Ship Resistance and Propulsion
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Lecture - 8
Dimensional Analysis II, Model Tests and Ship resistance Prediction Methods – I

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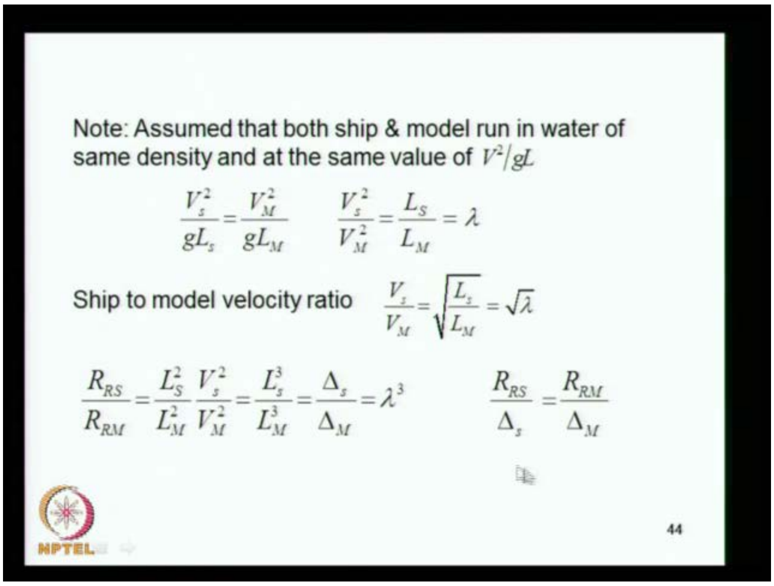

So, assume that both ship and model run in water of same density, the minor change in the density between fresh water, which is in the model base model towing tank and that of the sea water are ignored. The sea water density is you know it is 1.025 tons per metre cube and fresh water is 1 ton per meter cube. Approximately, it is taken so that difference is ignored here and we consider it same density.

At the same value of the Froude number that is V square by g L we are considering which a measure of some Froude number quantity is. So, if you assume the ship and model meet the same Froude number that is F N is equal to F N m, so this quantity remains same, we assume it is same for ship and model. From this relation, we take this ratio V s square by V M square that is equal to L s by L M g is constant, so that is equal to lambda, so which obviously means that the velocity of ship and velocity of model or the square of that is related by lambda.

So, from this, you will get we take the square root V s by V M the ratio of the ship speed to the model speed is equal to square root of L s by L M, which is the square root of the model scale. So, this implies that if you run the model with a speed is equal to V M is equal to V s by square root of lambda, it satisfy this relation. This means the Froude number of the ship and Froude number of the model are the same, if the model is run at a speed equal to the speed of the ship divided by square root of scale chosen for the model. The ratio of R R S, that is this resistance residuary resistance of the ship to the residuary resistance of the model.

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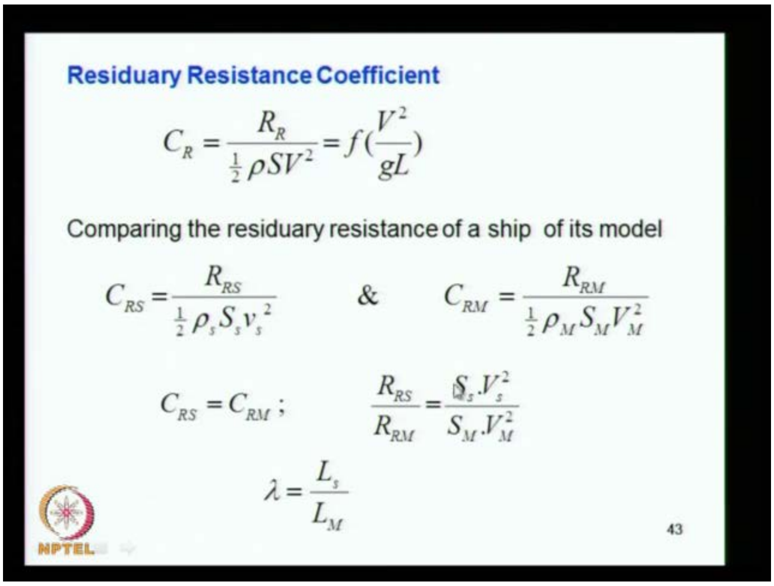

So, that is equal to L s, we have seen it from the above that is from here, from this ratio we know here, yes here look here from this you can put s in terms of L, so we are just coming L s square by L M square into ratio of this. So, from this you can write is equal to you are using the scale here V s by V M is equal to this or you can say that V s square by V M square is equal to lambda.

So, this is equal to lambda and this is equal to lambda square which leaves gives L s cube by L M cube which is equal to lambda cube. Since, its L s cube or length cube, it can be equal to the volume displacement or since we have assumed same density same as the mass displacement of the ship divided by mass displacement of the model. So, this is a relation that is what implies is that if you know R R S, then you multiply R R S, if you know R R M that is the model residuary resistance. You multiply it by lambda cube to get the residuary resistance of the ship the same as you can know from this relation these two.

This can take the ratio residuary resistance of the ship divided by displacement of the ship is equal to the residuary resistance of the model by displacement of the model. So, these things are known delta s is known delta M is known R R M is measured from the model thrust, when you run the model which follows this speed relation. So, from this, you will be able to find out what is the residuary resistance of the ship and that means all the three quantities are known except this, from which you estimate that.

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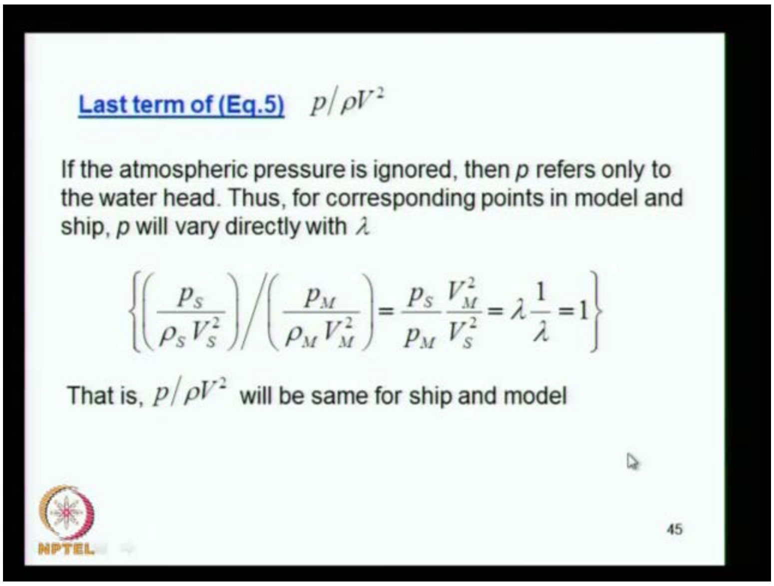

Here, we are coming back to this term which is one of the term which I had given in the parameters before it is p by rho V square. So, here atmosphere pressure which acts in the ship and also in the case of a model, so we ignore that, we take the same data for the atmospheric pressure. Then here p refers to this p refers only to water head, if you are considering a point in the water inside the water domain. Then this is the pressure relation p refers to the water head.

Thus for a corresponding point in model and ship if we are considering, then the p varies directly with lambda because you know that pressure if it is a static pressure water head it is rho g h rho and g are constant. We assume it is rho and g are also same for ship and model, so only variation is h, so for the model, the pressure is related to the lambda to the corresponding point.

So, here you consider this you are considering a ship quantity p s by rho s V s square divided by the model quantity that is p m by rho m into V M square. So, this is equal to if you can rewrite in this form and we know that this quantity V M square by V s square is equal to 1 by lambda and this pressure we have already explained here, this depends on lambda. So, p s by p m is equal to lambda, so lambda divided by 1 by lambda is equal to 1, so that is this quantity p by rho V square will be same for ship and model because p s. If you see this relation here is equal to 1 means it remains same for ship and model.

So, it is automatically satisfied, now we look the other term, so first we know which are the three terms considered the functions of Froude number Reynolds number and the non dimensional pressure or oilers number. We have seen the oilers number is not significant this between ship and model is same.

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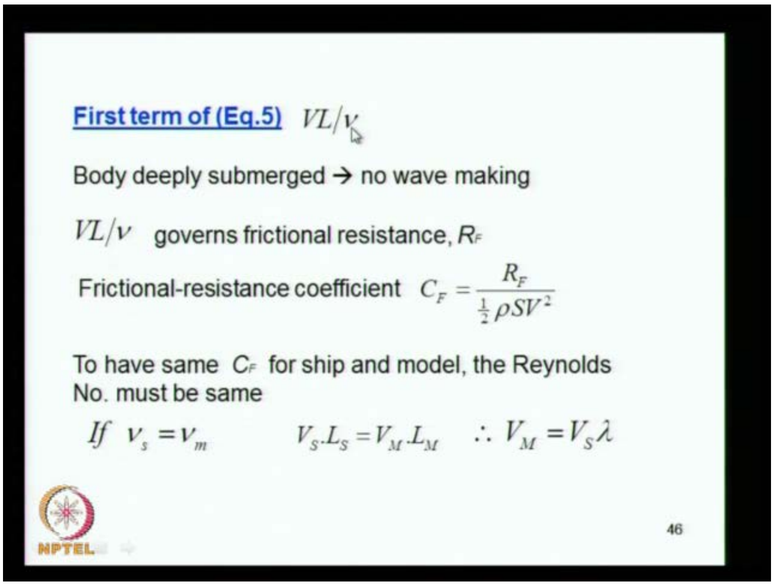

So, we have seen that ratio is equal to one Froude number, we have seen the Froude number if it satisfies the model velocity is equal to ship velocity divided by square root of lambda. The Froude number is satisfied, the third one what is left is the Reynolds number which is V L by nu, now here what we consider body is deeply submerged, there is no wave making. So, the initial case when we discuss about Froude number we assume in visit thing in visit flow so that we discarded or we ignored the Reynolds number and we finally, said it is only the wave making resistance or residuary resistance.

Now, we are saying that it is we are just considering the body is deeply submerged, when the body is deeply submerged, no waves are created and only resistance available. Now, for a deeply submerged body is the viscous effect due to the viscous effect, so V L by nu governs the frictional resistance, which is a major component. Also, it can refer to the viscous pressure resistance.

So, mainly the frictional resistance is considered here so the frictional resistance r f is now related to the Reynolds number. So, when do you say it is a double deep body deeply submerged, yes that is what I mean, so here it is coming later, I think about double frictional resistance coefficient c f is equal to r f frictional resistance divided half rho s V square. It is the same non dimensional rational parameter here as we did before they have the same C F for ship and model the Reynolds number must be same because the frictional resistance is depends on Reynolds frictional resistance coefficient.

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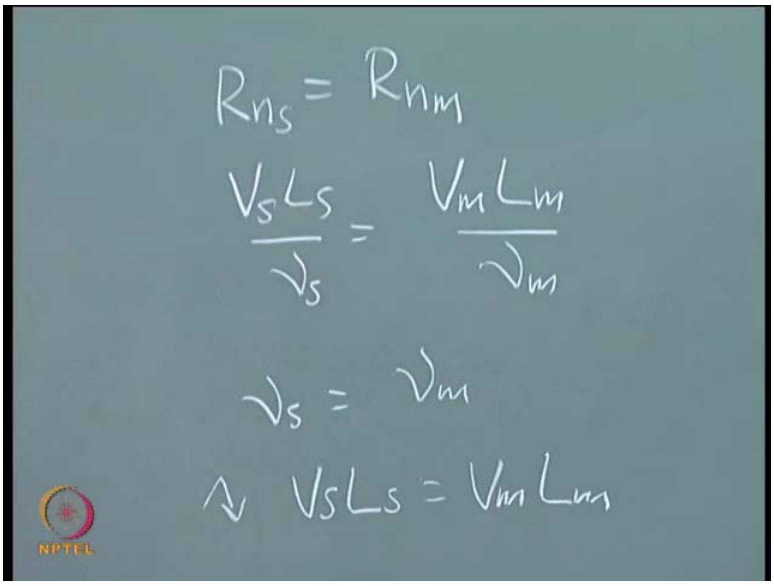

So, now we assume that nu s is equal to nu m, so here we say you just see the board and here we r and s that of the ship is equal to r n of the model that is V s L s by nu s is equal to V M L M by nu m. Now, we assume nu s is equal to nu m which implies that V s L s is equal to V M L M, so that is what is written here, so we get this relation here V s, L s is equal to V M, L M. So, from this, we can write V M is equal to V s into L s by L M and that is equal to lambda, so that is how you get this relation.

So, V M is equal to V s into lambda, so if you made this relation, then you will be satisfying the Reynolds number between ship and model that is the Reynolds number of ship is equal to Reynolds number of the model. If the model is run with the speed equal to the ship speed into the model scale, actually this is going to be different from the

Froude condition, but still if you can meet this relation, you can write with that requirement.

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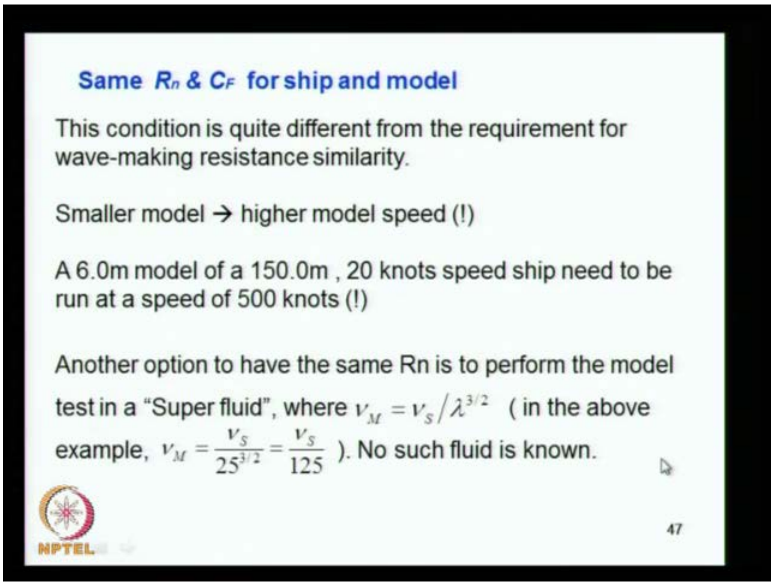

Here, what you do is this condition is quite different from the requirement of the wave making resistance. Similarly, because we have already seen the wave making similarity that is CRS is equal to CRM, when the Froude number of the ship is equal to the Froude number of the model.

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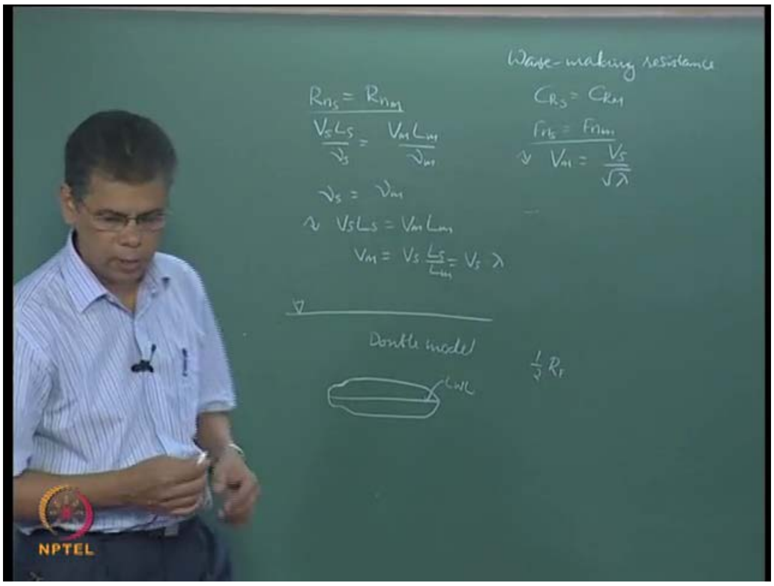

So, we have already seen that wave making resistance prediction from model test matches between ship and model only when that is you say the coefficient C R S is equal to C R M only when Froude number of ship is equal to Froude number of model. So, which implies that we have already seen that V M is equal to V s divided by square root of lambda, so here what you have this relation is this is for the Reynolds number satisfaction and here this is for the Froude number satisfying between the ship and model. So, here we have just seen that V M the model speed need to be V s into L s by L M that is equal to V s into lambda.

So, if you look to this these two are not have holding the same relation if you run the model, it will satisfy one relation if it is for the residuary resistance estimation. The model has to run with this speed or if it is for the frictional resistance estimation, you need to have a submerged body and it should run with this the speed in relation to that.

So, when you usually do the frictional resistance, when you say it is a submerged body deeply submerged. Suppose, you consider this is the water level and the body somewhere here you consider this a ship it is deeply submerged, but since you cannot afford to have such a boundary beneath that, so what it is up to the load water line. So, what you do is you put a double model that is the concept used, you just mirror image of that body. So, you consider this, so you are putting two ships this is the load water line this refers to the load water line or the water line at which the ship.

So, you consider double model this is called a double model body is deeply submerged, so there is no wave making and no the only effect is the viscous effect. So, you run the model or tow the model at such a condition when you get the viscous resistance this is for two models. So, you take half of it half of the resistance frictional resistance you get the frictional resistance of the ship. So, in this is the concept used in the double model, so that is what see the condition is quite different that is the relation what you have seen for Reynolds number satisfaction is different from the satisfaction of the Froude number between ship and model.

So, here if you use a smaller model what is the scale smaller model scale is high lambda is high, so then the model speed will be higher if you look to that relation here. If you look to this relation, if you go for a smaller model, means lambda is high, so if you say it is 1 is to 50 is the model and 1 is to 100. So, the lambda will be higher for a smaller model hundred for that, so V M is equal to V s into lambda, so when lambda is a higher value V M will be higher. So, that is what it means, smaller model higher model speed which is difficult you will see that from an example here difficult to achieve, we consider a model of a ship having 150 meter long and 6 meter is the model size model length.

So, here the ratio is 150 by 6 lambda is 25 and the ship speed is 20 knots and that means 20 knots is the speed, so the model speed need to be ship speed into lambda, so 20 into 25 which comes to 500 knots. So, the model has to be operated at 500 knots to match the Reynolds number between ship and model, so this is not achieved 500 knot speed in lab in a flowing tank it is not achievable. So, this is not possible to satisfy the Reynolds number between ship and model in a lab condition, another option is you have to go for another options to have the same Reynolds number is to perform the model test in a super fluid. You have to consider the nu the relation between nu m and nu s that is equal to lambda raised to 3 by 2, I think what you have to do is if you consider this one.

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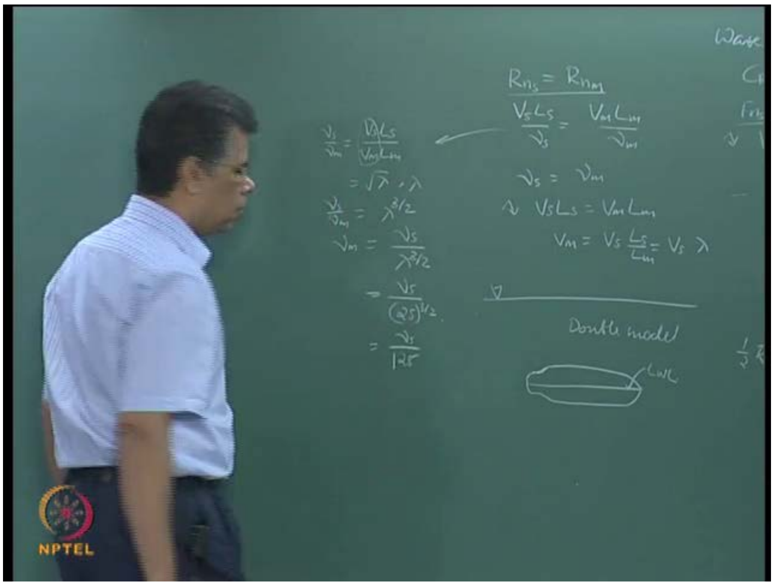

We have to consider the nu s by nu m is equal to V s L s by V M into L m, so that is equal to V s by V M if you follow the Froude number case, it is going to be square root of lambda this one V s by V M and L s by m is equal to lambda. So, that is equal to lambda raised to 3 by 2, so that means if you consider that is nu s by nu m is going to be lambda raised to 3 by 2. So, here nu s nu m that is the model the fluid in which the model is tested is equal to nu s divided by lambda raised to 3 by 2.

So, that is how it is coming, so there are two options of meeting the Reynolds number, one is increasing the speed, as I just increasing speed of the model is very high. The other option is you test the model that is nu m represents the viscosity of the fluid in a model basin or model towing tank the viscosity of the fluid should is equal to the viscosity of the fluid in actual. The sea water viscosity divided by lambda raised to 3 by 2 that means that is equal to for the example what we have considered here nu s by lambda is 25 raised to 3 by 2 or that is equal to nu s by 125.

So, you can meet the Reynolds number, if you use the fluid in the lab condition which has the kinematic viscosity equal to 1 by twenty fifth of that of the water sea water with there is no such fluid. Hence, again meeting Reynolds number from that perspective is also not so what it implies that the u is two options running the model at very high speed or testing the model in a super fluid. These two options are practically not feasible and hence meeting of Reynolds number between ship and model are not possible.

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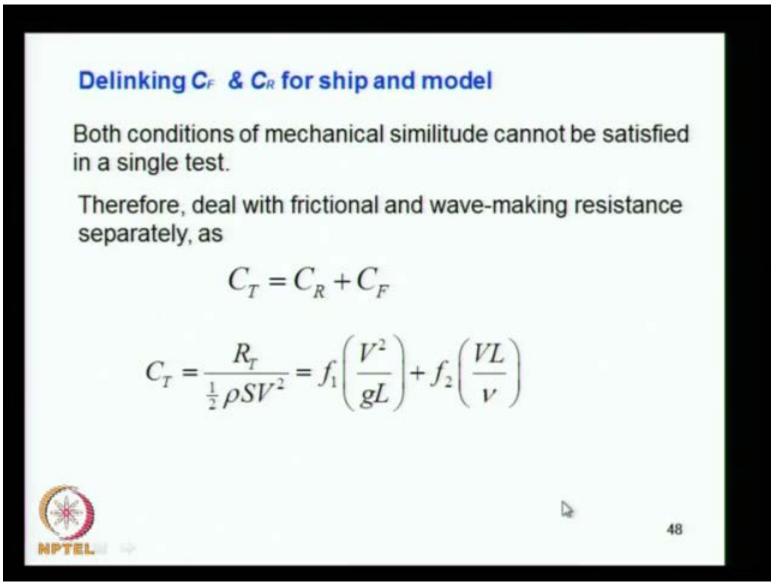

So, both the conditions of mechanical similitude cannot be satisfied in a single test, so here we have seen that there are two conditions one is mechanical similitude one is the dynamical similarity. The other one is the kinematic similarity dynamical similarity here it is referring to the wave making resistance which shows the ratio of inertia force to gravitational force from which you get the Froude number. Other condition second similarity is the kinematical similarity and which is represented by the Reynolds number and that is represented by the ratio of inertia force to viscous force.

So, these two cannot be satisfied in a single test we have already seen that velocity of model are totally different when you satisfy these two conditions which is not possible. In the same run, you would not be able to get to satisfy these two conditions and the other option maybe as I said now using a super fluid, again such a fluid does not exist. So, you cannot do it, therefore deal with frictional resistance and wave making resistance separately. So, that is an easier way of practically acceptable way of treating the resistance prediction from the model test to the prototype. So, the total resistance coefficient C T is equal to we can split into the resistance coefficient C R and plus the frictional resistance coefficient C F.

So, that means the total resistance can be separated out as one as residuary resistance and the other one as the frictional resistance. Now, you know C T which is represented by total resistance by half rho s V square and that is equal to a function of Froude number and here it is a function of Reynolds number. So, you are separating it out like using the method of separation of variables the function C T is now represented by a function closely depending on the Froude number. Another function exclusively depending on Reynolds number, so this one will represent the frictional component and this one will represent the residuary components.

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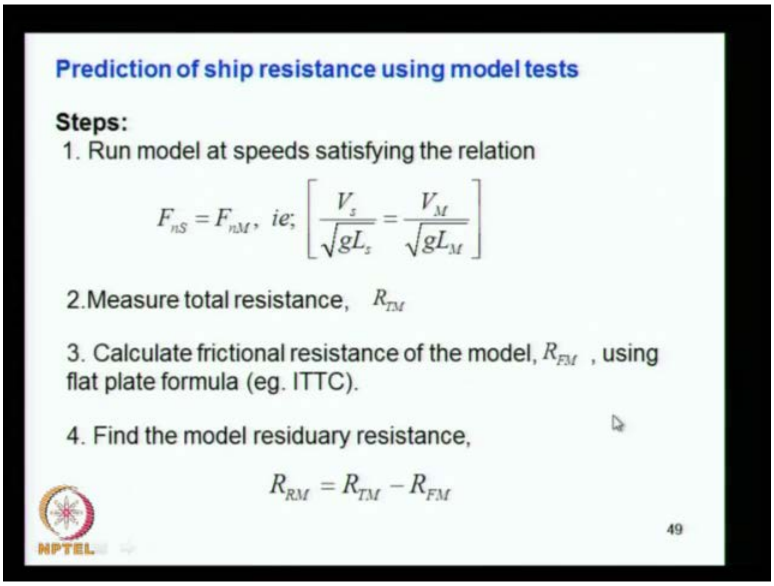

So, how do you predict the resistance using model test, so what you do is you run the model at the speed satisfying the relation. We have already seen that Froude number of the ship is equal to Froude number of the model. So, you satisfy that and you we have already seen that the relation is you run the model at a speed is equal to the ship speed divided by square root of lambda the scale as the model. So, that is the relation, so you try to satisfy this which is practically possible in a lab condition when you run the model. At that speed, you measure the total resistance of the model using a dynamometer or maybe using a load cell you measure the total resistance of the model at different speeds.

So, calculate now what you do is now you calculate the frictional resistance of the model RFM using the flat plate formula, maybe ITTC formula. We have already discussed this before what is the flat plate formula what are the different formulae normally used and how they are achieved, how the experiments are done, which we discussed before in one of the classes. So, here ITTC which I just came out with a simple empirical relation to represent the frictional resistance coefficient from which we will be able to find out, the frictional resistance of the model.

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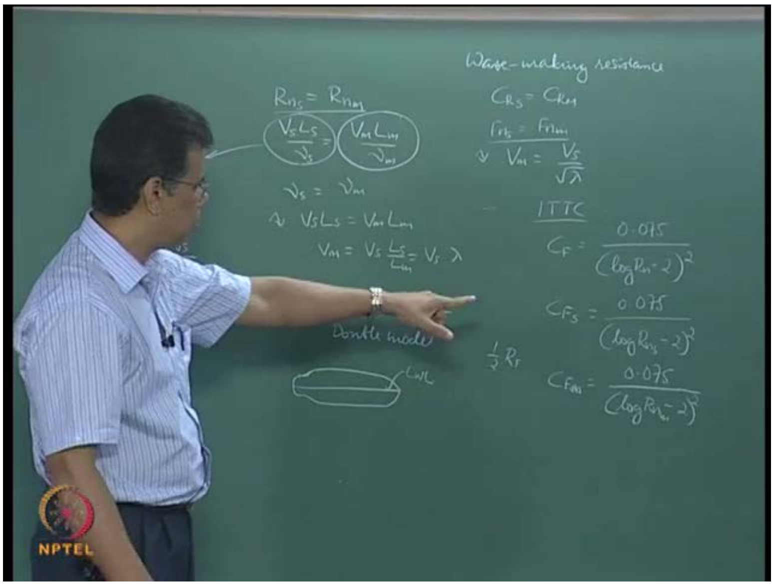

So, we know that the frictional resistance ITTC formula which gives a C F value ITTC or C F it is given as 0.075 by log R n minus 2 the whole square. So, this is the ITTC formula for frictional resistance, so if you are using for C F of ship what you use is 0.075 divided by log R n of ship minus 2 the whole square. So, you get C F as or for this model you get 0.075 by log R n of model, so the only difference here is the Reynolds number. If you are using C F s Reynolds number of the ship if you are using C F m the Reynolds number of the model should be used. You know that Reynolds number of model and the ship are given by this relation.

So, once you know the velocity length and the kinematic viscosity of the ship kinematic viscosity of the ship means it is the sea water. Then you will have you will get Reynolds number of the ship you substitute this straightaway, we get C F S or if it is for the model here, you use this relation. So, that is how you find out the frictional resistance, so what you do is you pressure total resistance of the model then you find out the resistance frictional resistance of the model using ITTC formula.

So, here you use 0.075 divided by low R n M minus to the whole square that formula you use then find the model residuary resistance from that. So, you know that the residuary resistance is a difference of the frictional resistance the total resistance and the frictional resistance, so you get the residuary resistance of the model from that.

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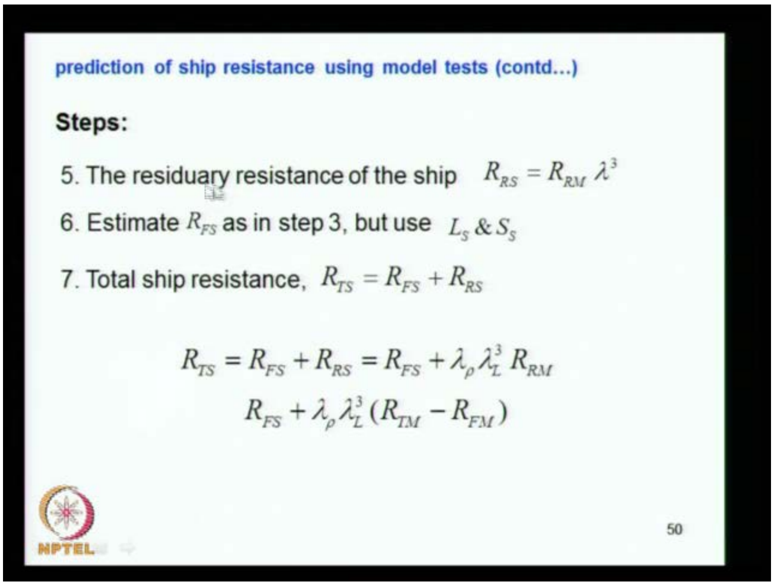

The next step is we have already seen the residuary resistance of the ship R R S is equal to R R M into lambda cube, we have already proved that the same relation here.

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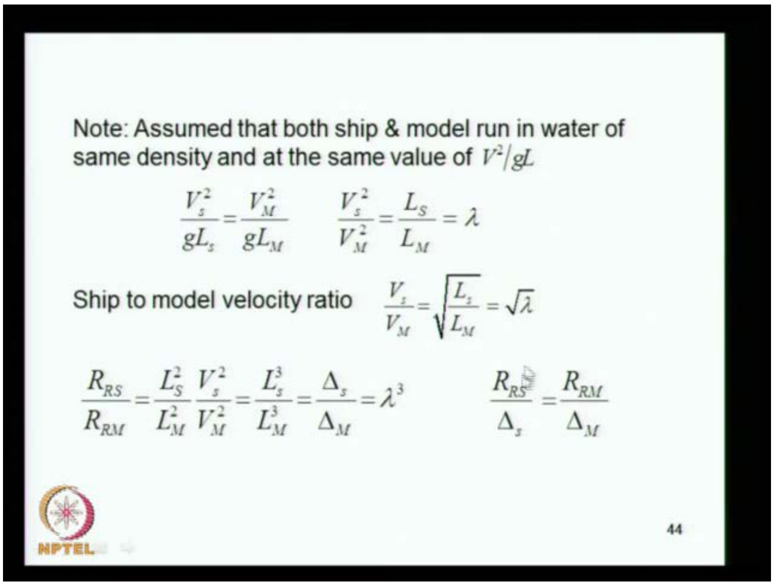

You can see the residuary resistance of the ship divided by R R M is equal to lambda cube, so that is what we did here, so once you get that you get R R S that is the residuary resistance of the ship is equal to residuary resistance of the model into cube of the scale chosen. So, that means you have got R R S, now what you do is you estimate R R S residuary resistance of the ship as in step 3 that is you find out the Reynolds number of the ship then use the ITTC formula of 0.075 divided by log r n s minus 2 the whole square. This gives the residuary C F S and then C F S multiplied by half rho s V square that gives the R R S, so that is the frictional resistance of the ship.

Here, only difference is you are using the ship dimensions L s and here that is half L s you use for the Reynolds number for the resistance estimation of the ship. So, now the total resistance of the ship is equal to R F S coming from here plus R R S coming from here. So, you get both, we get the total resistance of the ship, so that means the total resistance of the ship is equal to R F S by R R S is equal to R F S plus you can take the ratio of the densities of water.

So, lambda rho and the scale lens scale lambda cube it is coming from here and R R M, so which is same as you can just put it in this form this into R R M is equal to R T M minus R F M. So, you are just substituting for that so the total resistance of the ship is estimated in this form, so to put it brief in the model test as we have seen it is difficult to satisfy or not possible to satisfy Froude number and Reynolds number at the same time.

Also, it is difficult to or just not possible to meet the Reynolds number between ship and model what do you do is we run the model which satisfies the Froude number then get the total resistance of the model.

Then, you using ITTC formula find out the frictional resistance and take the difference which gives the residuary resistance, once the residuary resistance is obtained for the model, then you multiply it by lambda cube to get the residuary resistance of the ship. Then subsequently what you do is you use the ship's Reynolds number find out from ITTC formula the C F value for the ship and multiply it by the ship parameters to get the total resistance force of the frictional resistance of the ship.

Now, you just put it together to get the total resistance of the ship, so that is the procedure adopted in prediction of the resistance of the ship from a model test. So, what which implies that you cannot take a total resistance of the model that is you cannot just make a RTM from here. You cannot just multiply by lambda cube to get the total resistance of the ship, you have to follow this procedure and finally, you get total resistance of the ship.

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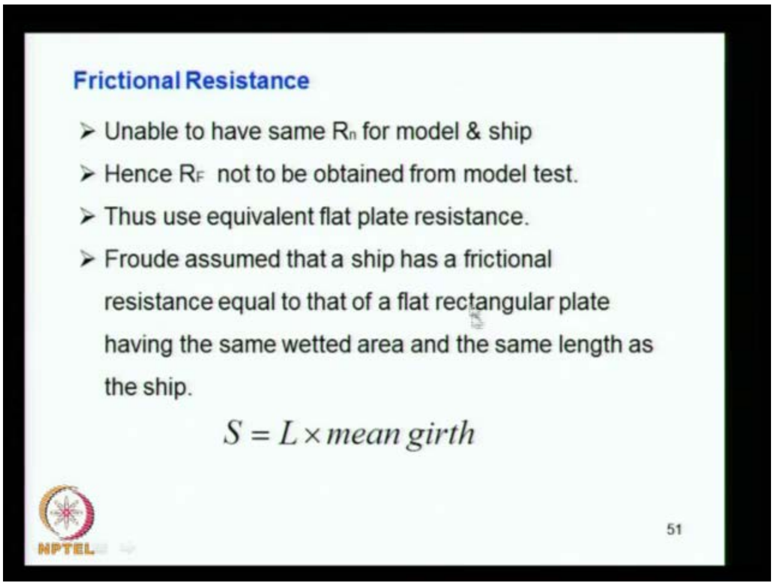

Frictional resistance we have already seen that unable to have the same Reynolds number for ship and model. We have already discussed that, hence you cannot you would not be able to obtain the frictional resistance from the model test. So, thus use equivalent flat plate resistance that is what we did in using the ITTC formula, so use an equivalent flat plate resistance formula. Then the Froude assumed that a ship has a frictional resistance equal to that of a flat rectangular plate and having the same wetted area and the same length as the ship.

So, this is what we have considered is that the flat plate experiments which they carried out by Froude, they assumed you should assume that the plate is having a length equal to that of the ship. The surface area of the plate is equal to the mean girth of the ship that is wetted girth of the ship. So, that is how the experiments have been conducted and from that only the ITTC formula or similar formula have evolved.

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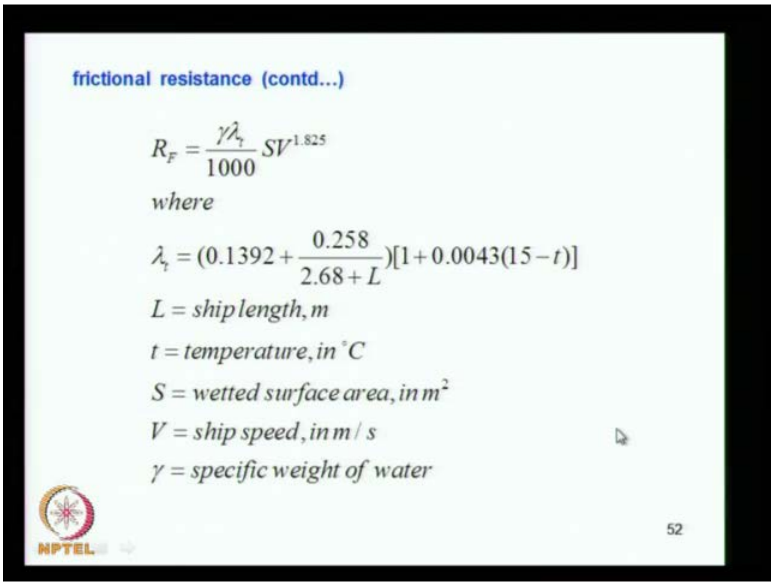

So, here the frictional resistance is given by this expression and here you can see that this depends on lambda t depends on the t and all that this is self explanative it is ship length which is represented. Here, t is the temperature the viscosity variation due to temperature is there wetted surface and the ship speed is given meter per second, gamma is specific weight of water, so this is a relation.

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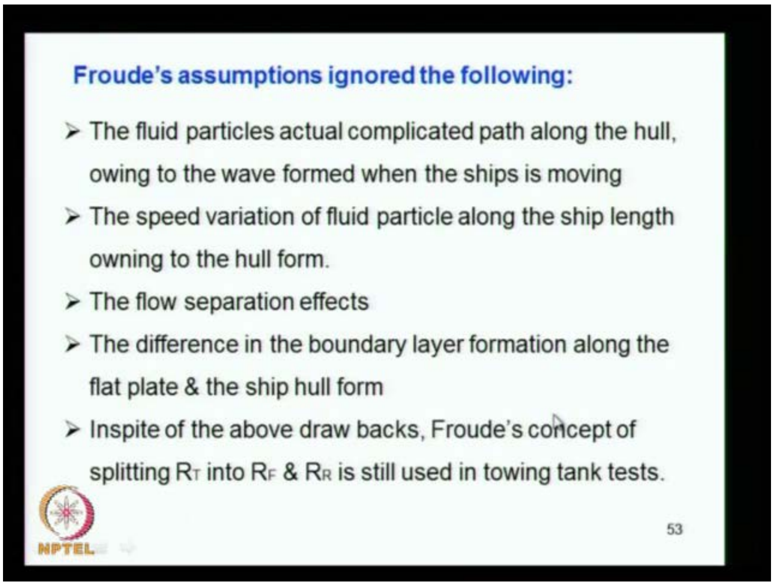

The Froude assumption when we split frictional resistance Froude assumes the Froude assumption led to us to estimate the splitting of total resistance into residuary resistance and frictional resistance. So, when it is done, the following things are ignored in that assumption the fluid particles actual complicated path along the hull owing to the wave form when the ship is moving. So, here we considered when the ship moves waves are formed the Froude particle path become maybe wavy in form, it is different from the case, when it is having a free stream flow that is when the submerged case when there is no wave.

So, that path variation of the fluid particle is ignored in the case of this problem, when it you bifurcate the problem into frictional resistance residuary resistance and frictional resistance. The speed variation of the fluid particle along the ship length owing to the hull form, here we used the flat plate formula the water particle velocity around the flat plate and around the ship which is having a three dimensional form or different.

So, when there is a curvature there will be increase in part particle velocity which is ignored in this case, the assumption because here you are using a flat plate formula for the estimation of frictional resistance. Then the boundary layer you can see the flow separation effects the boundary layer formation around the plate around the body and around the ship are different flow separations are different. The flow separation aspects are ignored so only the frictional resistance components considered. The difference in the boundary layer formation along the flat plated ship that is what I just mentioned the boundary layer is going to be different around the plate and around the ship.

That difference has been ignored in spite of the above drawbacks, we have highlighted many drawbacks in the assumption of the Froude. Here, the split of the total resistance to residuary and frictional resistance have been done, but in spite of all the above drawbacks Froude concept of splitting R T into R F and R R is still used in towing tanks. So, we do not we are yet to find out a better method better approach in predicting the or split predicting the total resistance from the model test, so still we follow in spite of all this drawbacks or limitations. We still continue to use the Froude's concept of estimating total resistance from the model test conducted in a towing tank.

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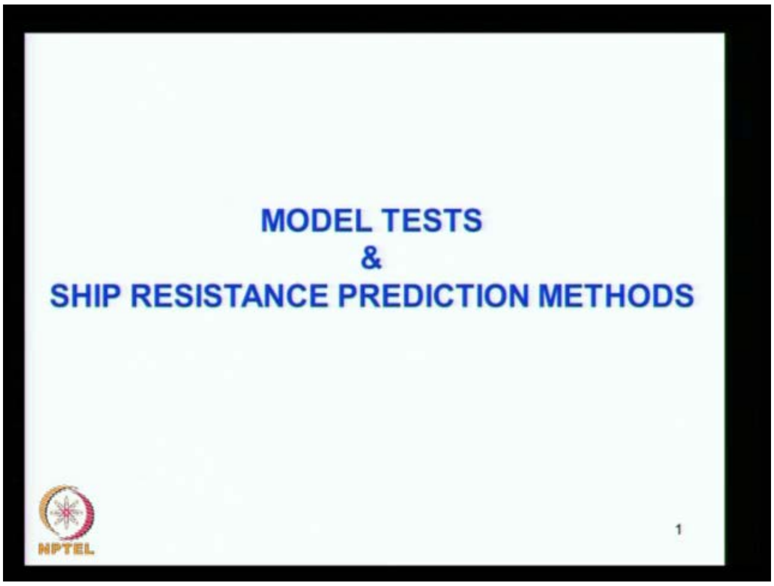

So, these model tests are done, now we know we have an idea how the model tests are done from model and once you get the model test of how the model test results are extrapolated to the ship. What are the methods used, how it is done that few methods which we go through, so here this we see that, so here this is a model test and the ship resistance prediction methods.

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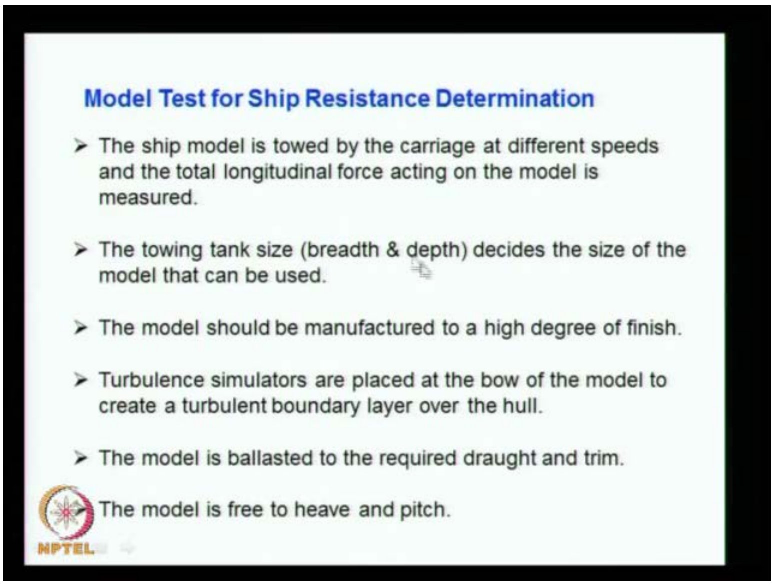

What are the methods which are used model tests for ship resistance determination, the ship model is towed by the carriage at different speeds and the total longitudinal force acting on the model is measured. That is the way the model test is done that is the ship model is there, it is velocity that the required draft of the vessel then the model is towed with constant speed. You measure the force longitudinal force coming on the coming to the model or you find out what is the tension coming in the rope, which is connected or which is being used for towing the model at that speed.

So, that gives a way you find out the or measure the resistance of the model or measure the resistance, here the towing tank size that is the breadth and depth decides the size of the model that can be used. So, if it is there is a restriction you have to know the model size substantially smaller than the model breadth, substantially smaller than the breadth of the tank or the width of the tank. The depth which will give the experiments are done in shallow, I mean sorry in deep water and the water depth condition in a towing tank should be in such a way that the water depth is sufficient in the tank.

So, the shallow water effects or not, so basically what it is looking to the blockage effects are not minimised, it is not happening the model is too wide vertices high. Then there will be influence coming from the tank boundaries which will obviously increase the resistance and hence mishit the results predicted from the model test. So, that is a limitation of the model, so depending on the trend and also size of the model when it increases the forces coming on the model also increases. So, the capacity of the load cell or dynamometer, which you use also go high, so if you have a limitation on the availability of this equipments to measure the resistance.

Then, that also put a constraint on the size of the model the model should be manufactured to a high degree of finish. So, model we know that the three conditions which are to be satisfied in a ship model test are geometrical similarity, kinematical similarity and dynamical similarity. So, one of the first and foremost thing is hitting a geometrical similarity, so it should be geometrically same. So, that is why it says that model should be manufactured to a high degree of finish even a slight variation in the form of the model matters a lot on the prediction of the resistance test.

We know that resistance prediction is lambda cube and even a minor change in the form matters that wrong results get predicted or get magnified by so many times the error when it comes to the ship would be too much. Then turbulence simulators are placed at the bow of the model to create a turbulent boundary layer over the hull. So, we have already discussed about that it is difficult to maintain the kinematical similarity because you are not in a position to satisfy the Reynolds number for ship and model. So, you know that the Reynolds number of the model is very low compared to Reynolds number of the ship and if the Reynolds number is less than 10 power 5.

The flow is in the laminar region or if the Reynolds number is more than 10 power 6, it is in the turbulent region. So, generally for ships the boundary layer around the ship is going to be turbulent because the Reynolds number is high, so when you do a model test, you would like even though it is not meeting the Reynolds number between ship and model. You would like to have a more a flow condition which is more similar to that around the ship, so that is it is not only affecting the boundary layer, it is also affecting, it also looks into the effective hyper dynamic form of the ship.

So, a model test turbulence is simulated we have already discussed what are the turbulent types of simulators used including net sand paper trip wire and all that, so here in IIT Madras we use generally a trip wire. This trip wire we discussed that even for a ship the forward end of the flow at the forward end of the ship is generally laminar in nature and so this turbulent wire this trip wire is usually fitted maybe 5 percent apt. So, a trip wire is used so that means the forward end still the forward 5 percent of the length it still remain as laminar flow and the one behind becomes turbulent, when it crosses over the trip wire, so that is what is done here the turbulence simulators are placed at the bow of the model to create a turbulent boundary layer over the hull.

So, next is the model is ballasted you know that you put weights and there is a procedure involved in that. So, you do that and see that the ballast model this places up to a water line as per the design load water line of the ship, so you should have the trim if there is ship is going to have a trim the same trim also should be used for the model. The model is free to heave we make the connection in such a way that it moves forward depending on the speed the model may heave, it goes down or it may pitch or trim, so this freedom should be allowed to the model.

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So, that the actual operating situation will be created when the model test is also done, so this is a model setup for the resistance. You can see here you have the model, this is a model and on the side of the model the model the first it has to be immersed or ballasted to the required draft. So, for which you can see the red items here which are the weights which are placed inside the model to get the required displacement. So, once you know the displacement of the ship which you usually get from hydrostatics, you know the earlier displacement as a design waterline.

That divided by lambda cube will give you information about the displacement required for the model, so then you will come to know what is the total mass in which you initially using a wave machine. You may waive the model hull alone plus the fixation and all that, then you find out what is the additional weight the red weights are what is required to be put inside the model and that also you measure. Then you place it inside, so the total finally will float at the design load waterline that is how the model is prepared.

Here, you have the there is a wayward joint here at this and there is wayward joint at the forward end, this favoured joints gives a freedom for them model to heave and pitch that is the last point we discussed before. So, this will give the freedom for heave and pitch or heave and trim and so that is a condition the model is prepared. Then we can see here some brake pad and the brake coming here there is a brake with a lever here up, so this can be this is held at the required I mean held by the brake the brake pad with a brake. It is held at a position and the yellow structure here is a carriage of the towing tank and the carriage is moved at the required speed.

So, here is another arrangement you can see it is not here there is a tow point which usually of the resistance there is a tow point from which a rope goes through a pulley and this pulley goes up. Finally, it is connected to a load cell, so when the ship moves at constant speed and when the brake is released the tow rope is actually that rope is pulling the model forward. With that, the carriage when you operate the carriage at different speed at each speed at you find out what is the pull coming on this rope, which is measured through the load cell, so this gives the total resistance of the model.

So, that is how the model test is done, so I repeat the model is made geometrically similar in here we have we make this model using fibre glass. There is a procedure adopted for the making of the model, where you make get the form maybe an autocad drawing from which you find out we make a plug to the scale required and scale is chosen in such a way that it is not a wall effect. We try to avoid that and even if there is small wall effect, we have to give apply correction path at and then from the plug you make the mould of using fibre glass and from the mould.

You make the model and the model then you put inside to retain the form and rigidity and that model is one which is used here. Then you put the fixtures like what you see here or the wayward joint, then the two patterns here for holding the brake and that brake is going up then all the setup of which I have already explained.

So, that is how the model test is done, so when you measure the resistance only when the model reaches a steady speed because your resistance is for a particular speed. So, there will be an acceleration phase for the carriage and finally, the deceleration phase you do not measure the resistance at that or you do not use the data at that point, use the data only when the steady speed region of the test. So, that is the setup which is used and you can see that because what I discussed the rope is coming.

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Now, that tow rope which comes here goes through a pulley, it is a frictional less pulley and which goes here and here, we see there is a load cell and from the load cell. It goes through the cables run from here to the data acquisition system here and that the results are processed we have the all the controls for the carriage everything here. So, the carriage speed and braking everything is controlled from here and the data is fed in and that the data can be processed into that acquisition system and from which the resistance is estimated.

So, this is the setup which you see above and the previous one what you have seen is the below water this two this setup is what we have here in IIT Madras to perform model test. We have a towing tank of about 82 meter long and 3 meter 3.2 meter wide and 2.5 meter water depth. So, that is a size of the towing tank what we have and the maximum speed of the carriage is 5 achievable is 5 meter speed per second. So, that is a system here that you for the prediction of I mean how the model test performs the ship model test and maybe we continue in the next session.