Performance of Marine Vehicles at Sea

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Lecture No. # 07

Model Experiments

Good morning. Today, we will talk about model experiments and extrapolation to full scale.

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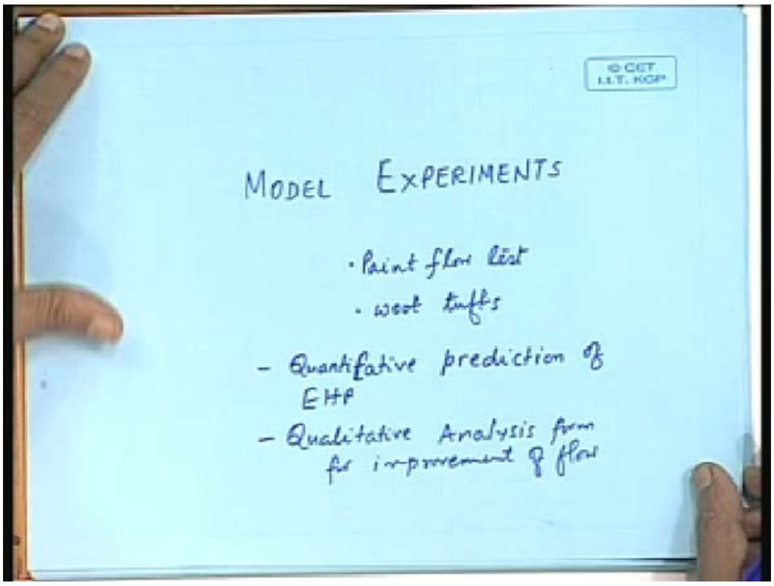

Of course, our model experiments will be limited to resistance thrust only and sometimes this experiment is called towing experiment because, as we have defined resistance before, it is the resistance of towing a vessel without its propeller working in water, so sometimes this is called towing experiments or resistance due to towing a model in a tank.

Why do we require model experiments? One, of course, we know, is to obtain the resistance of the ship in full scale; there is another reason why we do model experiments

- as I have explained earlier, we know that the resistance of a vessel cannot be accurately predicted by theoretical means, this also means that we cannot calculate the flow characteristics of water around the ship hulk theoretically very accurately, we also know that if the flow characteristics are bad, then resistance may go substantially, so it is sometimes necessary to do model experiments to find out how good the flow is around a ship, and if the flow is not as we have desired, it may be a necessary to change the model shape at particular locations, or even change the entire fore body or aft body of the model till such time that we can get a better flow hence, less resistance.

Flow is important not only from resistance point of view, but also for many other problems such as flow induced vibrations. Imagine a strut projecting out of the ship for some purpose such as forming a bracket, for holding the shaft, if the bracket is not aligned in the direction of flow, there is bound to be eddy shedding or separation near the bracket- in the aft end of the bracket- this separated flow may cause flutter of the shaft bracket or vibration; similar thing can happen due to flow around a rudder behind a ship, or due to unevenness of flow there can be vibration of the aft body, which is not fully supported by buoyancy that is, the overhang of the aft portion.

So, these vibrations can lead to harmful effects on the ship, causing vibration in the accommodation or even causing vibrations inside engine room or in particular locations depending on what type of ship, what type of flow disturbance you have. So, it is many times required to visualize the flow through a model experiment, now, how do you visualize the flow? We have seen that flow can be, we can understand something about the flow by means of a paint flow test- I have mentioned this before- and sometimes we use wool tufts, small woolen threads attached by means of pins to a model body at various locations, and when the flow past it is seen either through a glass panel mounted on the wall of the towing tank, which generally not the case, or by video recording the flow, the wool tuft positions on the side of the model and we can realize if the flow is stream lined or there is existence of separated flow- in that case, it is possible to modify the model shape and do the test again.

Sometimes we may do the model test for finding the best fore body or aft body shape such as we can have two or three different bulb shapes attached to the same model, the remaining portion remaining same, test them in a towing tank and decide which should be the best shape available to us. So, model experiments are done for a quantitative prediction of, I call it like this, quantitative prediction of EHP - I have told you what is EHP, is it not, effective horse power-or qualitative analysis of form for improvement of flow. So, this is the reason why we do model experiments.

We will not talk about paint flow test or wool tufts test anymore because it is a fairly simple test, we will talk about the quantitative prediction of EHP from a model experiment. So, what are the requirements of a model experiment? There are two kinds of similarities we will be looking at when we conduct a model experiment. As we have seen the Froude similarity is the basis of model experiments, which includes geometric similarity between the model and the ship that means, every linear dimension of the ship, of the model, should be directly proportional to the linear dimension of the ship.

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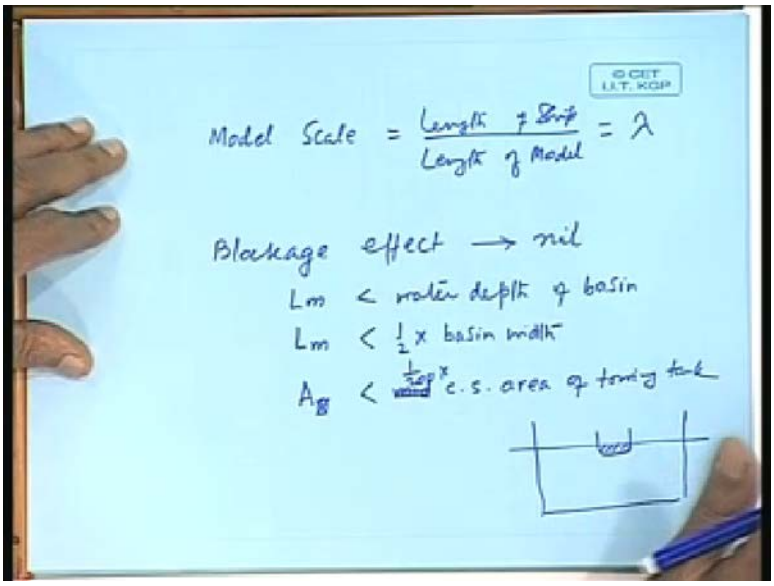

So, what happens is you come across a model scale, you have to have a scale of the model, which is defined as length of ship divided by length of model, and generally this is represented by the Greek letter lambda. So, if I have got a 100 meter ship and we want to test a model of that, I may decide to go for a 2 meter model length, then the scale will be 50- then every model dimension is reduced by the same ratio. So, what happens to displacement model, displacement, how much should be the displacement? Displacement is reduced from the actual displacement of the ship by lambda cubed times because displacement is multiplication of three length dimensions. Similarly, weighted surface will be reduced by lambda square- all area dimensions will be reduced by lambda square and all volume dimensions including weight will be reduce by lambda cubed.

What is the tolerance we can give in model manufacture? It is almost impossible to manufacture a model to exact dimensions of the model, as we get by dividing by lambda, so one has to be careful to see that tolerances are within limit; normally, on breadth we give about a millimeter tolerance and on length we give an allowance of 2 millimeters- within that tolerance you should be able to manufacture model, making sure the tolerance does not mean generation of roughness on the model surface or introduction of additional curvatures than what the main ship should have.

IITC defines, IITC has given tolerance limits on model scale and that is ITTC 78, I think, and one can see the IITC proceedings to know exactly what is the model tolerances recommended by a combined body of all tanks. One point I must mention here is that if you have a larger model, then your tolerances can be better than if you have a smaller model. Let us say, whatever be the material of the model you can reach only a certain level of accuracy say for example, you are generating a surface, that surface can be plus minus 1 millimeter of exact nature, now if you have a 2 meter model, then you have that same plus minus 1 millimeter tolerance, and if you have a 5 meter model you again have plus minus 1 millimeter on tolerance- you can understand that the accuracy level for a larger model increases, so if you want very accurate results it is preferable to go for a larger model.

What is the model made of? Models all over the world are made of wood, wax or FRP. Wooden models were made in earlier years where they had to be hand finished to get the exact shape of the ship and it used to take a long time, but with increasing or rather depleted wood sources and the skill for manufacturing models in wood reducing, we have switched over to wax models, which we do in our hydro dynamics laboratory here- wax models over a wooden, wood and bamboo frame work is called a composite model made of wood and wax. Or one can make an FRP model- so, there you make a wax plug, a female mold and then the male model. The advantage of making a FRP model is, which is thin, but it is strong and it can be preserved- wooden model can also be preserved, but wax models cannot be preserved, so wherever you do not require preservation of the model you can go for a wax model and the model can be destroyed afterwards.

Why do we require preserve the model? It may be necessary for us to study the model characteristics later on, or also do further tests which were not required at the beginning such as a propulsion test by fitting a propeller, or doing maneuvering test, or sea keeping test if need arises later on. Nowadays, if some tanks are using PVC foam- polyvinyl chloride foam- for manufacturing a model, that also is light, but it does not give the inner surface as much as a FRP model can give for housing other equipments and instruments. The model finish must be smooth- this we have discussed- model finish must be absolutely smooth, less than 25 microns roughness should be there- a micron is 10 to the power of minus 6 meters or 10 to the power minus 3 millimeters- the roughness of the model scale should be less than 25 millimeters, which can be considered as zero, so there is no allowance on model for roughness.

I have talked about larger models. Now, if you make a larger model, the model cost is more and also the facility in which this larger model can be tested will have to be different from the facility in which a smaller model can be tested; you require large quantity of force to be measured because larger model will give you large force, so you require different sets of instruments and equipment to measure them. So, therefore, larger models are more expensive, and larger model testing is more expensive because you are going to a bigger tank where more sophisticated equipments are there. So, the scale at this stage one has to determine based on your expense account and the accuracy level you want- it is a compromise between the two. The other aspect you must remember, if you have to go for a propulsion test, subsequently the propeller scale will affect the model scale because the propeller has to be fitted behind the ship; so, that is the other reason for which you can determine, if you are going for a propulsion test later on, then you must determine the scale of the propeller and the ship model simultaneously so that later on you do not get any problem.

Now, I mentioned that the tank in which we test the model will be small in case of small models and large in large models, why did I say that, can I not test a 5 meter model in a smaller tank? What happens, actually is, when I move a larger model in a smaller tank the waves that emanate- we have seen the waves going from the ship, the divergent waves, they hit the side walls generating waves, but they normally travel backwards, but what happens is the flow, the distance between the ship side and the tank side reduces on both sides and also the height from the water below the bottom of the ship reduces. As a result, you can imagine if I restrict the flow, then there is a tendency of the flow to go faster that is, the velocity of water what it would have been in open sea would be slightly more if I have the restrictions on the sides and the bottom, which would therefore, give a higher resistance. So, what we will be measuring will have slightly higher value than what it would have been if the tank was larger representing an infinite water domain- we do not want this to happen, that, this particular aspect is called blockage.

So, our blockage effect should be nil normally, for this there are some standards set by number of experiments done over may be 50-60 or 100 years that is, length of model should be less than water depth of basin. These are some thumb rules which are accepted world over: length of model should also be less than half the basin width and that the, one that is most severe is mid ship area of the model should be less than mid area, cross sectional area of the tank- cross sectional area of the tank is breadth of the tank into depth of water. So, mid ship area of the ship that is, if this is my tank, this is my water level, the model mid ship area, this area should be one-two hundredth or less of- I have not written the quantity- one by two hundred into cross sectional area of the tank towing tank. That is total cross sectional area of the tank divided by two hundred, that, my mid ship area should be less than that then I can assume there is no blockage effect; if I cannot achieve this, then I should make some blockage correction- there is number of literature available in standard text books on resistance which give the references of literature on blockage correction that can be used.

Now, when I say this, this blockage effect will primarily represent the wave making resistance, it will, because the flow will affect the wave making. So, in ships which are moving very slowly like barges and all, sometimes we may go for slightly larger models without incorporating a blockage effect. So, this will generally depend on experience of the towing tank personal. The other thing, other, this is regarding geometric similarity, it has so many effects, so you have to determine the model scale and make the model properly so that (( ))...

And the other similarity that must be maintained is called the kinematic similarity or similarity of flow between the model and ship; if flow similarity is not maintained, then water resistance we measure for the model does not represent what happens in case of ship, and if you have geometrically similar model, the potential flow similarity is automatically obtained that is- the wave making, this we have seen, CRmodel is equal to CRship.

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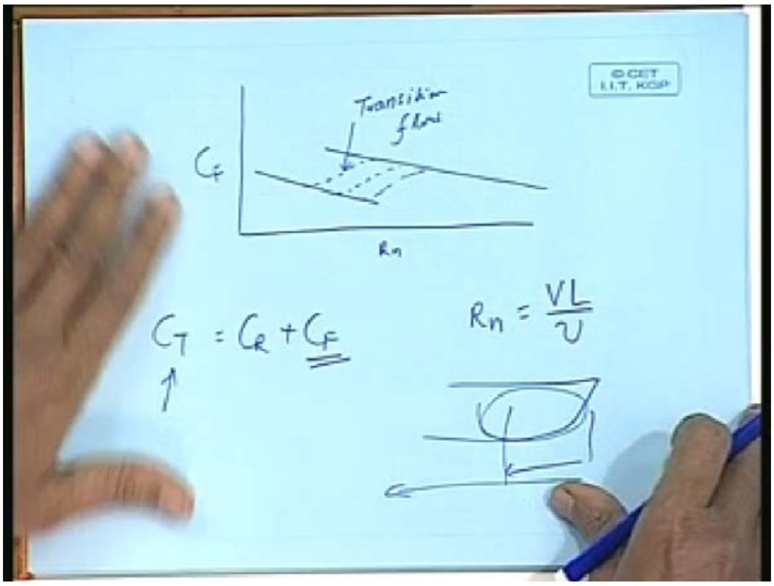

The main problem comes in frictional resistance. Why? We have seen. Let me draw it again, if I plot this as a function of Reynolds number CF- what I have seen?- I have seen the laminar flow resistance curve goes like this and the turbulent flow goes like this, this is if you remember we defined a Blasius laminar flow line and a Prandtl-Von Karman turbulence line, which was later advanced to the so called ITTC line, which is slightly higher than this straightly higher than this, slightly higher than Prandtl-Von Karman line.

But basically, whatever formulation you take there will be a formulation separate for laminar flow, and how do they match, how do they, how does the CF catch up with it? It should be a continuous curve; you can see this overlap region is a region where both laminar and turbulent flow stays that is, laminar flow changes to turbulent flow over a region of Reynolds number and this is normally called the transition flow, like this. Transition flow depends on local conditions take for example, a ship, we know that the model is much smaller in scale therefore, if I take the Reynolds number VL over mu for the model, then it will be much smaller than that of the ship. So, in the model, the model may be in totally laminar region and it will be more so if the model is smaller- can you understand that? This is our formulation for Reynolds number, model is being tested in fresh water, ships runs in sea water, there will be slight difference in viscosity, but they are nearly same.

Now, v, since we are maintaining Froude similarity, v of model will be reduced from v of ship by square root of lambda times, length reduces by lambda times, so this whole Reynolds number reduces by lambda to the power one and half. So, if I have a smaller model, this will reduce further than if I had a larger model, so larger model will have larger Reynolds number, so automatically there would be more turbulent flow in a larger model than in a smaller model.

Also we have seen there is the fore part of the model where the flow is just taking place, just starting to develop the boundary layer, the local Reynolds number that is, flow from the beginning till that position, somewhere here in this region, turbulence has not taken place yet because this is the length here is much smaller than the whole length of the model- do you understand? So, in the initial part of the ship there may be existence of laminar flow, initial part of the model, there may be existence of laminar flow over quite a region. So, if we do not make corrections to this, then again we will be measuring a resistance which is less than what would happen in the case of a ship. We are measuring the total resistance, see what will happen? We will measure little less resistance because of flow is turbulent and then- sorry- because the flow is laminar we will measure less resistance then, we will use the turbulent friction line to reduce the frictional resistance, so CR that you will get will be less than what the ship would actually, am I clear?

We have said CT equal to CR plus CF, now if CT is less because of presence of laminar flow, this CF we are calculating on the basis of ITTC line, which is turbulent flow, so this CR will be less. So, when you extrapolate to ship we use a less CR than actually what the ship should have, so we will be under predicting resistance, which is not at all desirable- we can over predict a little bit, but you cannot under predict.

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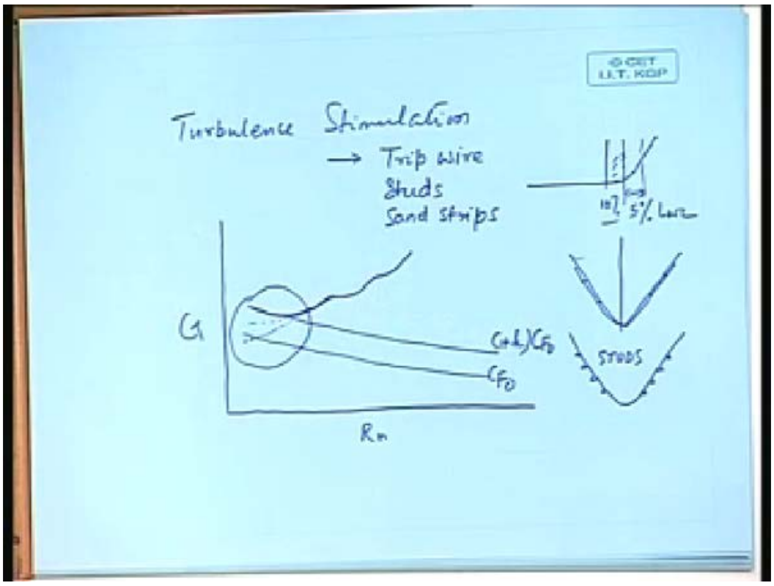

So, for this reason it is essential for us to ensure that the flow is made turbulent. So, we have to use turbulence stimulators; turbulence has to be stimulated, we have to stimulate turbulence in the fore part of the ship, and how do you do it?

We have to introduce artificial roughness at the front end of the ship so that the flow becomes turbulent because of existence of rough surface, as if we are introducing forcible turbulence on the ship's fore body. And what we use is called trip wire, this is the normal turbulence stimulator used in ships that is, I have got a ship model here, I can put a wire right on the front of the ship, or if this is a FP about five percent length aft of a FP, LWL, length on water line, normally model test we use length on water line. So, I can put a trip wire here that is, if I draw the section here, the section of the ship may be like this, I put a small trip wire all along the model with small anchors holding it by pins; if I have got a wax model, I can put pins and hold the trip wires- small pins which you insert inside the model surface.

Now, suppose, I put a trip wire here, what is the guarantee that the flow here is turbulent? The initial flow here will be turbulent, but because of pressure difference- we have seen there is a relationship between pressure and velocity- because of such pressure differences the velocity may further drop; if the pressure difference is high, pressure is high, then velocity may drop further, if velocity drops, turbulence again may fall because Reynolds number will, local, absolute regional Reynolds number will come down again.

So, the turbulence that you created may be suppressed again and laminar flow may take over. So, it is common practice to use not only one, but may be two trip wires at another, may be ten percent distance or seven and half percent aft, depends on the type of model, type of fullness etcetera (( ))

So, this is how the turbulence is stimulated. Sometimes instead of trip wire we may use studs, studs are again, if I draw the section here, studs are small little projections here at small intervals, this is a studs. Or we may use sand strips, sand paper strips, small sand paper strips may be fixed at around the ships girth at the forward end at five percent aft of a p and ten percent- sorry, five percent aft of AP and ten percent aft of AP.

So, this is how turbulence stimulation is used. Now, one has to be very careful, we are adding extra appendages to the model, as long as it is limited to only turbulence stimulation it is fine, it may so happen that it actually adds resistance- is it not?- that can also happen, if I have an appendage, it may also add resistance. So, we have to make a compromise how much turbulence stimulation has to be given so that just about turbulence is stimulated, but it does not add its own resistance to ship resistance- so, this has to be done carefully.

Now, how do you do this, how do we know the existence of laminar flow on a model? It can be easily got, obtained from the model experiment itself. If I have plotted Rn here and CT here, I know my CF line is like this and one plus k CF line is this; and mind you laminar flow will mostly occur at low speed, because the speed is low, Reynolds number is very low, if we actually go for high speed, laminar flow may be suppressed by large extent- depends on model scale. Now, here, we have seen that the resistance curve should have been like this that is, at low speeds it should follow this line when there is no CR and then it goes like this; it may so happen you will find that the resistance curve is actually going like this or even coming down to this line, even going below the CF at low speeds, then you know something is wrong here and the reason for this will be laminar flow.

Now, all these things I am telling is very simple to hear, on the drawing, on the, on a piece of paper actually, when you do experiments the resistance at low speeds is very low, so there is bound to be, if the measuring equipment has a small error, a constant error, then that reflects here maximum, because the quantity we are measuring is small.

So, the error part of the model experiments shows mostly at low speed region whether its Rn, Fn, or speed, whatever we plot the graph width, if there is an error it shows mostly at low speed and therefore- I mentioned before also- the estimation of k itself and the nature of the curve here is always a little suspect and this suspicion reduces if you go for bigger models in a bigger tank.

Now, we have seen the model, we know how the flow simulative has to be maintained. What about the carries, the carries, how does the model get towed in a tank? You have to tow the model- we have said it is a towing experiment initially, we mentioned that a resistance experiment is called a towing experiment.

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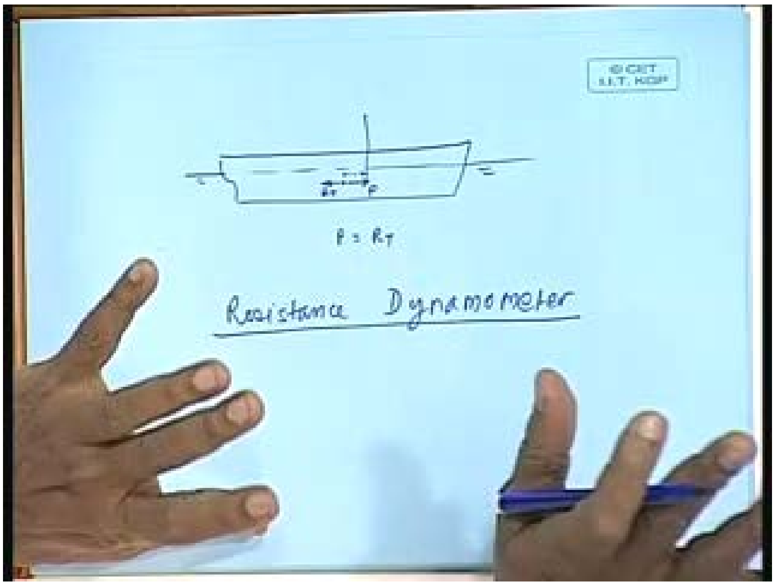

So, if I have a ship model is here, if this is the water level, if I moved it at a constant speed, its resistance will act opposite, horizontally and the entire total resistance will have a centroid somewhere in the middle where the resistance will act this way- am I right? Yes, the resultant you can easily calculate if you take moments of the individual resistance components and calculate then, you should get this thing if you know at each section what is the range, if you know- we do not know- but roughly it will be somewhere in the middle of the length of the ship and somewhere in the middle of the draft or may be slightly lower, because the bottom portion will come.

I should be able to pull the model at this point providing a force equal to the resistance, my tow rope pull should be, if I has this tow rope pull, I give a pull to the model, that should be equal to RT- is it not?- and applied at the same point that is, resultant point where the resistance works, as I have mentioned we do not whether resistance works, we only know that it can be somewhere in the middle of the ship, may be mid ship, and slightly less than half the draft, above the keel line- this is all we know.

Suppose, they are not on the same point, what will happen, suppose, this P, I have applied here, what will happen? It will give a small trimming moment, now hopefully this trim will not be large to affect the model resistance, you remember we assumed that the model will not trim or sink, one of the assumptions we made for any calculation or resistance, that the between model and ship the trim should be similar, geometrical similarity has to be maintained. Now, by putting the tow rope point somewhere above the where the resistance worked, I will be introducing a small trim, now since I do not know where the resistance is I cannot help it, it will, some small error will be there, but mostly in all the model experiments that has been carried out for merchant ships within less than 0.3 Froude number, putting the tow rope point at half the draft or slightly less than half the draft has not shown any change in trim and in sinkage.

If you think of trim actually, we know there is pressure acting, normal pressure acting on the ship surface, we have found out the axial component of that and we have said now that is equal to resistance, what about the vertical component? We have said the vertical component gives buoyancy. Now, I am moving the ship- that was in static condition when there was no axial component, only vertical component- now moving the ship the pressure distribution changes everywhere, we have said the horizontal component is equal to resistance, what about the vertical component, that will not remain same because pressures are different now.

So, it may so happen that if there are large changes in vertical component of the force, in the fore part and aft part, the vessel may actually trim, but if I am maintaining kinematic similarity of flow, then whatever trim the ship will face my model will face the same trip, geometrical similar trim- do I, do you, I am making myself clear? So, when I am talking of this trim, this is in addition to that trim, all you have to take care is this does not cause any trim. So, as I said to about 0.3 Froude number there is no visible trim of the vessel and there is no visible trim in the model. So, this method is more or less, but one has to use one's own perception of the resistance force how it is acting. For other cases, particularly high speed vessels when we are going beyond 0.3 and the pressure forces do cause a trim, how the tow rope, tow hook position should be for applying the (( ))? Do I make myself clear?

So, this point is very important and we have to keep it in mind, I am not saying that it has be done accurately, it cannot be because we do not know. For example, if I am taking about planning craft towing resistance, the vessel actually comes up, it lifts itself, so the bottom is more or less near the water surface. So, actually in that position my tow hook should be near the, attached to the bottom of the ship, but I cannot attach it to the bottom, it has to be, there must be some distance between the bottom and actually the attachment point. So, I do introduce small amount of error, but my effort should be that this error should not affect my resistance, which I am going to extrapolate.

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((But how many come to nearby edge points almost))

That is by experience for example, for 0.3, up to 0.3 Froude number half the draft is a good enough measure or slightly less than half, one third to half the draft from bottom, that is the range in which we can fix, because you see any fixing device you make, it has its own thickness, own sitting arrangement, you do not really have that much of a accuracy that I will just take it to half the draft. So, it will be between one third draft to half draft from the bottom, that is the rule; in a planning vessel, we try to bring down the tow rope point as much as low as possible that is all, you cannot do more than that; sometimes to ensure that tow hook is not introducing any error we do this, many times we attach the tow hook at two or three different positions and repeat the test to see that we are getting same results- sometimes one has to do it.

Now, one thing we have known that whatever arrangement you make, this tow hook, how do I apply the pull? It must be applied from top somewhere- is it not? So, what we have is what is called a resistance dynamometer and this resistance dynamometer is a device which is helped by a carriage on top of the model, the carriage being held separately on rails mounted on the towing tank. So, the carriage and model have no connection except through the dynamometer. Now, dynamometer is held by the carriage and it has a pillar, which moves inside the dynamometer, this pillar is fixed on the model. So, model takes the pillar, but not the dynamometer, the pillar is free to go up and down in this thing.

Now, this arrangement is such that as we have said here, just in this diagram what we said that the model can go up and down, this pillar must allow free sinkage of the model that is, free flotation and also must be must allow trim. Trim and heave motion, the towing arrangement must provide, sometimes it is through this one point attachment, sometimes the dynamometer is too large and you cannot have this one point attachment, then you can have guides on the model through which the carriage dynamometer and the model are kept in single axis, so the model is free to heave and trim.

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Sir (( )) also as to be exactly how along (( )).

Yes, that is why the dynamometer is attached and the attachment is such that the force is horizontal and axial, there is no transverse force therefore, there is no roll sway or yaw, the model is constrained against roll sway and yaw, it can only heave and trim. And you must have measuring devices to measure the resistance, the force, the heaving and the trimming, the other thing that must be measured is the speed. So, the carriage is the one that provides the speed, constant speed.

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Carriage speed, carriage is attached to the model by the dynamometer. So, as long as the carriage, what force the carriage takes we are not bother, the dynamometer, that pillar, what force it exerts on the model that we are bothered, that we measure through a strain gauge type of measurement between the pillar and the housing that is held. So, if the housing is exerting a force in the pillar to pull it, that is measured through a strain gauge type of instrument. And similarly, we can measure the sinkage and trim. So, this is how the model experiment is conducted.

How do you prepare the model for experiment? Preparing the model, we have manufactured the model, we know the light weight of the model, we know what should be the displacement, what we know of the model?

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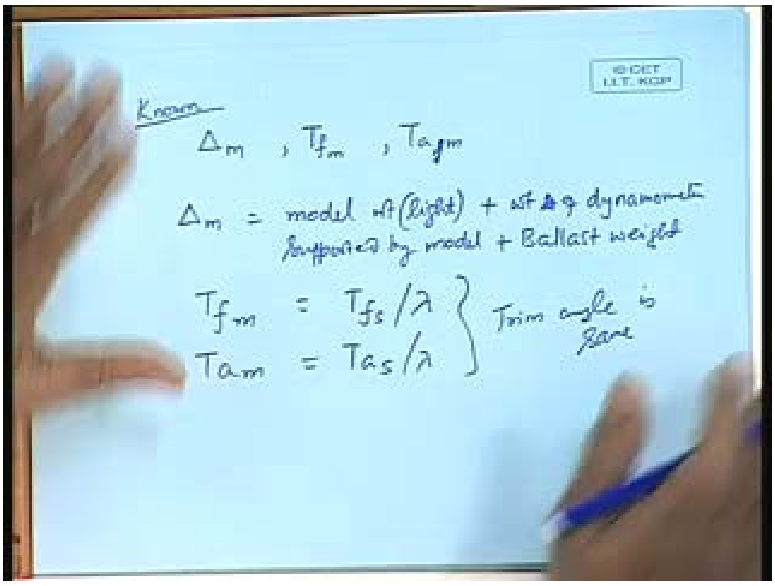

This we know, we know the draft forward of the model and draft aft of the model, known quantities are these. So, this displacement model will be equal to model weight, light weight, this is light weight, light model weight plus weight of dynamometer supported by model, you see this pillar, that will sit on the model, so that weight will come on the model, that will not be held by the carriage, plus to get the proper displacement we have to add ballast weight. So, you have to calculate how much ballast weight will go and then the model has to be weighed, and you can get the model displacement.

Similarity, what is draft aft and draft forward? That is ship draft divided by lambda, geometric similarity, and similarly draft aft is that is, trim angle is same, angle will be same. So, this as to be model has to be prepared when attached to the carriage this is achieved, once this is achieved you run the model at different speeds and get the resistance. Can I quickly go over extrapolation procedure? I think I will do it very quickly because we do not have much time.

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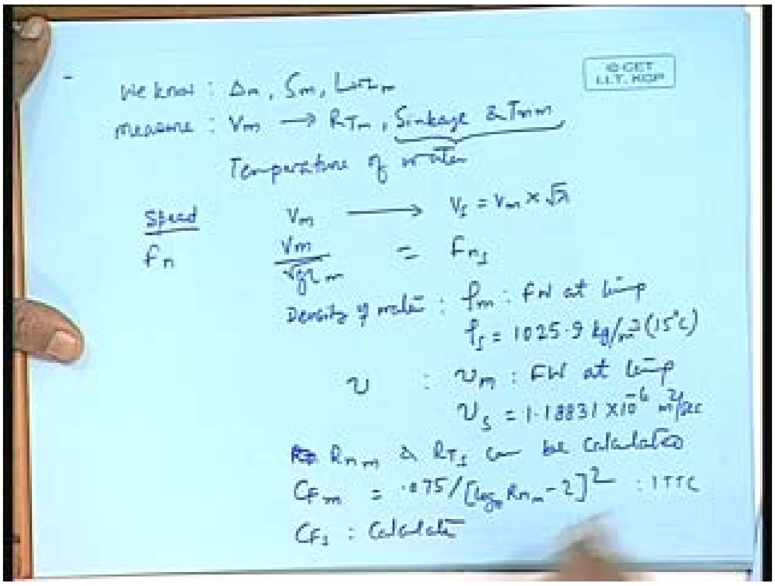

We are measuring Vm, RTm, sinkage and trim. For normal conventional merchant ships we will ignore this, this is important for other types of vessels, but not for conventional displacement type merchant ships moving below 0.3 Froude number. What else do we know? We know model displacement, model weighted surface, length on water line of the model, and we will see what else is required- all this is known. We have also measured, we also have to measure temperature of water, because the density and kinematic coefficient- these two items that are very important for our calculation- are temperature dependent, so you have to measure the temperature to get these values.

Now, let us see how are things extrapolated? Speed of model, Vm, gives Vs equal to Vm into root lambda, Froude similarity; Froude number, Vm by root glm equal to Froude number ship- Froude number is same; density, density of water, now, this is fresh water for model, rho model is fresh water at temperature measured, and ship, sea water, and for all calculations we take 15 degree centigrade as standard temperature, 15 degree centigrade and this sea water density at 15 degree centigrade is 1025.9 kilograms per meter cube, at same temperature rho m is 999 kilograms per meter cube. So, you see there is an increase in density.

Kinematic coefficient, similarly, for model it will be fresh water at measured temperature and ship will be equal to 1.18831 into 10 to the power minus 6 meter square per second, this unit we have seen yesterday. So, this is the standard kinematic coefficient of viscosity at 15 degrees. So, using this we can calculate Rt, Reynolds number RTm and RTs can be calculated. I am giving you steps. Now, CFm is equal to 0.075 log 10 Rnm minus 2 whole square- this is the ITTC line. And we can calculate CFS similarly, we got all the values.

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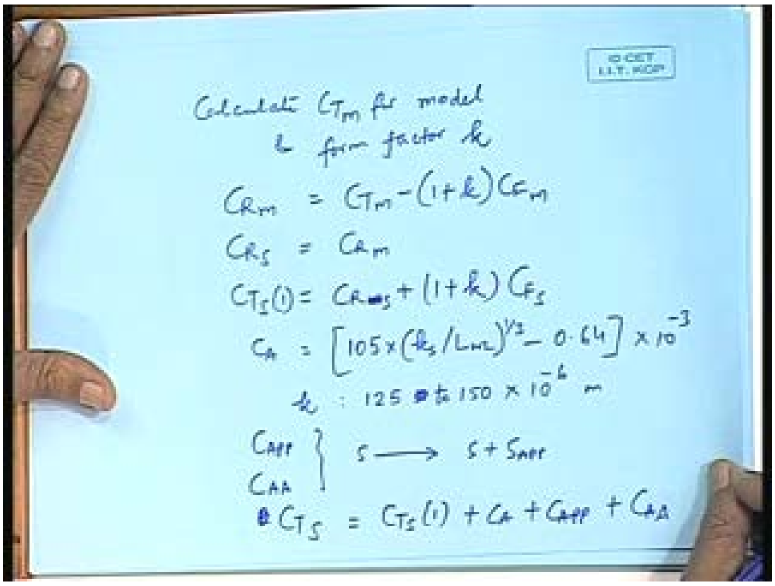

Calculate CT for model, CTm for model and form factor k- this has nothing to do with the ship, from the resistance curve we can calculate using the value at Froude number equal to 0.1 as we have discussed before, or drawing the full curve and seeing where it is parallel to the CF- we have seen some methods of calculating Froude form factor. Then, CRm is equal to CTm minus 1 plus k CFm; CRs is equal to CRm. So, CTs at this stage is equal to, I will just put a 1 here, CRm plus 1 plus k, or CRs, we have already said this is equal to CRm, CFs- this we have calculated

Now, we have said that there will be a correlation allowance that is, CA. I told you yesterday that ITTC has given as length dependent CA value and that formulation is like this: 105 into ks divided by length LWL to the power one third minus 0.64 into 10 to the power minus 3 where k s is the roughness of the surface. Normally, for new ships, k s is taken as between 125 to 150 microns or 10 to the power minus 6 meters- all in metric units. So, this for a 400 foot ship it would come to about 0.4

Then, we have the appendage resistance. You have to calculate the appendage resistance and convert it to a coefficient so that you can add it to CT. And similarly, you have to have the wind resistance coefficient. Again, calculate the total wind resistance divide by the total weighted surface, how the CT is calculated, half rho s v square, that S may be changed to S plus appendage weighted surface. Then, you can calculate resistance for the total ship including that of appendage weighted surface. Then, you get CTs is equal to CTs(1) plus CA plus CApp plus CAA, all these will give you the actual ship resistance either at zero before or at before three- the CAA will determine that depending on what sort of trial condition you want to do.

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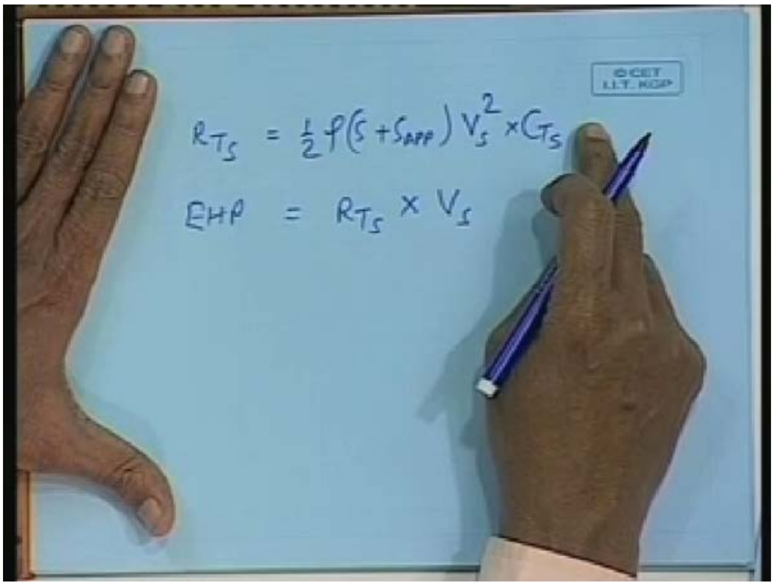

Once you get CTs you can calculate RTs as half rho S plus SAPP rho s v a v a Vs square for various speeds, and EHP- effective horse power- we have seen will be equal to total ship resistance into (No Audio from 52:09 to 52:13 min) -Sorry?- into CTs. And if this is in kilo newtons, this will be in kilowatts, this is meters per second, this will be kilowatts.

Now, you have to be careful because the whole calculation we have given is in newtons, so somewhere along the line you have to convert it to kilo newtons, may be dividing by thousand. So, this is the way you have to extrapolate from model scale to full scale. We will stop here today. Thank you.

Preview of Next Lecture

Lecture No. # 08

Shallow Water Effects

Good morning, gentleman. Today, we will talk about how the resistance of a ship gets affected if it moves in shallow water as compared to its movement in deep water. Practical experience of course, has shown as that when a vessel goes from deep water to shallow water typically, from a sea to a river, speed drops tremendously. We will see if it is possible for us to determine a speed-power relationship, or speed-resistance relationship in shallow water taking the values of deep water as known.

What happens in shallow water? Imagine a vessel moving in a limited water depth, as the vessel moves forward the water flows past the ship, as we have seen, and because of restricted availability of water depth the water will speed up at the bottom, the velocity will increase. If the velocity increases, what will happen to pressure? Pressure will drop. We have seen previously that, as in the mid ship region that is, middle of the ship, the pressure is low anyway, so this pressure falls further and as it falls further the immediate effect is with the same emersion of the ship, the upward force reduces therefore, the vessel will experience a sinkage- because ultimately for the vessel to remain afloat buoyancy has to equate weight. So, if the pressure drops in a large portion of ship's length, buoyancy reduces at the same water level therefore, the vessel must experience a sinkage so that the buoyancy and weight equalize and the vessel (( ))...

Scrap the paint, short blast the surface- short blasting is around primarily to smoothen the surface- and then paint it again; it should become as good as new. But it has been found by measurement that generally even after a five years survey there is a small increase in roughness, the ship never comes back to the new condition in spite of placement of plates, which are reduced to a large extent in things. In between these five years what happens? The plate roughens of course, and there is large amount of fouling- fouling may be removed once in a while, but generally fouling will grow.

Fouling is a bio phenomenon depending on the environment in which the ship is operating that is, whether its tropical climate or temperate climate and whether it is moving or not moving. It is fairly well known if the ship spends a large time in ports, particularly tropical ports, fouling is very heavy. So, when it goes out after being in a port the speed drops.

Now, the roughness, resistance increase due to roughness can be calculated using this formulation if we know what is the roughness, k s, of the ship at any time. But it is very difficult to estimate the resistance due to fouling because of the uncertainty in growth of fouling as I have said.

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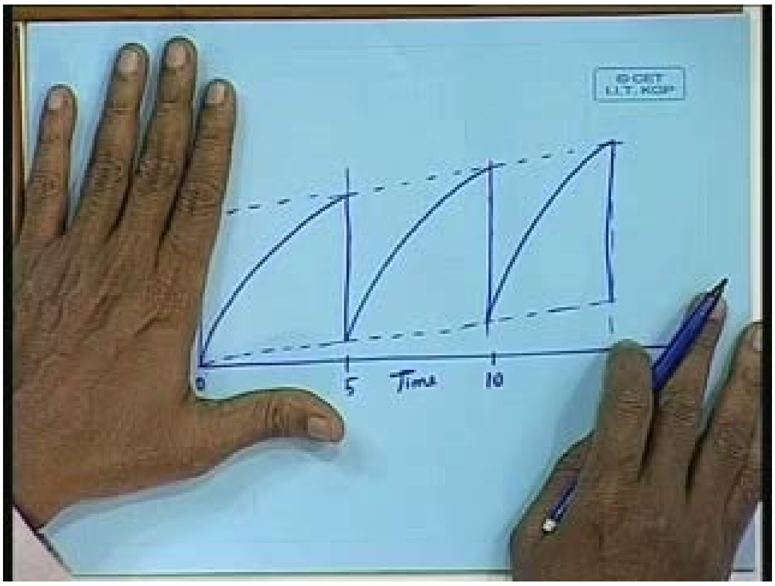

If we can estimate the, from the measured speed, if we can estimate the resistance increase, we know at what point of time we require to maintain the hull, maybe a scrapping of the hull, removal of fouling, even in approved condition may be desirable.

But more important is the trial condition, which I have already said is a very critical for the ship builder and ship owner. You have taken the ship to the dry dock, you have cleaned the ship, painted the ship again and you are ready to go out to trial- for whatever reason, maybe the, it may be as simple as the surveyor not being available or the life boat not being available hence, the ship cannot go out to sea, or may be some major production problem, it could also be that there is a storm brewing and you have to wait for fifteen days after you have undocked the ship to go to sea track. This fifteen days is critical- because what is happening?- the ship is standing in water in a port environment for fifteen days, so the fouling that will come up in this case will definitely show you a drop in speed. So, you have to be careful, when you go out for trials in what condition your ship is and if you cannot bring back the ship to its original new condition, you must be able to apply suitable corrections to get the proper trial speed. I think we will stop here, thank you.