Performance of Marine Vehicles At Sea.

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Lecture No. # 02

Components of Resistance – II

Gentleman, we will talk about a ship coming to the surface now. What is the main difference between a submerged body and a body floating in the surface? The main difference is now the body is moving in two media instead of one medium, and between the media there is a surface which is free, we call it free surface. That surface, the geometry of that surface will depend on interaction between the two media and basically the pressure, do you understand?

Now, suppose for example, you see a water wave on the sea surface, can you tell me what is the pressure on the top of the wave surface?

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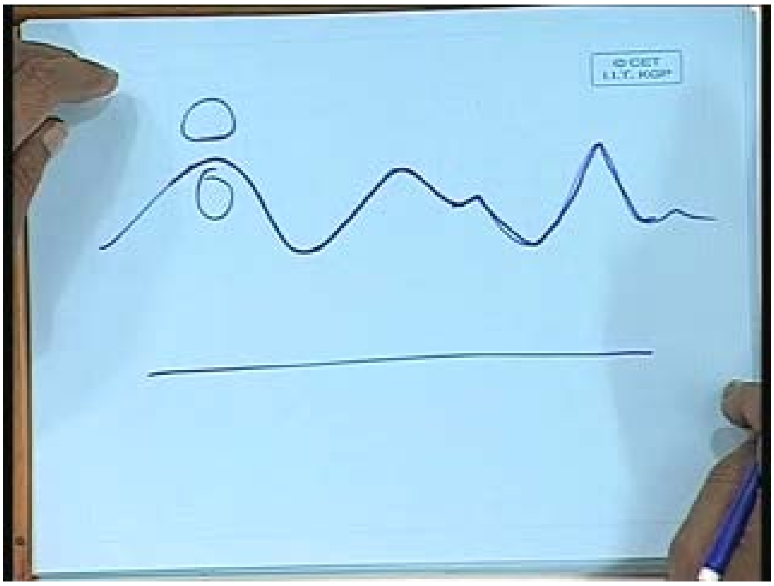

Top of the surface, top surface... Suppose, I have got a wave surface like this, what is the pressure here, here and here, is it constant? No sir. No, then you are in big trouble; it has to be constant and equal to atmospheric pressure.

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((Pressure also less there then only it is going up now pressure))

No, pressure here and here are different, they are equal, they are adjusting themselves in such a manner that the pressure on the surface is constant-it has to be constant, that is the atmospheric pressure.

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((It is the wind keeps the material of the load and then the lower condition then the total straight line))

Yes, if it is straight line, there is no wind, pressure is same- pressure is atmospheric.

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So, that is still we can make out that sample this one is chaining as soon as.

On the free surface it must be constant pressure, this is simply one of the conditions imposed on any flow that the pressure on the free surface- otherwise it will not remain free, it is constraint, it is a free surface- therefore, the pressure at any point is equal to atmospheric pressure on the free surface, it will vary drastically as you go down, it will vary as you go up; the atmospheric pressure will change because of the velocity of the air. Here it will change because how can you have high pressure, a pressure here, and without any variation? So, that will change, but on the surface itself the pressure will be constant. Now, you see, you have got, let us go back to this page when we discussed about distribution of pressure due to potential view.

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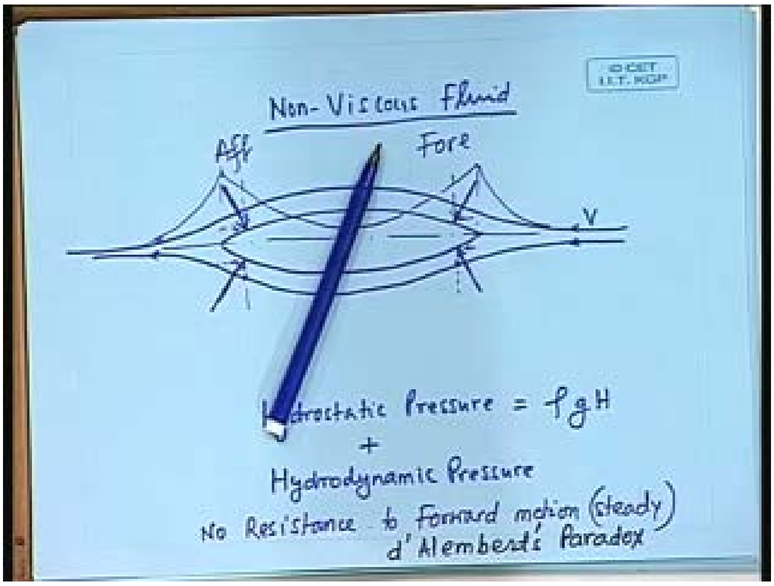

Now, there is a high pressure here and a high pressure here. Now, you have brought the body up to the surface, still the flow around it will generate high pressure here and high pressure here, what will this mean, how will the free surface appear? As soon as you have a high pressure point, it will generate a wave- you understand?- as soon as a high pressure point, it will push the water up till such height that the atmospheric pressure becomes constant, it becomes atmospheric pressure. So, there will be a high, a wave generated due to generation of high pressure due to potential flow or non viscous flow, do you understand that?

Non Viscous

Yes, non Viscous. We consider non viscous, viscosity is there, but apart from that in the forward end we have seen that there is hardly any effect of viscosity. So, primary forward wave generated by the ship will be due to generation of high pressure at the forward end, clear?

So, what will happen is a wave will be generated in the forward end, similarly, a wave will be generated at aft end. There may be small waves generated elsewhere in the ship, we will see it as we go, as we as discuss wave making resistance in more detail. There may be further waves generated in along the length of the ship because of generation of high pressure- wherever there is a high pressure point along the length of the ship, a wave will be generated. Now, how is this wave generated?

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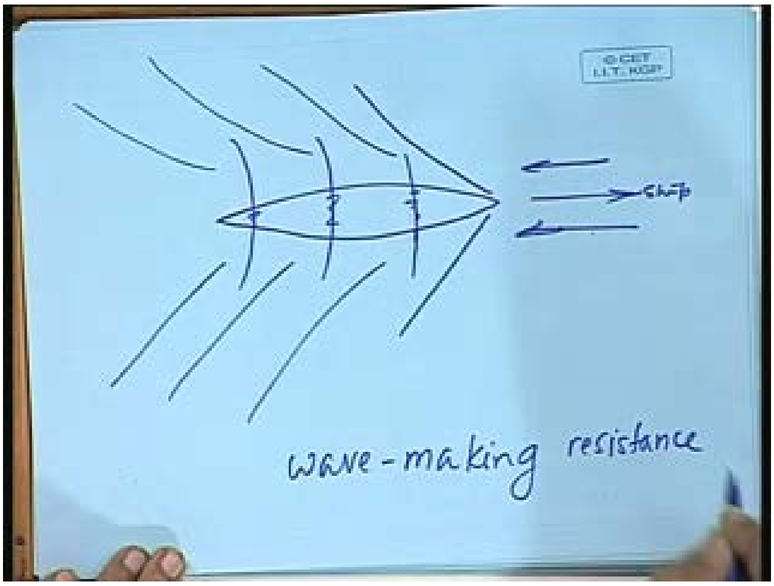

There are two sets of waves again, we will see it in further detail later on, but primarily there will be a set of transverse waves which are transverse to a direction of the ship going away like that. And ship is moving like this, that is, water is moving like this in ship that means, water is moving in the opposite direction- ((this is a plan)). There will be a set of waves going away like this is called divergent waves, that is, a set of waves which will go far away in the transverse direction, they will diverge, and a set of transverse waves; waves, the crest of which is in the transverse direction to the longitudinal axis of the ship.

You have seen this, you all must have seen this, you must have photographs where they show the divergent waves of a ship, yes? And if you have observed a flow around a ship, you would find that near the ship body- see this is, this is the body so, you would not see anything here, is it not?- you will see crest near the ship hull, which is going in the transverse direction- have you seen?- so, you have two waves systems generated around the body. Now, these waves, as we know waves are carriers of energy so, to sustain this wave making in a continuous manner form the ship, the ship will have to spend energy that is called wave making resistance, which was not there when the body was submerged in water- this was not there, no waves were created, do you understand?

Just imagine for a movement that there is no viscosity; just imagine for a movement that the fluid is without any viscosity like the non viscous fluid we saw in this case. When the body was immersed we found that the opposing force is equal to the supporting force and we had the D’alembert’s paradox, now we have brought the same body up, same non viscous fluid, but now the waves are being generated, waves are being generated means-what?- energy is being taken out, now you cannot say that the resistance is zero, do you understand? Physically you see the waves are being, waves are, you might have learnt that waves are basically a gravity phenomenon and it is not affected by friction, by viscosity.

Yes, it is not affected by viscosity. So, therefore, all ocean waves, that is true for all ocean waves, in fact, that is true for all waves- basically a pressure phenomenon. Here also we have a pressure phenomena unlike the body when it has submerged- you had the D'alembert's paradox that there was no assuming a non viscous fluid; there was no resistance to forward motion as the body comes up to the surface, there is resistance to forward motion due to generation of waves this is also due to a pressure phenomenon, but the effects are different, you understood?

Let us see what happens to viscosity? Is viscosity there? Of course, it is there. You have the frictional resistance, as we discussed the boundary layer develops and it becomes wider as you go across the back of the ship, same thin boundary layer coming right up to the surface free surface; so there is a small thin boundary layer right on the free surface itself along with the wave, you have the viscous pressure resistance, how does it manifest here? Here the stern wave is damped; though the stern wave effect will be same, if you try to reduce the, it will try to support the motion, we have seen that, that depends on, now it depends on where the stern wave is generated for example, if the stern wave is due to some hard shaping of your body under water, if the stern is stern wave is generated aft of the stern, then you may not get the support, can you understand this?

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We are making a strictly a surface phenomenon. We are making a strictly a surface phenomenon, that is correct, wave making a strictly a surface phenomenon, as you go down there is no wave making.

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((Only that moving or may be drank usage))

That will also be there on the surface shores.

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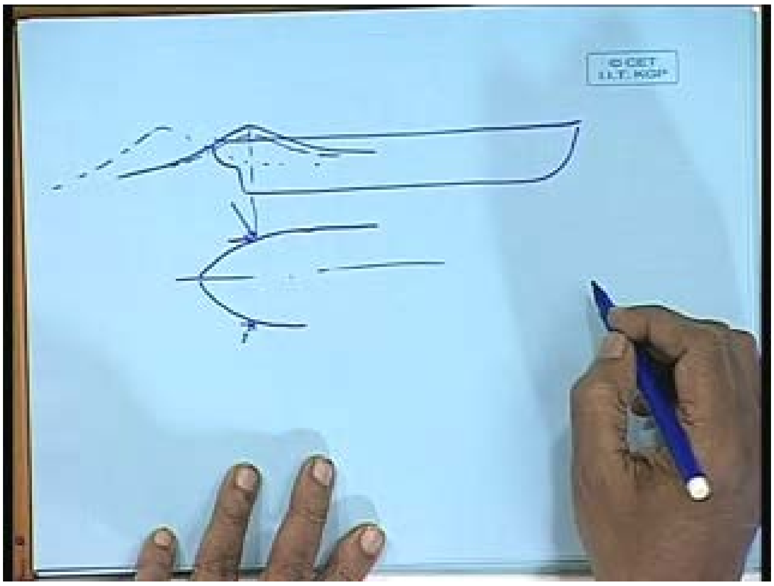

Let us take two cases. What I am saying, suppose you got a wave, which has a stern like, I am not talking about the aft, let us say this stern pressure is high here, so when the body is here, if I draw the body here, the pressure is high here therefore, there is a large component supporting the motion, this component, is that clear?

Let us take second case. Somehow the crest is generated here and there is a trough here, what does this trough mean? Low pressure, so this now becomes this small, so this reduces, can you see this? So, now, the support that you are getting from the stern wave you are not getting, so forward resistance is more. So, where the wave is generated has an effect on the total resistance of the ship because it is not only dependent on the wave height as such, which determines the pressure, it also depends on the slope of the body at that point.

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((Then how we control this)).

You will see that, let us not go very forward. First, let us understand wave making is a very complicated phenomenon and at the stern it becomes more complicated because you have got the boundary layer now, already blunting of pressure is there; so, if I considered a body without any viscosity, you may, I may have got a wave profile which looks like this, but as soon as I bring in viscosity the wave profile will reduce in size, then again you see the viscous pressure is coming into effect, is that understood?

So, this is the wave making phenomenon which is dependent on the shape of the body primarily, at the water level and the curvature all along the body, all along the length and towards the aft tent, there is a little blunting of the wave making resistance due to presence of boundary layer. So, from this you can understand the wave making part is primarily a contribution of the fore body of the ship, aft body does play a part we will see this, but primarily the fore body.

So, we have this wave making resistance, now let us come to the fore body once again. Let us take a very blunt ship like a tanker or a bulk carrier where the fore body beam is large, block coefficient is very high 0.85 or even higher than that- you know what is block coefficient is- and then what happens the water lines close in at the water level not like this, but something like this.

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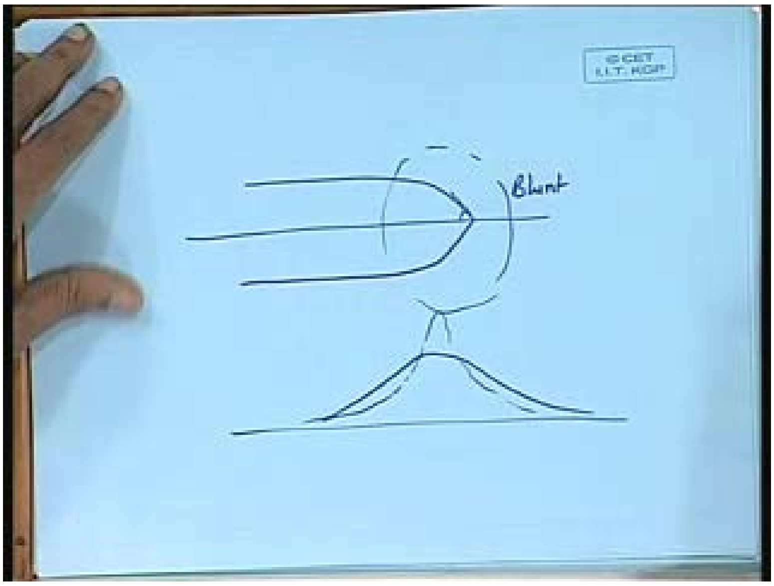

You can see this portion is blunt, a large angle of entrance- half angle of entrance- so the discontinuity is very large, what will be its effect? We can well imagine that it will give a very large wave slope on the surface because wave will depend on the discontinuity of the body, and the discontinuity is very large here therefore, you will get a very large wave and that wave cannot come along the length of the ship, but it will be pushed out because the body is there- you understand- those we talked about those divergent waves, those divergent waves will now go very at a large angle.

Almost transverse to a ship

Almost transverse to a ship. So, this waves that is being created will have large amplitude, high amplitude even at low speed and it will try to be, it will be pushed to the side. So, the wave slope, the slope of the wave will become high, do you understand? If I had a wave previously like this, now the wave will become like this, do you understand? And what is the effect of wave slope, can you tell me? A gravity wave which has a very large slope, what is its effect?

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((More Resistance))

It cannot retain itself, it cannot maintain the shape anymore, it will break- what you see in the sea coast- because of the reduction of depth as the wave comes to the coast the wave height increases and it cannot be maintained and it breaks, same thing will happen here, a large wave slope will be generated, the waves will start climbing up and it cannot maintain itself, so it will break. As soon as it breaks, like it happens in coast, where does the energy go in the coastal wave breaking, where does the energy go? It goes in the form of sound and creation of eddies, that is how that wave is totally observed by the sand and the water particles, eddies are formed, you see the white mass and the energy goes.

So, here, similarly, now, the wave will not propagate as wave anymore once it breaks, you will see the white mass, you have seen in large ships you will see the white mass right in front like this- you have seen that?- that means the wave has broken; you do not see large waves far beyond, you will see waves in fine smooth ships, but in large bulk carriers and tankers you will not see those big nice waves that you saw before, but you will see in the front the white fluid, flower like things. So, there is a big difference between these two phenomena, in one case the waves that carrying away the energy as wave making resistances, in the other case though the waves are generated due to a potential flow effect its manifestation is in breaking waves in that this thing, that also takes away energy, initial formation of this was due to taking away of the energy, but its manifestation is in the form of wave breaking.

So, you see when somebody tells you that in a slow full form ship wave making resistance is almost negligible, it is true because you cannot see waves, but there is a large amount of wave breaking resistance, do you understand? Similarly, in the forward and bottom there may be eddies and separations exactly for the same reason as we had in the aft because of the sharpness of the curvature, again it is a phenomenon of full form ships; in fine form ships like frigates or naval vessels or container ships and passenger ships this may not be there, but in case of full form ships this is something which you may expect that some drag resistances, some formation of eddies and vortices and going away from the bilges of the forward end- forward bilges- take away energy. So, there will be that component of resistances also coming.

So, on a surface ship you will have the wave making resistances, depending on the fore body shape you may also have wave breaking resistances, you will have the frictional resistances, you will have the separation drag or eddy drag and you may also have the viscous pressure drag which may be substantial, may be, we do not know.

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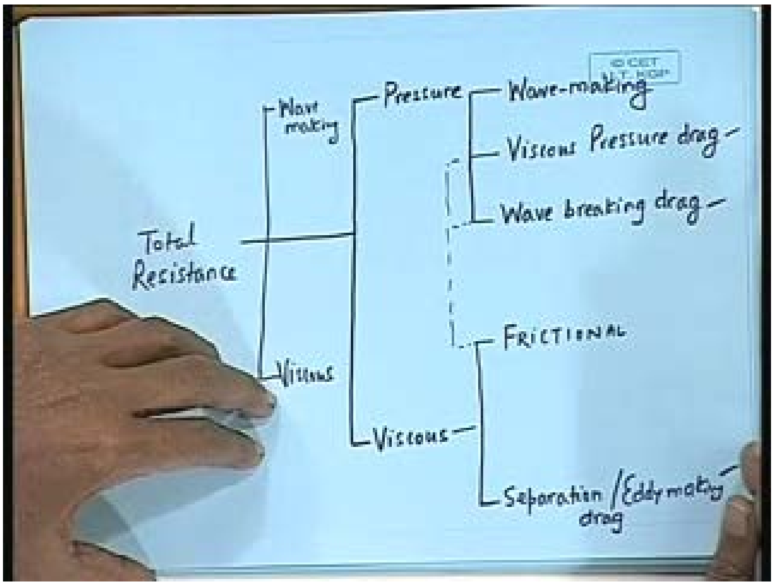

So, if I divide my resistance now into various components, how will I get? There are two phenomena: basically, pressure and viscous. I also want to mention to you, please understand that pressure resistance is a normal pressure on the body surface- normal force- the components in the axial direction give us resistance, the components in the transverse direction cancel each other. Similarly, the viscous resistance is primarily a tangential force, just perpendicular to the pressure, can you understand that? Pressure, if a body is there pressure is acting perpendicular, and this is tangential to the body.

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((So, it will perpendicular that again))

More or less, understand that there is a boundary layer which makes adjustments, so this perpendicular will be little bit less than perpendicular, but primarily this is tangential force and this is normal force.

Now, pressure resistance mainly shows itself as wave making, then it has another effect, viscous pressure drag- and what we have seen- it also generates; and viscous, frictional and separation or eddy making, is that clear? Now, these pressure and viscous can be, you can see that these two effects are due to viscosity- viscous pressure drag and vibrating drag; so, sometimes these two are included in the viscous resistances, do you understand? Though their origin is in pressure their manifestation is viscosity. So, viscous resistance consist of all these. So, sometimes the resistance is composed of two cases only- wave making and viscous; sometimes we say wave making and viscous, sometimes we say pressure and viscous, where these components are both reflected in pressure and viscosity, is that clear?

Now, this frictional resistance, we will see this in more detail perhaps in the next class itself. But understand that this is not exactly same as if the body was completely two dimensional in nature; that is if I had a flat plate, if I had a flat plate which I moved in water, it should have experienced some frictional resistance; if I had a nice smooth stream line body, which did not have ends, it could have been very large in depth and very large in length, this could be considered as two dimensional body, again it would have had two dimensional friction, that is, all the flow would have been horizontal.

But when you come to a three dimensional body like a ship things change, I like to explain this to you. What do you have in a ship is we have a water line; ends come to an end in some shape and what happens in the sectional plane? There is a bilge which curves in the forward end, this in the middle it is this wide and it curves in, but in forward end this body, this entire body comes in like this- do you understand?- and same happens to the aft body.

So, if you look at the body shape, it is highly three dimensional, how does the flow happen around this body? If we start form the free surface, we know that on the free surface there is a wave profile, and wave profile you have a crest in the front, a trough in the middle and a crest in the aft normally, this will be the case around the ship, far away you will have the divergent and transverse waves.

If I trace a particle just below the free surface what will I see, how will the particle go, will it go parallel to the wave or it will go some other manner? It will in fact, go in some other manner, it will normally go very fast downwards expanding as it goes; if there are two particles in the central line one going port one going starboard, it will not go horizontally like this nor will it go following the wave profile like this, but it will dip down sharply, depending on the curvature of the body it will dip down sharply and as it dips down suddenly near the bilges it finds that it has to go like this because the body has closed- do you understand what I am saying?- that is, the flow on the free surface went like this, but just below the free surface the water will go like this and then it will go like this.

So, we see it has got a transverse component is going out, it has got a vertical component going down and at the bottom it has got a change in direction all the way. So, flow is highly complex, and the viscous resistance will depend on this complex flow going around the body, which is no more anywhere near two dimensional flow, do you understand this? I do not know whether you are understanding or not understanding.

In a two dimensional flow, flow will go in two dimension, that is, in one plane, either in the horizontal plane or vertical plane, in case of ships it will horizontal, it will go in this, but when it is going down like this, just imagine that the distance travelled is more apart from anything else plus there may be some eddy making and all those things because of the curvatures ((incomplete))

So, the frictional resistance to a flat plate and a frictional resistance due to a body having the same weighted surface, but a three dimensional shape, will be different. So, sometimes we say it is a form effect. So, normally this, this and this three components together we call friction form effect, because it is very difficult to calculate this, this and this separately and their effect of form only.

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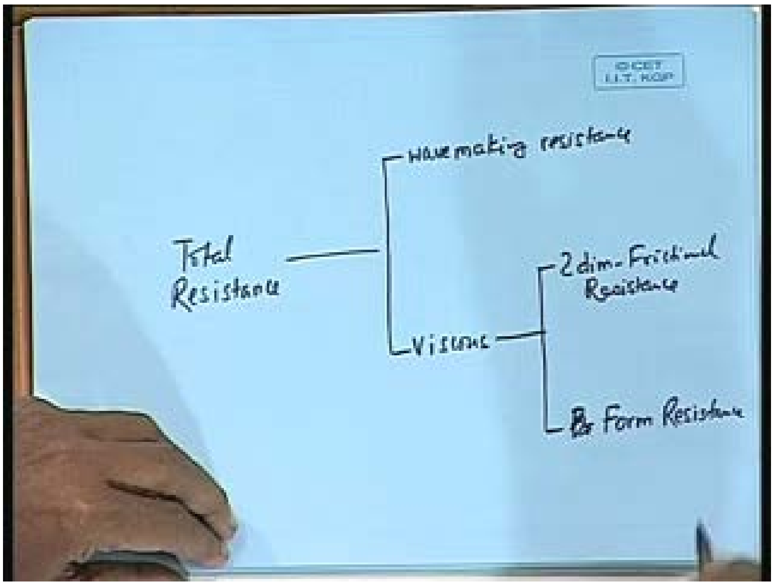

So, in conventional components of resistance analysis we say that total resistance is composed of wave making resistance and viscous resistance, which is two dimensional frictional resistance and form effect form resistance due to form. Normally, this is taken as a percentage of this; so, we have frictional resistance estimate in some manner multiplied by constant, do you understand?

So, this takes into account separation and eddy making, wave breaking if any and viscous pressure track, unless we go into more details of how to calculate each component separately, am I clear? Can we calculate each component separately? Next question is can we calculate each component separately? We look at this little more deeper in our future classes, but so far, as far as the present technical knowledge level goes it is extremely difficult to calculate all components of resistance theoretically to an accurate level which can be used by engineering practices- powering of ships or something more on this.

So, what is normally done till now is model experiments and how to get the resistance extrapolated to the full scale from model experiments, this you will be looking at more thoroughly. Now, so far we have only talked about water resistance, that too water resistance in calm water, now what are the other components of resistance that affect powering of a ship? Some of it you can well imagine, air resistance will be one, ((every resistance)) to forward motion in air also, only thing it is very small compared to water resistance; therefore, we do not go scientifically into estimating air resistance, we have some statistical data drawn from various wind tunnel experiments of the ship above water portion, and we can extrapolate statistically to different ships and different superstructure configuration.

What are the components of resistance are there? You have the trial resistance as we mentioned, trial will be mainly the air resistance component that will come in, then in a ship you may have some appendages typically, in a merchant vessel we will have a bilge ((skills)) and you will have a radar, propeller we do not consider resistance because-because of what- propeller if it is left free, if it is free to rotate, then its resistance is very low, but if it is locked its resistance is very high.

You do not normally tow a ship with the propeller locked, so that is not affecting our powering. Whereas, the radar appendages bossings if you have, shaft bossings, shaft brackets, sonar dooms in naval vessels, bow thruster units in the forward part of the ship or stern thruster, these all had to resistance. So, all those appendages have to be added and the trial resistance at zero speed condition can be calculated.

(Audio not clear from 34:24 to 34:31 min)

((It is a normal part of the hull Bal boa's flow))

Balboa's flow is a part of the integral part of the hull.

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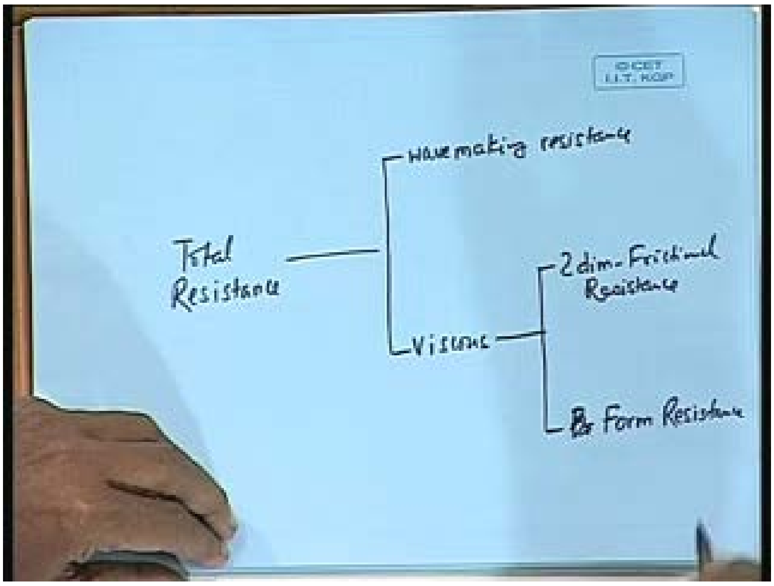

No, it is not like ((build scale)), ((build scale)) is a flat surface, its effect is mainly in frictional resistance. So, flat plate,, unless this one little problem with ((build scale)) if the ((build scale)) is aligned in the in a stream line that would flow pass the ship, then the resistance due to ((build scale)) is only due to two dimensional friction, but if it is not aligned in a stream line the built skill itself may disturb the flow creating separation and eddies.

Therefore, before drawing of the ((build scale)), before finalizing the ((build scale)) it is essential to do a what is called a paint flow test on the model; you have to see the direction of water flow on a model and based on that you have to align your ((build scale)) otherwise, it will, see whenever there is a flow disturbance is not only that the drag is more, it is that you will have a humming sound because body will vibrate, and that vibration if it is sufficiently large, it can affect your ship which is a case in many small vessels, large vessels you do not realize it because the vibratory force is very low compared to the whole ship, but in small vessels which are very much appendage oriented forms- they have large number of appendage like bossings and ((rud, tut)) some things like that, they have many times this problem with flow and this shows up in the living conditions inside the ship, working condition even machinery operation etcetera.

So, normally, the trial condition it is told that the ship should be able to, the trial speed is to be obtained of, in a wind speed up to before scale three, so how do we take that into account? It is mainly the wind resistance which is augmented due to the large wind speed; we normally up to before scale three the sea is rippling only and we assume that there will be no added resistance due to waves, as is calm water with regard to sea condition, but wind resistance increases, because before scale three means, it will be another 20 knots or so wind speed added to the speed of the ship. See, when a ship is going at 15 knot the wind is blowing fast at the same speed, fifteen knots now, if on top of that there is before scale three there is another 20 knots wind added to it so, 15 plus 20, 35 knots. So, that wind resistance part increases, that has to be take into account in trial condition.

In service condition it is very difficult to estimate what will be the added resistance due to waves because wave condition itself keeps varying. Sometimes we assume a standard sea state in a particular sea wave, say North Atlantic or Pacific or something, we assume a standard sea condition and we can add some value, due to such a sea condition which may be supported by model experiments. But so much of thoroughness is not required; what we can do is for sea condition we can add a percentage of total resistance say ten to fifteen percent depending on the sea for service allowance, but what is more interesting is as the ship goes into service its paint peels off, the ship corrodes and fouling takes place, that give a large chunk of increase in resistance that has to be added to resistance if we really want to get a good estimate of the service speed.

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((The flat plate that will also effect))

Normally not. Such fluctuations in the body surface if it is within the boundary layer, then the boundary layer takes care of it, because, we will see this; we are actually talking about turbulent boundary layer, boundary layer which is turbulent- there are two types of boundary layer: laminar and turbulent- so, if I am talking about turbulent boundary layer, then this is automatically taken care of, small variations or weld marks on the ship, but on the other hand they add to roughness of the ship, so due to roughness there is an increase in turbulence that has to be taken to your account, that has to be taken to account.

So, but in general we do not bother because you see previously ships were riveted, lap jointed and riveted, that used to add a large portion to resistance, after the welding has come and with thorough supervision the weld mark, the discontinuity due to weld mark is not so prominent. So, what we, so, actually if we are talking of model experiments and full scale tow rope resistance comparison, model vessel is very smooth either in wax or in fiber glass or whatever you make the model surface is very smooth, but in actual ship the surface is rough, it can never be to that smoothness. So, what we do is we add what is called a correlation allowance, that is a small increase in the resistance as we extrapolate it to full scale to take into account the initial roughness of the ship, which includes weld marks and any discontinuity in the hull surface, one thing must you understood any discontinuity must necessarily be small if it is large, it will create separation- that is not taken into account.

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So, we will talk about this when we talk about extrapolation from model to ship which is going to be our main theme in these set of lectures, we will see how we can take into account such discontinuities that happened. So, next class we look at, I think we will first look at frictional resistance and then look at wave making resistance and then we will see model experiments. Thank you.