thing is visible from the photography itself which occurs it is a reality.

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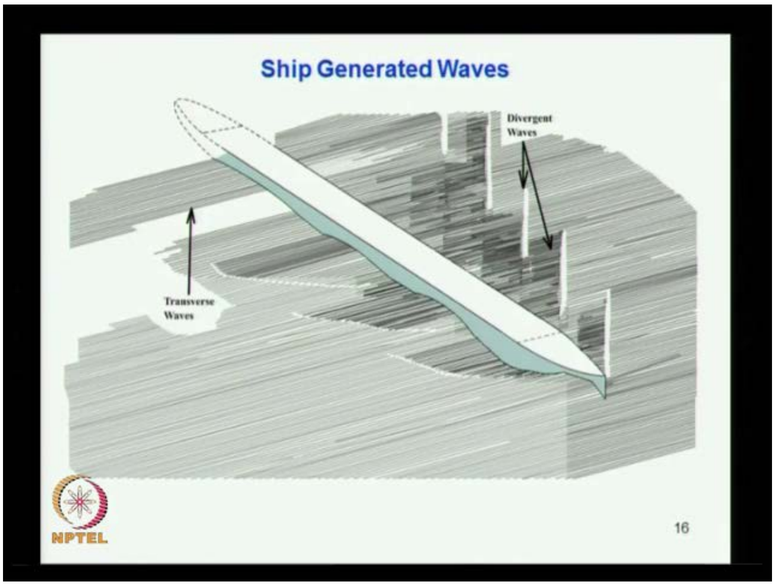

So, next we consider the ship generated base, when the ship is moving forward you must have also noticed that, it consists stilled water the ship is moving forward it generate waves. The wave pattern is very characteristic you see this particular pattern of wave is created. So, it will have a wave just diverging, then you have waves coming across it transverse waves, these two types of is characteristic then it the same thing we can consider that I do not know whether you have noticed that, when you put a in a channel or river, where we consider this a uniform flow.

And often you might have noticed that made in the irrigation canals, they put a pole to measure the water depth the pole may be just coming out of water from the bottom fixed. So, if you notice the flow around that pole you see that there is a pattern of wave generated, it is almost similar to that of a ship moving forward in still water, you see there is a pattern of wave resembling to the same as the previous. So, here you have a wave system generated by the ship, ship you have see the waves are generated from here this is that. So, if waves go propagate, so these are the diverging waves divergent waves which diverge out, and here you can see this these waves under the one that transverse direction.

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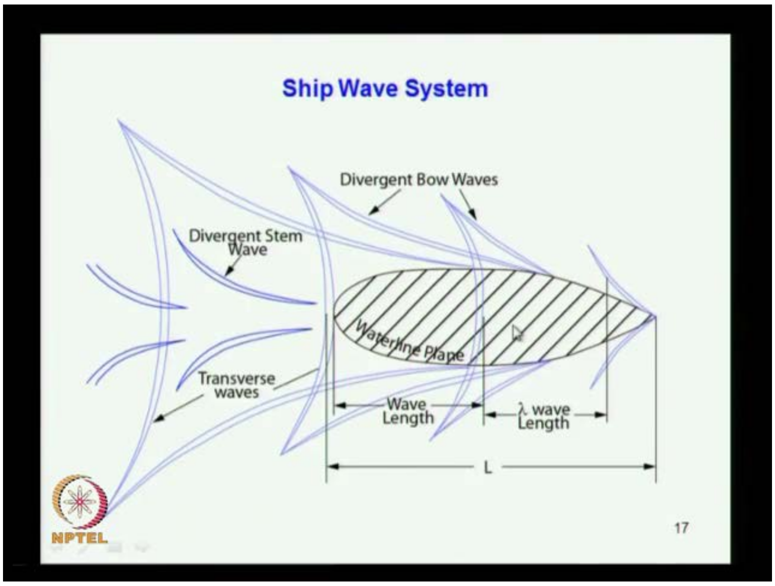

This is another systematic representation of that ship base system, we can see the ship waves are generated and the give this a divergence wave is coming out. And these waves which tangentially you know join at you know, which get such a shape converse shape here this is called the transverse waves. And these waves systems are generated from different regions of the ship, you can say that starting from here another system from here another from here another wave system from here.

So, usually the ship when idle is the form, we say that there are four waves system related from the ship one from the bow, one from this region usually calls the forward shoulder. And this region is a where you call this a aft shoulder regulate somewhere here and this is the stem region. So, four wave systems are generated, but what do you see is only the result anyway you do not may be difficult part, the visibility that is a divergent wave and transits waves are visible remain in the real operating conditions. You will be able to visualize the presence of divergent waves and transverse waves, when a vessel operates.

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This we have already seen discussed about the bow wave.

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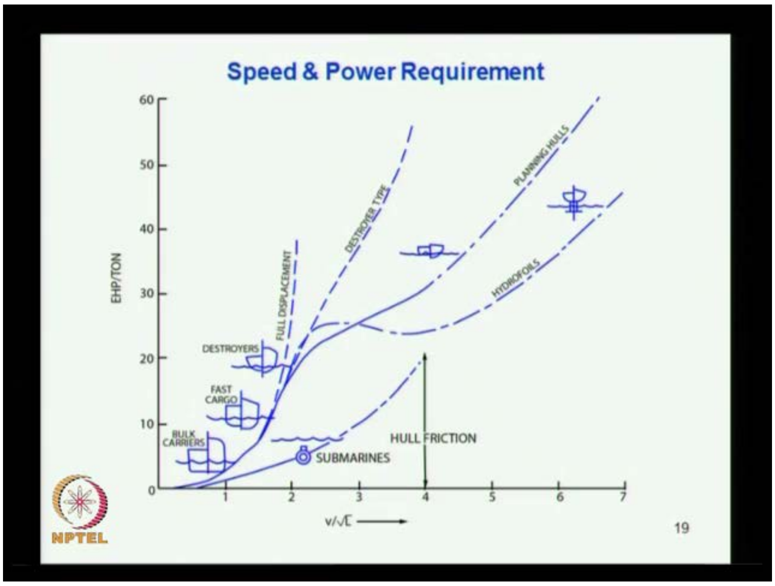

Now we look at the speed and power requirement see you like to have less power and attain high speed may attain high speed with low power. That is your intention of how far it is achievable, you know that when the vessel is ship, I mean when the vessel is water bound. Density of water is much fair compared to that of air. So, when it is water bound, more part under the water you get more resistance, we have seen is proportional depends on the fluid density.

So, if you can evolve the technique where the vessel can be brought out of water, out of water means not completely at least partially. So, that the contact with water will be reduced and the resistance belong less. So, you need to have some technique if you can generate where it can be pushed back. So, here this is some of the types here we will see that hydrofoil craft what is here planning craft all these, these two types they have a system due to hypo dynamic lift it is pushed up.

Sometimes in hydrofoils fully out of water, so that resistance become less and with the same power it can achieve very high speed. So, that is basically this diagram is a comparison of different vessels, what is the power requirement power unit displacement per ton. I think we will continue in the next class, with this power requirement and other aspects of resistancy.