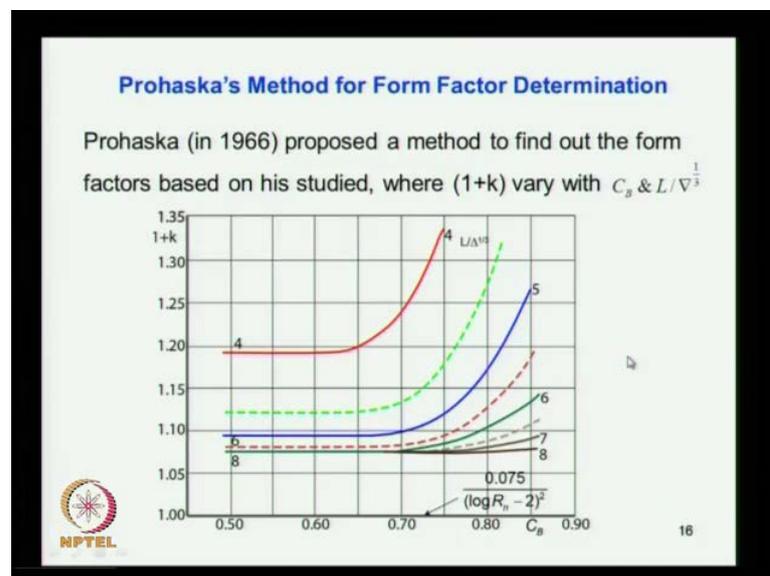


**Ship Resistance and Propulsion**  
**Prof. Dr. P. Krishnankutty**  
**Department of Ocean Engineering**  
**Indian Institute of Technology, Madras**

**Lecture - 10**  
**Model Tests and Ship Resistance Prediction Method – III**

Back to your class, so we have been discussing about the form factor on decisions. This is due to the use of a flat plate formula for the representation of the fractional decision coefficient, such as the ITTC formula which we normally use to find out the fractional decision coefficient of ship in model. Since, this form this type of formula they have been revolt based on the experiment carried out using flat plate. The three dimensional form of the form effect on the resistance fractional resistance or viscous resistance is not taken care of in this formula. So, the ship and of model which is having a three dimensional form will have a hydro dynamic variations in the flow around it and subsequently on the fractional resistance.

(Refer Slide Time: 01:05)



So, that difference in the flow pattern between the flat plate and the ship should be taken into effort. And that is what you call the form factor and behalf already gone through the method suggested by Prohaskar in the determination of form factor. This we have already discussed.

(Refer Slide Time: 01:27)

**Prohaska's Method (contd...)**

Prohaska proposes a method for determining the 3D form factor on flat plate friction.  $k = \frac{C_v - C_{FO}}{C_{FO}}$

$C_v$  = Total viscous resistance coefficient of the 3D form  
 $C_{FO}$  = The frictional resistance coefficient in 2D flow.

Where no separation is present,  $C_T = C_w + (1+k)C_{FO}$

$C_w$  = Wave-making resistance coefficient =  $C_w = yF_n^4 \rightarrow (61)$

$y$  = a coefficient and  $F_n$  = Froude no.



17

So, this are things we have seen representation of the wave making resistance as  $V^6$  of Froude number power raise to 6, and subsequently the wave resistance coefficient will be proportional to Froude number raise to 4.

(Refer Slide Time: 01:47)

**Prohaska's Method (contd...)**

In the above equations,

$R_w \propto V^6$  hence  $C_w = R_w / (\frac{1}{2} \rho S V^2)$  is

$C_w$  is proportional to  $V^4$  or  $F_n^4$

The constant of proportionality is  $y$ .

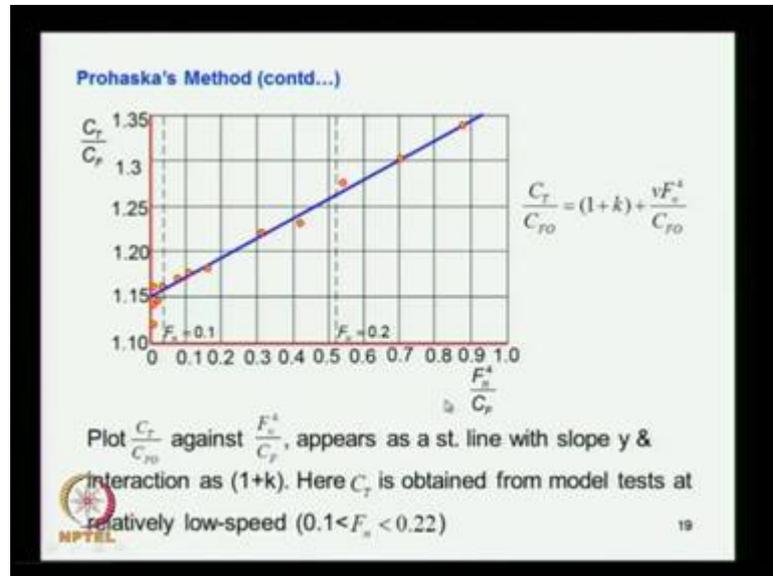
$$\frac{C_T}{C_{FO}} = (1+k) + \frac{yF_n^4}{C_{FO}}$$


18

So, this things we have already discuss and finally we have arrived that they equation expression that this  $C_T$  by  $C_T$  by  $C_{FO}$  I think it is represented here. This  $C_T$  is equal to 1 plus  $k$  into  $C_{FO}$  plus  $y w$ , which is represented by sub function of Froude number raise to 4. So, this is a equation which is represent as Froude line, if you plot this against

this with this giving as the inter section of the straight line, which is shown on the next diagram we can see that if you plot this quantity that is  $C_T$  by  $C_F$  against this quantity.

(Refer Slide Time: 02:25)



So, you get the equation proportionally that our straight line  $y$  is equal to  $mx$  plus  $c$  form. And where the  $c$  is represented by the  $1$  plus  $k$  which shows that this is a intersection point. So, what you do is you perform experiments on the model for very low speed and where the wave making effect is in significant. So, it is mainly due to the viscous effect the resistance.

And that viscous resistance you plot it here using this  $C_T$  are total resistance coefficient divided by the fraction resistance coefficient obtain from ITTC formula. So, you have this ratio and then you plot it against this value that is the Froude number power 4 divided by the fraction resistance coefficient obtains from ITTC form. So, then you get the red points here these are the point which come from model tests. And to that point you fit a straight line you can see that is almost following the pattern following a straight line. And this straight line is represented by this equation and from which the inter section you get that is  $1$  plus  $k$  is obtain from this.

So, here in this it is coming to almost  $1.15$  that is  $1$  plus  $k$  the form factor is equal to form fraction is equal to  $0.15$ , so that is how it is estimated through experiments. So, model has to be operated very low speed where the wave making effect is in significant. So, the total resistance is due to the viscous of it this points also we have seen that when they.

(Refer Slide Time: 04:12)

**Prohaska's Method (contd...)**

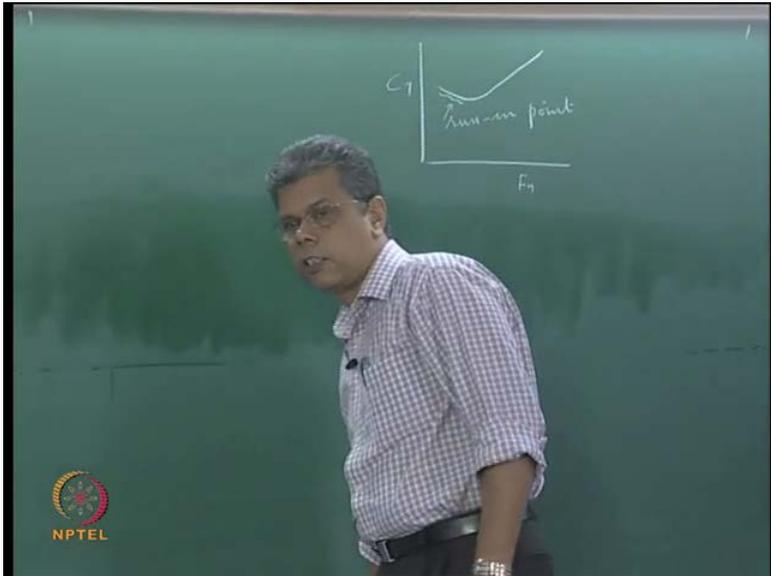
- The uncertainty of measuring resistance at very low speed is relatively large.
- This means that it is difficult to determine the "run-in-point" (see step4 in Hughes method) exactly.
- For fuller form ( $C_B \sim 0.8$ ), the plot is a concave curve.
- $(1+k)$  and  $y$  are speed dependent
- It may be better to use a power for  $F_n$  between 4 & 6 instead of 4.



20

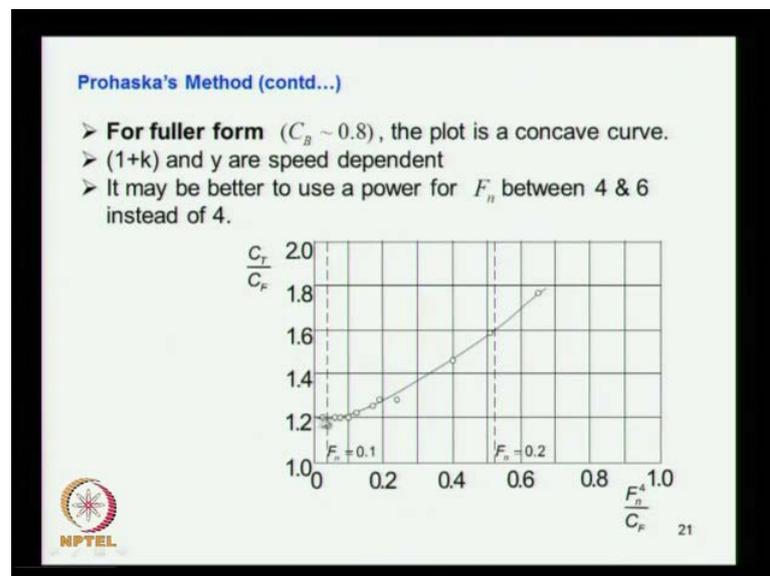
So, here the uncertainty of measuring resistance at very low speed is relatively large because the value is resistance varies very small. So, when you try to measure a small value even a slight division in there measurement leads a large error, so one has to be very careful. So, that is way it says us uncertainty in measurement of resistance in at low speed. So, this means this is difficult to determine the run in point we have already discuss the resistance curve where is the run in point which shows that. So, I think I have already explained that run in point.

(Refer Slide Time: 05:05)



If you draw the  $C_T$  against Reynolds number I just put a Froude number, Froude number you see the resistance goes like this and then increases like this. So, this is the run in point, so this we have already discussed the when we discuss about the huge methods for the prediction of resistance from model test. So, it is difficult to determine the run in point because that is a region with a not the straight line have the uncertainty because here to operate the model at very low Froude number. So, for fuller form this plot is concave curve as we seen in the next as slide when you plot this values.

(Refer Slide Time: 06:00)



You can say that when the form is full it comes a concaves not the straight line when the fuller form ships like tankers in and bul carries when you can consider the wave making resistance is high. And hence a wave making resistance generally represented proportional to  $b$  power 6 that may not to hold strictly good for fuller form ships. So, we have to put a higher power, so that means we have to put the  $C_W$  this is a function of or this proportional to normally we had put a  $F_n$  raise to 4. But, that power of 4 is not sufficient for a ships having fuller form. So, it is advise to give a the power between 4 and 6 that is all it meant.

So, it is better to use a power of for  $F_n$  between 4 and 6 instead of 4. So, if you are having a testing a tanker ship or a bull carrier or and full form ship may be a batch. So, what you do is you use the relation where you used I think this relation in place of 4 you use 5 or 6. Otherwise if you do not use it then you get this curve, so if you use 5 or 6

appropriate power for that then you get a straight line and you see representation of the resistance and then to find out the form factor.

(Refer Slide Time: 07:22)

**ITTC1957 Method**

Model total resistance,

$$C_{TM} = \frac{R_{TM}}{\frac{1}{2} \rho_M V_M^2 S_M}$$

$$C_{TM} = C_{FM} + C_{RH}$$

ITTC formula  $C_{FM} = \frac{0.075}{(\log_{10} R_{nM} - 2)^2}$

$$C_{RM} = C_{TM} - C_{FM} = C_{RS}$$

$$C_{TS} = C_{FS} - C_{RS} = C_{FS} + C_{RM}$$


22

So, we have see huge method for prediction and ITTC in 1957 method is an next method which is used for the prediction of ship resistance from the model tests data. So, later it has been revised as ITTC in 1978 which follows this one. So, the model test the model tests the model resistance coefficient of the model  $C_{TM}$  you know that it is represented by total resistance of the resistance of the model divided by half rho M. That is fresh water density models velocity square into surface weight is surface head of the model. So, this case needs the total resistance coefficient of the model.

And we know that total resistance coefficient of the model is represented as the summation of frictional resistance  $R_H$  also ((Refer Time: 08:27)) resistance this is actually M. So, ITTC formula gives a friction resistance  $C_{FM}$  based from the plate flat plate experiment. So, this expression is given as 0.075 divided by log  $R_{nM}$  minus 2 to the whole square. This the expression know you, so here there you specifically note that the Reynolds number is used the here is that of the model. So, model Reynolds number, so you find out this quantity from the ITTC formula.

And then you can substitute it here, so that you will get  $C_{RM}$  is equal to  $C_{TM}$  minus  $C_{FM}$ . This is what it is here  $C_{RM}$  is equal to  $C_{TM}$  minus  $C_{FM}$  because  $C_{TM}$   $C_{FM}$  is known, now from this expression. So, from which  $C_{TM}$  is already measured  $R_{TM}$

measured total resistance of the model measured you know this parameters. So, total resistance coefficient is also known, so you know these two quantities  $C_{TM}$  is known  $C_{FM}$  known. So, you can find out what is  $C_{RM}$  which is given by this relation and we already know that it follows the Froude assumption. The test is done based on the Froude assumption.

That is the Froude number of the ship is equal to the Froude number of the model. So, that is the one which we are telling and based on which you know the model speed is equal to ship speed divided by square root of the scale test. So, under that condition you say  $C_{RS}$  is equal to  $C_{RM}$  procedure resistance coefficients of the ship. And models are same since its satisfying the Froude number. So, the total resistance coefficient of the ship is equal to  $C_{FS}$  that is factor resistance of the ship minus  $C_{RS}$  and that is equal to  $C_{FS}$  plus  $C_{RM}$  because both are same.

So, I just say this is plus this is I think it is a mistake there should be plus. So, here the  $C_{FS}$  you that again from ITTC formula same thing only difference is use the Reynolds number of the ship not the Reynolds number of the model. So, here you use the Reynolds number of the ship you get  $C_{FS}$  and this  $C_{FS}$  value used here and  $C_{RM}$  equal  $C_{RS}$  which is obtain from the modellers we are substituting here and from here you will get this total value that is  $C_{TS}$ .

(Refer Slide Time: 11:01)

ITTC1957 Method (contd...)

To the above the model-ship correlation allowance (to take care of the ship roughness) is also to be added.

$$C_{TS} = C_{FS} + C_{RM} + C_A$$

Where  $C_A = 0.0004$   
*Ship resistance,*

$$R_s = C_{TS} \left( \frac{1}{2} \rho_s V_s^2 S_s \right)$$


23

So, what you get is you have estimated  $C_{TS}$  where ((Refer Time: 11.08)). Then for the model we have to give elements call the model ship a correlation allowance model ship. Correlation allowance is the allowance given to taken to your account the discriminancy of the surface softness between the model and ship. The ship model is made of any you know fibre glass of wax models and all very smooth, where as the ships of a surface is not so smooth. So, that is a variation the roughness that are various reasons which we discuss in the preliminary classes what is a roughness causes. That is the well joints determination of plate there are many other causes which acts adult a test of paints, so many reasons which contribute to the increase in roughness.

For the ship which is not accounted or which is not scale down to later the model so that different in roughness increases the resistance of the ship. So, that difference which you call the model ship correlation allowance which is normally given as this value is substituted here. So, you get the total resistance coefficient for the then you multiply the total resistance coefficient by the ship parameters including the sea water density ship velocity square and ship vector surface area. So, then you get the total this is  $R_{TS}$  total resistance of the ship. So, that is the procedure adopted in ITTC in 1957 method for the prediction of ship resistance from the model plus data.

(Refer Slide Time: 12:54)

**1978 ITTC performance prediction method**  
for single-screw ships:

$$C_{TS} = (1+k)C_{FS} + C_R + C_A + C_{AA}$$

Where

- $k_s$  = the form factor determined from the resistance test
- $C_{FS} = C_F$  of ship as per ITTC1957 ship model correlation line.
- $C_R$  = residuary resistance calculated from the model test  
 $= C_{TM} - (1+k)C_{FM}$
- $C_{FM} = C_F$  of models as per ITTC1957 ship-model correlation line

 NPTEL 24

So, here you might have notice that the form factor has been not considered and eight ITTC 1957 model the effect of form has been ignored. So, here when it comes to this has

been notice and the difference has been understood that and accepted that by ITTC, and came out in 1978 with a prediction method modified prediction method for the ship resistance from model tests. So, here what it does is  $C_{TS}$  is equal to  $1 + k$  into  $C_{FS}$  plus  $C_R$  plus  $C_A$  plus  $C_{AA}$ . What are these quantities  $k$   $1 + k$  is a form factor  $C_{FS}$  is ITTC in 1957 great that model for resistance expression  $C_R$ . The  $C_A$  resistance which is already resistance  $C_R$  this are coefficient how its measured.

Then this is a model ship correlation allowance for roughness and this one easily air resistance by this also taken consideration in the next. So, here that is all explained form factor  $k$  is the form factor  $C_{FS}$  coming from ITTC in 1957 expression  $C_R$  we have already seen from the model. So, if here the  $C_R$  will be  $C_{TM}$  minus  $1 + k$  into  $C_{FM}$  it is not just in the previous one it 57 expression you had  $C_{CR}$  is able to  $C_{TM}$  minus  $C_{FM}$ . But, here the form factor is coming to effect, so the form factor effect is also considered in the 1978 ITTC performance prediction method. So,  $C_{FM}$  is equal to  $C_F$  of models as per ITTC again same thing  $C_A$  roughness the expression given is this one  $C_S$  is equal to tune by this  $x$  where  $k$ .

(Refer Slide Time: 14:38)

**1978 ITTC method (contd...)**

$C_A$  = roughness allowance

$$C_A = [105 \left( \frac{K_s}{L_{wL}} \right)^{\frac{1}{3}} - 0.64] \times 10^{-3}$$

$K_s$  = the mean apparent amplitude of the surface roughness over a 50mm wavelength

$K_s = 150 \times 10^{-6}$  if  $K_s$  value not known

$L_{wL}$  = length as waterline

 NPTEL 25

Has you see you know the surface is not going to be the even surface it is a rough surface. If you measure it microscopic value see that it is totally a random surface it is not is. So, then what you do is you measure it you map it then you analysis it and find out what is a main apparent amplitude of the surface roughness cover a over a 50 mm

wavelength, so that is how the value has been, so unfortunately may be during the design or estimation side of resistance, you do not have the information about the roughness of the ship into the details. So, you do not have a you know a picture of a graph representing the roughness. So, you would not be able to use this information from the actual surface what you do is if you do not have this information. Then use this 150 into 10 power minus 6 K s.

So, use this you put it here L WL you know length of water line say get what do you C A and you said that value instead of putting 0.0004. That is the value normally we used even now also we use that 0, you can say that this is the value it is. So, may be its more operate, if we know the information about roughness use this formula for a C A.

(Refer Slide Time: 16:11)

1978 ITTC method (contd...)

$$C_{AA} = 0.0001 \left( \frac{A_{VT}}{S} \right)$$

$A_{VT}$  = projected front area of ship above WL  
 $S$  = wetted surface of hull

For ships with bilge keel

$$C_{TS} = \frac{S + S_{BK}}{S} [(1+k)C_{FS} + C_A] + C_R + C_{AA}$$

Where  $S_{BK}$  = surface area of the bilge keels

 NPTEL 26

So, C AA this is upper sending the air resistance coefficient you know when the ship is moving air is flowing opposite to that. And then the resistance Indus may be air media flow of air, so that is accounted by here this expression this is A VT divided by S. A VT is a projected frontal area that needs if the ship is we have already explain that one of the previous class when the ship is moving forward. So, the blocking area it take the transfers area wind the air is flowing the opposite direction. So, the transfers area the above outer portion of that if the ship is taken is equal to A VT as a projected front area of the ship above water length yes same wetted surface of the hull.

Then for ships with bilge keel, so you have once. You know the ship geometry you can find out what is  $A_{VT}$  and also what is wetted surface. We substitute in this you get  $C_W$  that is it, so you know in this calculations say may dot of included the wetted advantages like bilge keels or winds are whatever it may be, so you do not have. So, what do you do is how do you take into account the effect of bilge keel bilge keel. Bilge keel is you know deeply submerge it is at the bilge proportional of the ship. So, the wave making effect is in significant because is deeply submerge that is the ((Refer Time: 17.42)) to the bottom of the ship.

So, the fractional of factor is small, so on the resistance. So, what do you do is you just consider the same the frictional aspect that is  $1 + k$  into  $C_{FS}$  plus  $C_A$ . This you know already for the Bahell model without their bilge keel. So, what do you do is you multiply when you multiply this the you take the ratio of the total wetted surface area of the ship plus wetted surface area of the bilge keel then divided by wetted. So, that ratio will take care of the variation and the apprentices, so they just what is considered here. And then you have a ((Refer Time: 18.23)) resistance coefficient and air resins curve, so putting all this together you get the total resistance coefficient. Then you multiply it by half row  $S V$  square of the ship then you get the total resistance for the ship, so that is the prediction.

(Refer Slide Time: 18:43)

1978 ITTC method (contd...)

**ITTC recommendations**

- ITTC recommends the use of form factor for better representation of ship-model correlation than the ITTC 1957 method.
- Prohaska's method for form factor with suitable exponent for  $F_n$ , was recommended for conventional ship shapes.
- Resistance results of  $0.12 < F_n < 0.20$  may be used.

NPTEL 27

Suggested in the 1978 ITTC method, so ITTC recommends the use of form factor for better representation ship, in that is what we have seen 1978 method it shown compared

to ITTC 57 method Prohaskas method has been recommended you have seen that Prohaskas method for the prediction form factor ITTC is also recommend the same thing. So, in Prohaskas method you know you run the model at very low Froude number also the data obtained very low Froude number then you have plotted  $C_T$  by  $C_F^4$  against  $F_n$  raise to 4 by  $C_F^4$ . Then you got a straight line take the inter section of the that is  $1 + k$ .

So, it is a form factor and this is procedure adopted by Prohaskas if the the cell is fuller form like tanker or a bulk area of bar just in all the. So, then instead of plotting the absences  $F_n$  raise to 4 by  $C_F^4$  you put  $F_n$  raise to 5 or may be  $F_n$  raise to 6 by  $F^4$ . Then you get the straight length for that Prohaskas method for form method recommended. Then resistance usually at low speed here it is says if too low of Reynolds number then measurement becomes very difficult us to in there laminar region. So, it generally recommends is this region usually go. But, very low Froude number in this blower of this range to get the estimate the form factor.

(Refer Slide Time: 20:16)

**1978 ITTC method (contd...)**

**ITTC recommendations**

- For ships with partly submerged bulbous bows, the effects of wave-breaking resistance prediction is not convincing. Lower speed limits may improve the situation.
- Instead of determining  $k$  on the basis of Prohaska's proposal ITTC recommends,

$$\frac{C_T}{C_F} = (1+k) + c \frac{F_n^n}{C_F}$$

where the values of  $n$ ,  $c$  &  $k$  are to be determined by a least squares approximation of the measured data points.

 28

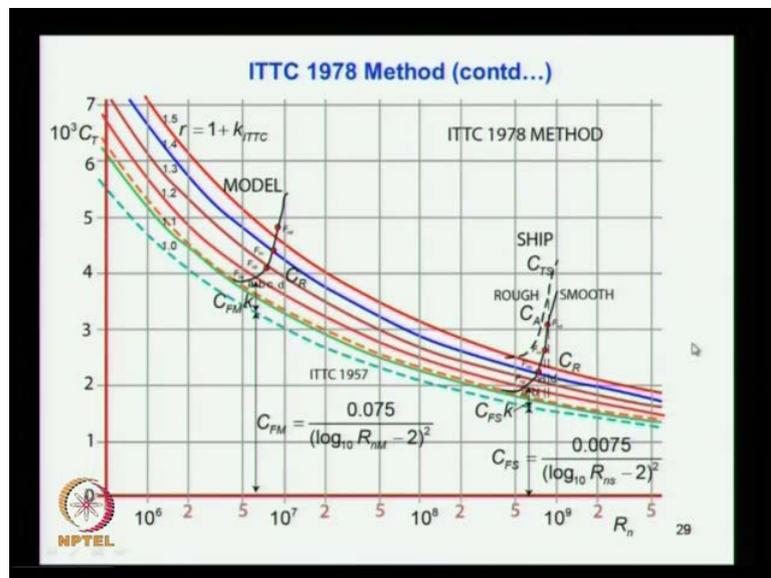
So, for ships with submerged bulbous bow the effect of wave breaking resistance prediction is not convincing. So, you that means hardly with hardly submerged bulbous bow, so we have to design the bulbous bow. And if it is partly submerged they estimation wave breaking resistance it is not convincing, because of the you know part of

hidden wave creation you know bulbous bow is provided for reducing a wave breaking resistance. And I have already discussed when we discuss about bulbous bow effect.

So, one of the aspect second aspects of bulbous bow is to it creates a wave system which you will this actually interfere with the ship wave system. And thus bring down the resultant wave system and hence let is the wave making resistance, so its two counts the two effects for bulbous bow. The bulbous bow generally you it submerge condition you cannot say thus sub surface and if is partly submerged that is part above the water. Then you have problem in predicting it, so instead of the determining k on the ways of prohaskas that is it instead of using a power 4 here and constant in all that this is a general expression put forward by ITTC.

So, the n and other covers c and all these it various with a respect to the type of cell. So, the values of n c are determined by the square approximation of the measured data. So, you have measured data and fix it then you find out what are the values of this. So, you fix an equation to the data we will find what is the n what is c n what k n all that.

(Refer Slide Time: 22:05)



So, in 1978 ITTC 1978 method a same thing we just put in the graphically form what do you have is you have the base line here as ITTC 1957 C F formula. This one this depending on Reynolds number, so you plot this C F or value in this axis and against the Reynolds sample. So, you get this curve this dotted line of here this is given by the ITTC 1957 formula. Now, what you do is you do the experiments for different Froude number

you get values you can see here Froude number very low Froude number increases. So, this is the C T curves for the model. So, you do the model you know you get the measured the total resistance of the model divided by half by S P square of the model, so you get C TF of the model.

So, for different Froude number you get the values you plot it and here this region this is all run in point which I said this is the run in point. So, this region one has to be very careful we get the this point more close and more accurate, so that the form factor estimation become liable. Now, what you do is you multiply this you have the base line you multiplied 1.1, 1.2, 1.3, 1.4 like you red dot lines along with the throughout we just draw the lines. And now you have this value this by this is C F value from ITTC this is C F value from ITTC into 1.1 this is C F value into of ITTC into 1.2 like that.

So, you get power range of Reynolds number submerge you get this curves. Now, we know the run in point here it is coming like this, so you can see that the run in point is considering with the red dot of line here we will say red dot of line. So, run in point consists with this line and hence this value that is that lies between 1.1 and 1.2 line. So, that interpolate at you see that you see that that is a form factor that is may be 1.12 or 1.13 that is a value we getting it there, so that is a form factor you get. So, here I can say that this curve here that represents the actually the k factor.

So, if it this is same this factor up to this red line, so we have extended that line even to the ship sight Reynolds number is a large number of ship is very high. So, ship come operates in this region and the model operates at low Reynolds number in this region usually this is a huge number. So, you put the logarithm is l in the x axis is not it, so that is what is done here. So, what you do is so you have the red line, so you have know the form factor of the model and form factor of the ship are remain same. So, you base on red line now you estimate the C FS from the ITTC formula where you put Reynolds number of a ship. And then you get C FS then you have the form factor then you get the total viscous of it and over which we know C RM which same as C F C RS.

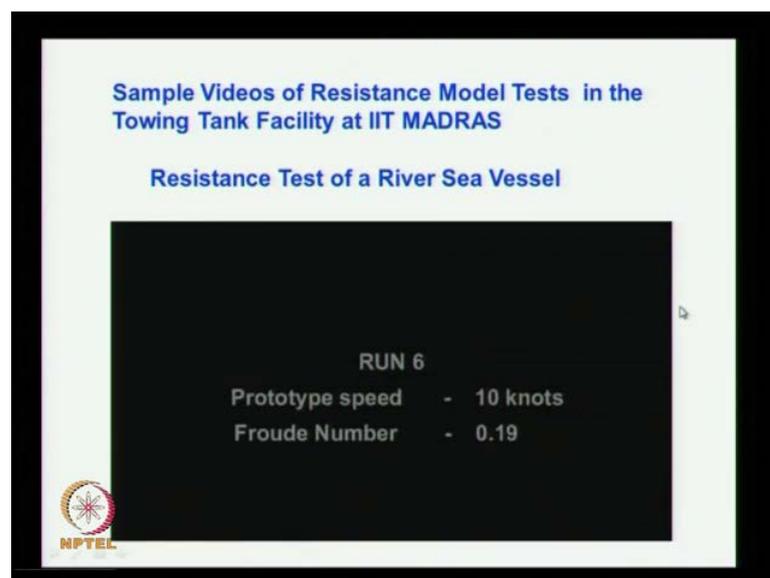
So, you put the C RS value over that, so you get the point here for the different Froude number. So, here for Froude number we have C RS values and here also you put the same value, so you get this curve that is for the smooth hull of ship. Now, we know that the ship surface is different is more over of, so you give the c a allowance here. So, this a

so you get allowance for C A you get this curve here this is a curve for the, so this is a C TS of the ship. So, this are prediction method proposed that by ITTC 1978 you find out model tests the model you find out C T of the model when you get this curve for different Froude number. Then you have the C F coming from 1957 ITTC formula you generate curves multiply it by 1.1, 1.2 like that you generate the curves.

Then you know you find out what is the run in point here that run in point shows. That the that is the region having no viscous no wave making effect. So, that fairly viscous for that run in point you can say it considering with some of the line parallel to already drawn line. So, then you find out what is the form factor by inter plating that the same length continuous here the form factor the ship and model remains same. So, here you just come down over to the ship region and then you put the form factor.

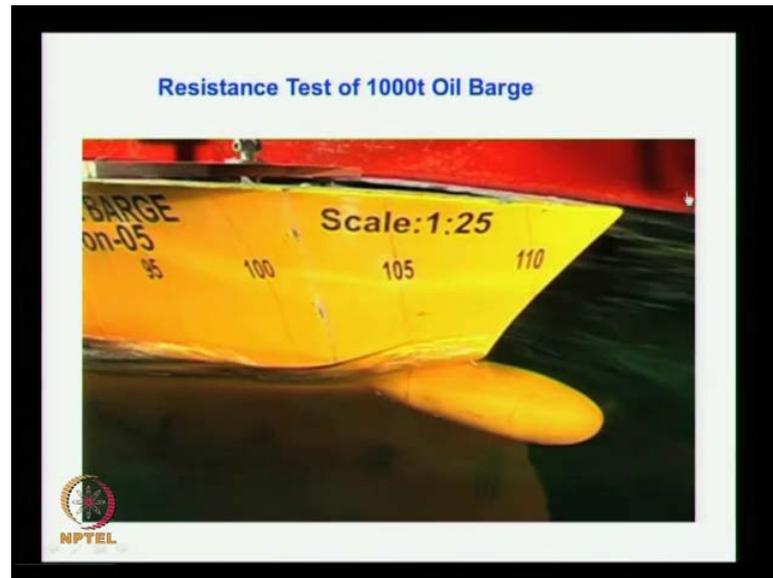
And also the C F the its already there, so from there you Froude C RS which is and C RM which is equal to C RS and that value you get this as curves. And then we have play the correction form roughness that is model correlation allowance. Then you get the total resistance of the ship, so that is the prediction method adopted by ITTC 1978 method. So, that is the method we also follow in our drawing tag, so we are following this procedure.

(Refer Slide Time: 27:33)



Just want to see that tests are done we have the facility here and IIT Madras and the towing tank we do undertake different projects and tests and all that and.

(Refer Slide Time: 27:48)



This test you can say that is one of the video of reverse sea vessel it is a vessel, which except operate meant for operation in river and also to the sea.

(Refer Slide Time: 27:57)



So, this gives you can see this test not only resistance. It also gives the pattern of wave around the vessel you can see that pattern of the around the vessel from the video or form the observation. If you find out the wave is going to be high and the wave makes resistance high you will get an information which art of the ship is creating more wave. And where you need a attention to modify the form that region, so that wave making

resistance can be brought down. So, this gives a total resistance and also gives information about the flow characteristics around that around the vessel. And the same model will be subsequently use to for self preparation tests and flow line test drawn that, so this another type which thousand tone oil barge.

So, another project you can see that if I tap ball be here we have studied the effect different types of valve. That is valve parameters vary and found the effect of resistance on the vessel due to the change in the bulbous bow parameters. So, what would be there effect this is new generation fishing vessel being plant and so this is normally waves fishing vessels or displacement type. But, here this is proportionally coming with that a semi displacement or semi planning vessel. So, here intension is are that the vessels which can reach from the fishing harbour into the fishing ground fast as because the vessel which reaches fast are first get more catch. So, you would not have vessel to higher speed.

(Refer Slide Time: 29:56)



So, what you do is the fishing school is identified may be by ideal survey may be from satellite information that is that information that identified. That if school is available such and such location, so much latitude and longitude into and all that. So, then that information spread to the fishing harbour where the fishing vessels operate. So, once that information obtained information pass on to the fishing vessel operators they will put the vessel to operation. So, the vessel which reaches the fishing ground first will have more

chance of getting more catch. So, this invention for that to go for a semi plain vessel, so it move faster and reaches as fishing ground faster.

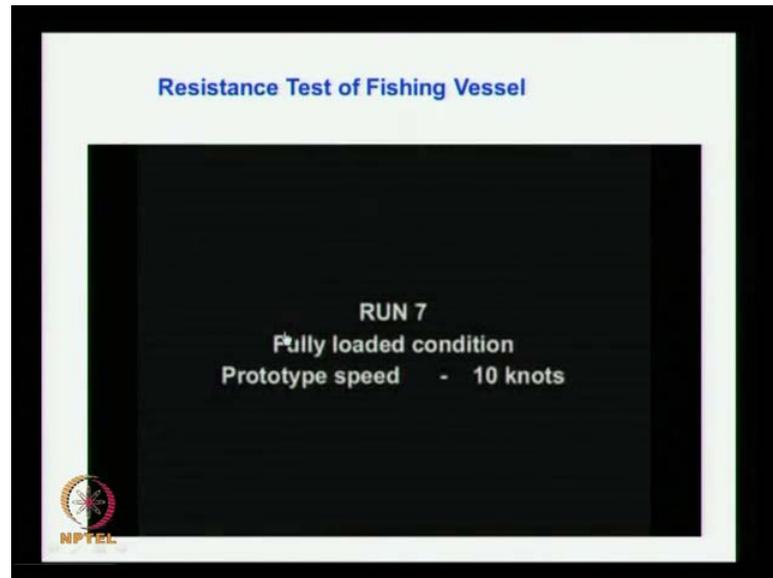
But, thing is when it come back it is loaded with fish, so that time it is difficult to plain. So, they will coming back you can take little more time does not matter was already the fishes is with you with the ship does not matter. So, it takes the fish and come in normal displacement in lower speed.

(Refer Slide Time: 30:58)



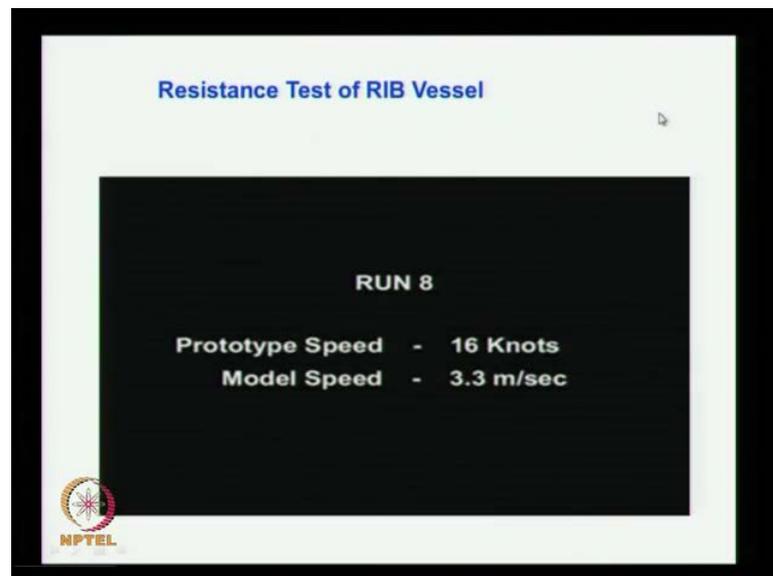
So, this is to study the effect of the vessel for different speeds and you know how it performs in different condition. You can see that this the stepping here which gives a actually the rusting the spray of the water.

(Refer Slide Time: 31:16)



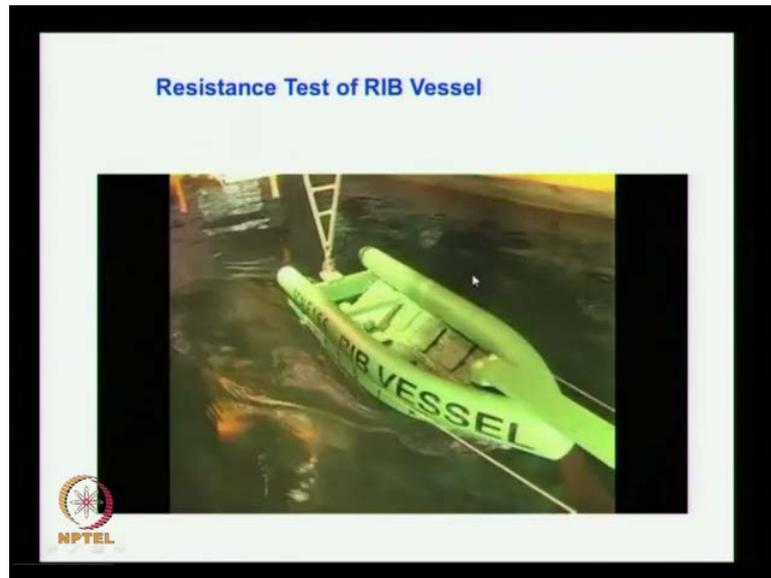
When it is moving at the high speed.

(Refer Slide Time: 31:19)



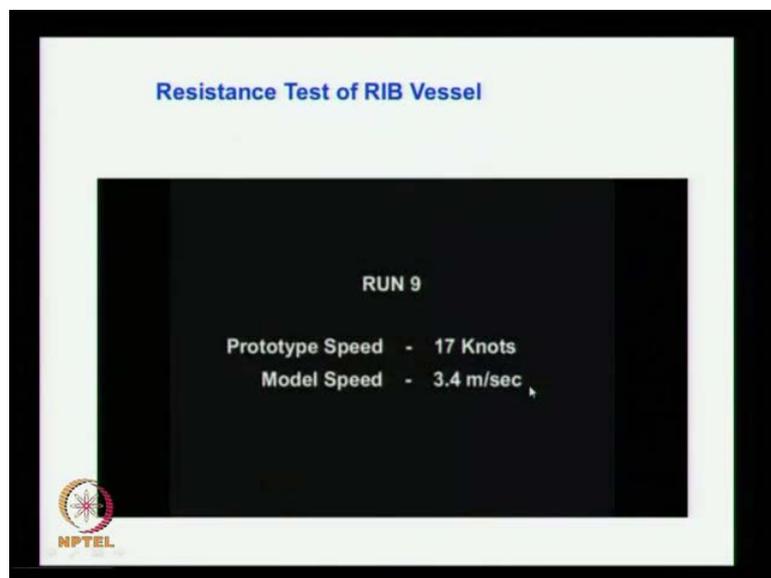
And this also here way of check the rigid inflatable boat RIB vessel you can see that how does it also done in our tank, which is the plain in your obviously it is the high speed vessel.

(Refer Slide Time: 31:25)



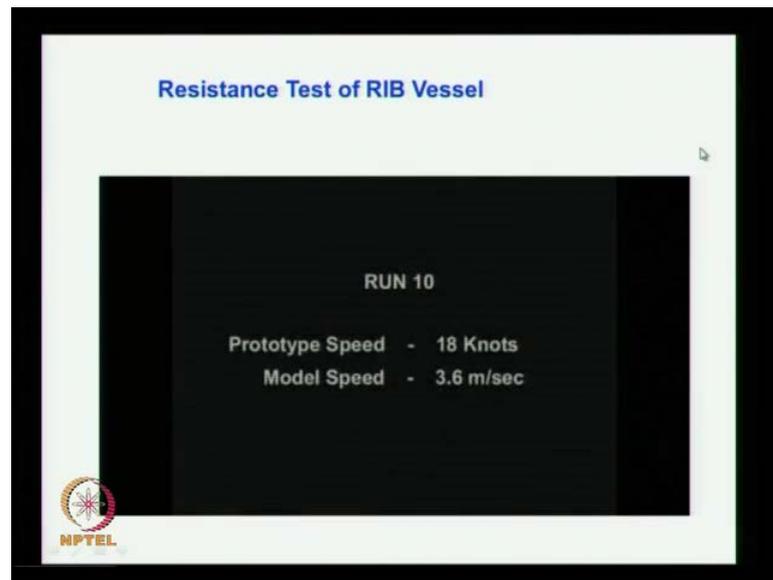
So this you can see is resist in fightable boat. And you can say the planning effect how it plains is yours planning sufficiently and what would be the position of centre gravity on the planning and all that.

(Refer Slide Time: 31:47)



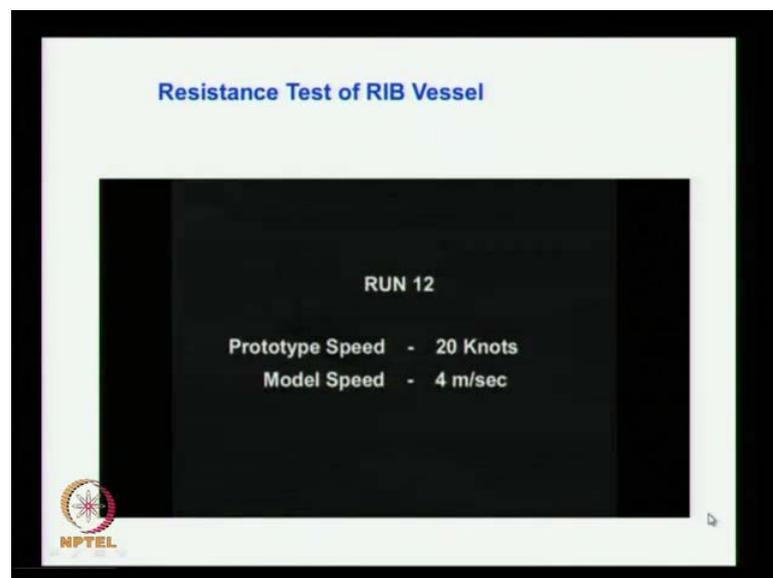
This effects are studied in during this also related in measure the resistance also and you know what is a power requirement.

(Refer Slide Time: 32:16)



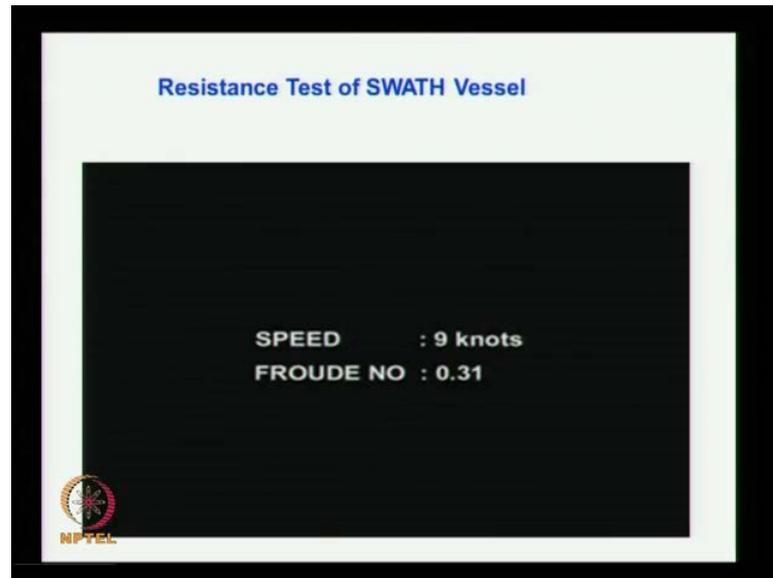
For the vessel at that speed I think it is not moving here some problem let me check.

(Refer Slide Time: 33:11)



So, up one minute it is not moving to next slide one second we have in watching that.

(Refer Slide Time: 34:09)



The one other the rib vessel model test and now you look to the a case of a Swath vessel you here. This is another experiment which we carried out this intention is basically to find out the what is a powering requirement.

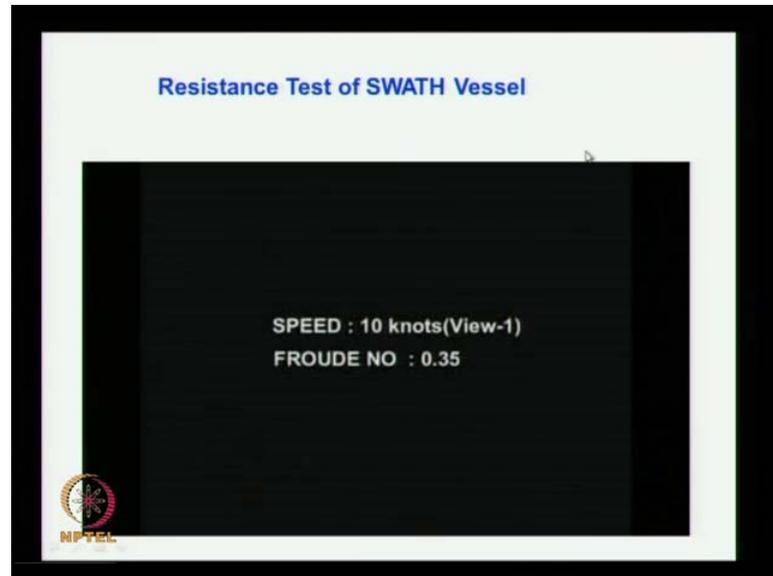
(Refer Slide Time: 34:36)



We tried different version of the and also different configuration of the Swath vessel and the you can see here in the middle there is a gap. This is actually 4 hulls 1 hull 1 hull here another hull here the same thing on the other side. And you can say the middle

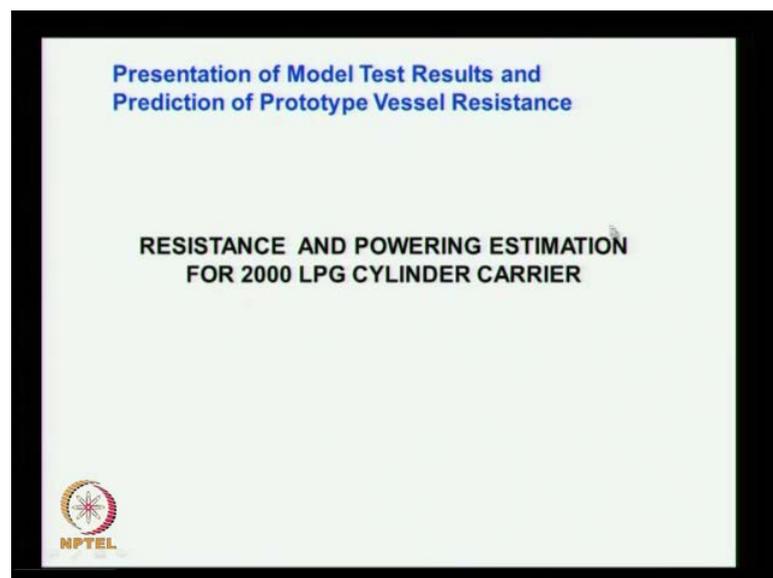
portion there is a gap, so there is a connection. So, it has been found that the middle region is creating lot of waste.

(Refer Slide Time: 35:19)



And when we fill that that opening it was found to improve the flow condition, and finally we suggest such a configuration for this Swath proposed and which always reduce the total resistance.

(Refer Slide Time: 35:23)



Now, you see the prediction of model test simple example here how it is done resistance may consider 2000 LPG cylinder carrier which is done for a as a part of a project.

(Refer Slide Time: 35:42)

Particulars	Prototype	Model
LOA	41.2 m	3.17 m
LBP	40.0 m	3.08 m
Breadth	9.5 m	0.73 m
Depth	3.5 m	0.27 m
Design draft	2.3 m	0.18 m
Displacement (at design draft)	618 t	281.29 kg
Design Speed	11 knots	1.57 m/s
Model scale	1 : 13	



These are the main particulars of the vessel and model you can say. This is the length between perpendicular breadth then depth draft displacement and speed we use the model scale of 1 is to 13 and this is the corresponding model parameters.

(Refer Slide Time: 36:08)

<ul style="list-style-type: none"><li>➤ The model is ballasted to represent the loaded condition.</li><li>➤ Model towing tests are conducted in the speed range to cover the design speed.</li><li>➤ Results are obtained by extrapolation on the basis of ITTC 78 prediction method using Froude's law of scaling.</li></ul>
---



So, it is model of to make the model is a procedure here which is adopted you make the from the drawing of the that is the next plain you find out you take the template cut the template from that if you get the body plan. And from you make templates of the record scale and this templates are relate and then as per the designated position length wise.

And then it is covered with wooden strips to get the form and the form is finally feared and with application of different material and all that and. Finally, from that you make the mould is see fibre glass and this fibre glass mould is use to make the model. So, and some model is made with the proper stiffing inside, and all that to keep it resist and then the model is taken to the tank and the model is blasted to get the load condition.

That means we have already mark the load walk line and also the stations, so the model has to displace till the water line that is a design load water line. So, for that you way the model and you find out what is a difference of weight to be place on the model and the model is velocity or then it displace it. As it displaces up to the load and this unload water length, so then that is I think it is shown here may be the next we will see. So, model towing tests are conducted in the speed range of cover the design speed that is you start with very low speed for the model we going increase it gradually. And it discrete a model speeds you measure the resistance and usually it is done may be about may be 10 percent or 15 percent more than the survey speed of the model.

So, this the whole range or speed is covered and the from the towing tests you find out. What is the resistance corresponding resins for the corresponding speed results are obtained by extrapolation on the basis of nineteen ITTC 1978 prediction method using the Froude law of scaling. So, we have already seen that Froude law of scaling which implies that Froude number of a ship is equal to Froude number of the model. From which we get the velocity of model is equal to velocity of ship divided by square root of lambda that is a scale.

(Refer Slide Time: 38:49)

**CALCULATION FOR FORM FACTOR**

#2

$R_{tm}$  → Model resistance (N)  
 $\rho_{fw}$  → Density of fresh water at 25 °C = 997 kg/m<sup>3</sup>  
 $V_m$  → Model speed (m/s)  
 $S_m$  → Wetted surface area of model (m<sup>2</sup>)  
 $L_m$  → Waterline length of model (m)  
 $\nu_{fw}$  → Viscosity of fresh water at 25 °C =  $0.8929 \times 10^{-6}$  m<sup>2</sup>/s  
 $g$  → Acceleration due to gravity = 9.81 m/s<sup>2</sup>  
 $C_{RM}$  → Coefficient of residuary resistance of model



So, here the calculation of the form factor what suffers method we have to adopt as again we have to find out when the model very low speed very low Froude number and get the form factor. Say the these are the terms we use this use analysis that is the model resistance  $R_{tm}$  total resistance of the model. Then density of fresh water model speed sub wetted surface area of the model then the length of the modellers waterline length is consider. Then a viscosity new fresh water acceleration due to gravity then you have the  $C_{RM}$ . These are residuary resistance coefficient of the model say are the viscosity taken up fresh water viscosity is taken as this value for 25 degree Celsius and this are the density used.

(Refer Slide Time: 39:45)

**FORM FACTOR (contd...)**

Total model resistance coefficient,  $C_{tm} = R_{tm} / (\frac{1}{2} \rho_m S_m V_m^2)$

Reynolds number of model,  $R_{nm} = V_m L_m / \nu_m$

Frictional resistance coefficient of model,  $C_{fom} = 0.075 / (\log R_{nm} - 2)^2$

Froude's Number,  $F_{nm} = V_m / \sqrt{g L_m}$

$$C_{tm} = (1+k)C_{fom} + C_{rm}$$

$$\frac{C_{tm}}{C_{fom}} = (1+k) + \frac{C_{rm}}{C_{fom}}$$

$$\frac{C_{tm}}{C_{fom}} = r + b \frac{F_n^4}{C_{fom}}$$


So, the total model resistance coefficient we know we have already seen that its coming as a  $R_{tm}$  divide by half  $\rho_m S_m$  into  $V_m$  square. These are model parameters used Reynolds number define by this relation are well known then you use ITTC formula to get the  $C_{fm}$ . And you know the Froude number is given by this parameters Froude number of model say  $V_m$  by root of  $g L_m$  which is same as equal to Froude number of a ship. So, the total resistance now is surplus by consider form factor 1 plus  $k$  into  $C_{fom}$  say  $C_{fom}$  is a flat plate resistance coming around my ITTC formula for the model. And then the  $C_{RM}$ , so we know this procedure we have already seen Proraskas method. So, you represent that this form and finally you get the  $C_{RM}$  transfer the  $F_n$  raise to 4 into, so this get this expression  $k$ .

(Refer Slide Time: 40:51)

FORM FACTOR (contd...)

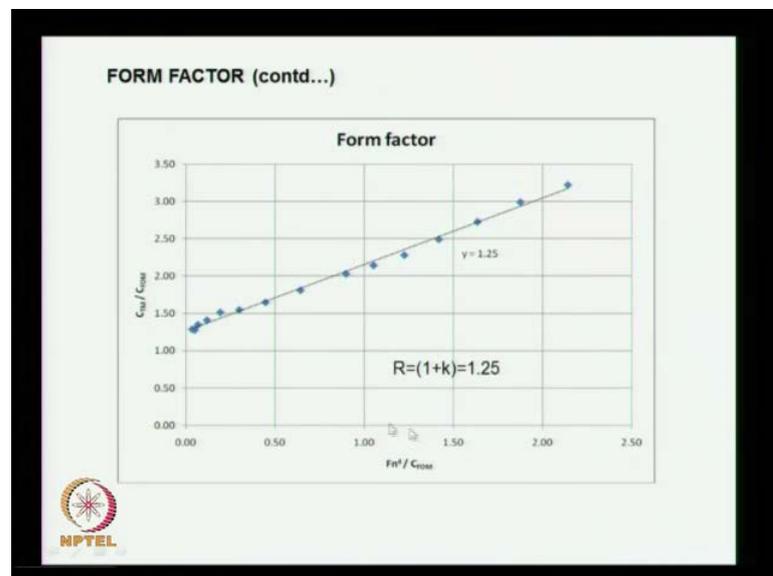
Data for Form Factor Plot

Sl. no.	$F_n^4 / C_{FOM}$	$C_{TM} / C_{FOM}$
1	0.035	1.289
2	0.049	1.279
3	0.067	1.350
4	0.117	1.411
5	0.192	1.515
6	0.299	1.550
7	0.446	1.649
8	0.642	1.811
9	0.898	2.031
10	1.052	2.146
11	1.225	2.283
12	1.419	2.494
13	1.635	2.731
14	1.876	2.995
15	2.142	3.225



So, from this we get what we say parameters it is  $F_n$  raise to 4 by  $C_{FOM}$  and also  $C_{TM}$  by  $C_{FOM}$ , so if that the columns.

(Refer Slide Time: 41:06)



Then you go for plot you plot this values here then you get the points then if it is straight line. So, the point using recreation, so you get a straight line.

(Refer Slide Time: 41:24)

**Extrapolation method for obtaining prototype resistance**  
**ITTC 1978 Method used**

**Symbols used:**

$\lambda$	=	Geometric scale of model
$R_{ts}$	=	Prototype resistance in Newton
$R_{tm}$	=	Model resistance in Newton
$V_s$	=	Prototype speed in m/s
$V_m$	=	Model speed in m/s
$S_s$	=	Wetted surface of prototype
$S_m$	=	Wetted surface of model
$\rho_{sw}$	=	Density of sea water at prediction temperature of 25°C
$\rho_{fw}$	=	Density of fresh water at prediction temperature of 25°C



And finally the inter section here that will give the form factor, so that is a Proraskas method. Now, extrapolation of method to the photo type what we have done is for the model. So, how you extrapolate disabled, so the thus go through symbols for duos scale is a model scale is  $R_{ts}$  is the resistance of the total resistance of the ship  $R_{tm}$  as a total resistance of the model. So, this is a spade of the ship spade of the model based on the Froude law, then wetted surface spade of ship and model then fresh water density and sea water density and fresh water density, so there is so other things.

(Refer Slide Time: 41:58)

**ITTC 1978 Method (contd...)**

**Symbols used:**

$C_{ts}$	=	Coefficient of total resistance of prototype
$C_{tm}$	=	Coefficient of total resistance of model
$C_{rm}$	=	Residuary resistance coefficient of model
$C_{rs}$	=	Residuary resistance coefficient of prototype
$C_{tom}$	=	Coefficient of equivalent flat plate resistance of model
$C_{tos}$	=	Coefficient of equivalent flat plate resistance of prototype
$R_{rm}$	=	Reynolds's number of model
$R_{rs}$	=	Reynolds's number of prototype
$L_m$	=	Waterline length of model
$L_s$	=	Waterline length of prototype
$\nu_{fw}$	=	Kinematic viscosity of fresh water for model
$\nu_{sw}$	=	Kinematic viscosity of sea water for prototype
$(1+k)$	=	Form factor



Coefficients all this are self explanatory way again what is that transients coefficient of the is a total is eighty of this  $C_{ts}$ . Then you have the  $C_{tm}$  that is the model  $C_{rm}$   $C_{rs}$  and all the coefficients here. Then length kinematic viscosity and the form factor definition.

(Refer Slide Time: 42:27)

**ITTC 1978 Method (contd...)**

**Physical data and constants:**

Density of sea water at 25°C,  $\rho_{sw} = 1025 \text{ kg/m}^3$   
 Density of fresh water at 25°C,  $\rho_{fw} = 997 \text{ kg/m}^3$   
 Viscosity of sea water at 25°C,  $\nu_{sw} = 0.9425 \times 10^{-6} \text{ m}^2/\text{s}$ .  
 Viscosity of fresh water at 25°C,  $\nu_{fw} = 0.8929 \times 10^{-6} \text{ m}^2/\text{s}$ .

$R_{ts} = C_{ts} \times 0.5 \rho_{sw} \times V_s^2 \times S_s$   
 $C_{ts} = C_{fos} + C_{rs} + 0.0004$  (correlation allowance)  
 $C_{rs} = C_{tm} - C_{tom}$   
 $C_{tm} = R_{tm} / (0.5 \times \rho_{fw} \times V_m^2 \times S_m)$   
 $C_{tom} = 0.075 / (\log R_{tm} - 2)^2$   
 $C_A = 0.0004$



The physical constant used for sea water the density is taken as ten twenty five kilo grams parameter  $\rho$  and fresh water density is taken us this one viscosity sea water at 25 degrees when by this quantity and that mean fresh water done by this one. So, know what do you it so you have  $R_{ts}$  is equal to  $C_{ts}$  in the half row is half row  $S$  into  $V_s$  square into  $S$ . So, you get then  $C_{ts}$  is equal to this distance I mean  $C_{ts}$  is equal to  $C_{fos}$  plus  $C_{rs}$  plus the correlation allowance. So, from this we get  $C_{rs}$  is equal to  $C_{tm}$  minus  $C_{tom}$  and that is obtained  $C_{tom}$  is coming from this expression and  $C_A$  is used these are value for  $C_A$  used.

(Refer Slide Time: 43:24)

**ITTC 1978 Method (contd...)**

$$V_s = V_m \sqrt{\lambda}$$

$$C_{ts} = C_{fos} + C_{rs}$$

$$C_{rs} = C_{rm}$$

$$C_{rm} = C_{tm} - C_{fom}$$

$$C_{tm} = R_{tm} / (0.5 \times \rho_{tw} \times V_m^2 \times S_m)$$

$$C_{fom} = 0.075 / (\log R_{vm} - 2)^2$$

$$C_{fos} = 0.075 / (\log R_{vs} - 2)^2$$

$$R_{vs} = V_s L_s / \nu_{sw}$$

$$R_{vm} = V_m L_m / \nu_{tw}$$

$$R_{ts} = C_{ts} \times 0.5 \rho_s \times V_s^2 \times S_s$$


Then you have all this parameters are known, so finally get  $C_{rm}$  is equal to  $C_{tm}$  minus  $C_{fom}$  and all this quantity is coming from that of the  $C_{fom}$  of the model  $C_f$  of the ship. And Reynolds sum are estimated and finally you have the quantity is here the model and.

(Refer Slide Time: 43:44)

**Test condition – Hull fitted with all appendages at even keel.**

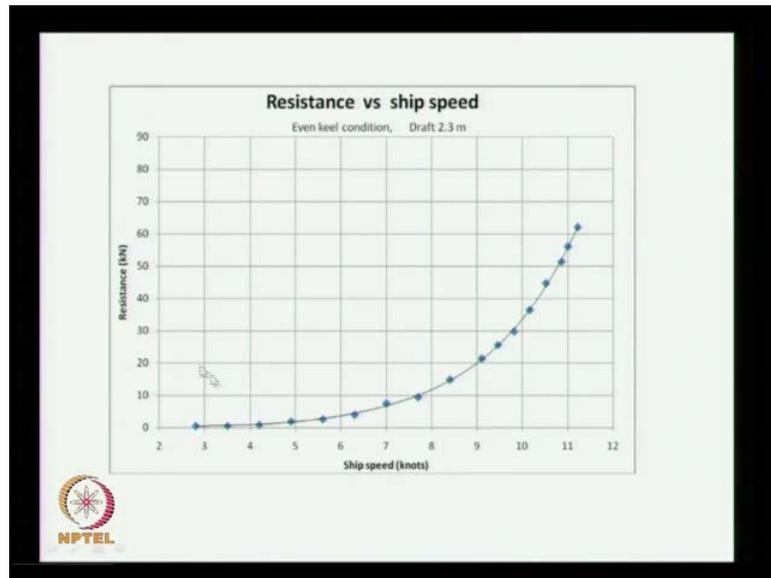
**Draft 2.3 m**

Sl. no.	Model speed (m/s)	Model resistance (N)	Ship speed (knots)	Prototype resistance (kN)	Effective power (kW)	Effective power (HP)
1	0.40	0.7	2.8	0.4	0.6	0.8
2	0.50	1.0	3.5	0.5	1.0	1.3
3	0.60	1.4	4.2	0.8	1.8	2.4
4	0.70	2.2	4.9	1.9	4.8	6.6
5	0.80	2.8	5.6	2.6	7.5	10.2
6	0.90	3.7	6.3	3.9	12.7	17.2
7	1.00	5.7	7.0	7.5	26.9	36.5
8	1.10	7.0	7.7	9.4	37.3	50.6
9	1.20	9.8	8.4	14.8	64.1	87.1
10	1.30	13.1	9.1	21.3	99.8	135.6
11	1.35	15.3	9.5	25.6	124.6	169.4
12	1.40	17.4	9.8	29.7	149.9	203.6
13	1.45	20.6	10.2	36.4	190.4	258.7
14	1.50	24.5	10.5	44.7	241.7	328.4
15	1.55	27.8	10.9	51.4	287.2	390.2
16	1.57	29.9	11.0	56.0	317.1	430.8
17	1.60	32.8	11.2	62.1	358.0	486.5



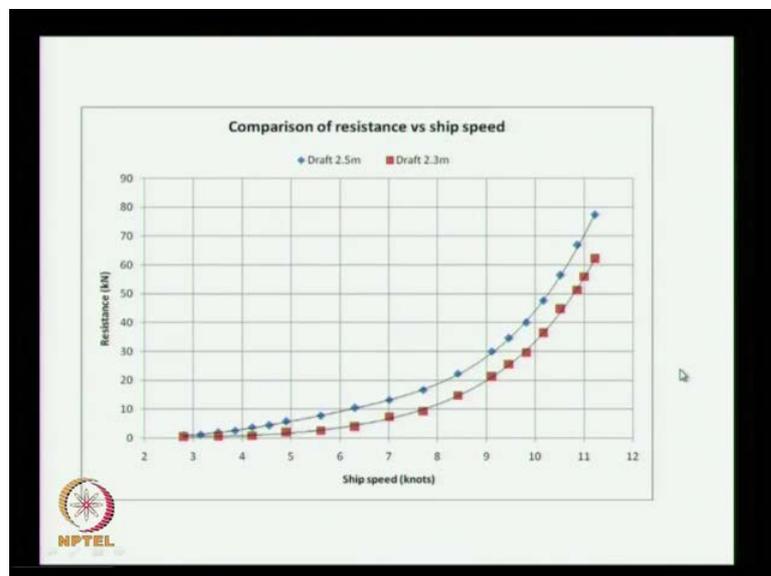
So, here this is tested front after 2.3 metres and hull fitted with all appendages and its even keel partition no trim considered. So, this are the values and this one what you shown in the yellow colour that is for the survey speed of eleven not so.

(Refer Slide Time: 44:06)



Then its plotted you get the resistance seconds speed you get the resistance curve. And then you have the  $R \cdot t$  into  $v$  that gives a effective power.

(Refer Slide Time: 44:22)



So, you plot effective power against the speed of the ship so this is a effective power of the ship. Now, with the tests have been repeated for another draft for 2.5 metre, so this varies plotted here and this what is shown here. This is for the 2.5 metre higher draft and this is for allowance, so this test may be required when their case. When the ship is you know see more or may be a ship is design to have more displacement and when it

operates what is up power requirement and what will be the speed it can achieve. So, this are same thing for the effective power  $R_t$  into  $V$  for different Froude that routers.

(Refer Slide Time: 44:57)



With this covers the total deport or resistance cases what do you have discuss, so for we have seen what are the how the model are the ship resistance is predicted using model test. What are the steps involved in that what are the similarities required that we have know we have to have the geometrical similarity dynamical similarity and dynamical similarity. So, all this similarities required to predicted, but we have seen that it is difficult to make the kinematical similarity because the Reynolds number which is a representation of the kinematics are not going to be save for ship. And model due to practical resistance we have already sent, so it is difficult to do.

So, what do you do is Reynolds is a fractional force is estimated using the values obtain from flat plat resistance test done for by a different agencies. We have seen the formula like a shown a formula shook formula ITTC formula we have seen different formula to find out the  $C_f$  value that is the affection resistance. Why it is done because it is not possible to find out the fraction resistance from the model because tests why it is not possible dynametical condition are not similar. Why it is not similar this two cases the ship and model are not operating on the same Reynolds number, when this Reynolds numbers are not same. Then natural the flow condition close to the ship and the boundary lawyer of the ship will be different.

So, where the model you have Reynolds number low which operates in the lamina condition and where as the ship the Reynolds number is 5. And the boundary layer is going to be tabulate form, so the flow kinematics are different. The water part dig in motion inside the lamina boundary layer in model and inside the tumbler boundary layer in shape of the different. So, the dynamic of similarity is not match between ship and model hence the prediction of fractional resistance is not possible from the model test for the ship. So, that is why the problem total problem of resistance is been divided into two one is fraction resistance component.

The total resist a fraction resistance plus the other component we call you a resiger resistance component of which the wave making resistance is a major one another similarity condition is the dynamical similarity condition. Dynamical similarity condition is referring to the forces of pressures and which is coming from which is represent by the Froude number. Because they gravitation they ratio of in ratio force to gravitational forces that a Froude number. So, the Froude number of forces whether phase of its waves, so it is easy to satisfies the Froude number between ship and model provided you operate, the model at a speed equal to that of the ship divided by square root of the scale.

So, if you model then you can satisfy that that is why the models operated lowers speed compare to that of the ship. So, from this you will be able to find out the resigned resistance coefficient and since its satisfying the Froude number, if the resigned resistance coefficient between the ship and model are same. So, you choose the value that the resigned resistance coefficient from the model and that is put it for the ship resistance estimation and later we have seen the form effect not consider the flat plate. So, you have to cancel the form five and we have seen the Prohaskas method and also run in point in the things like that which will account.

And which will be able to estimate the form factor from the model and the same form factor is used for the ship and from using the model due of considering a whole viscous effect including friction and the form effect. So, that effect is included in the prediction of the ship resistance and that is what you have seen in the 1978 ITTC method. When compared with the 1957 ITTC methods that difference is the form factor influence is a major one. And early the resistance tests are done which will give not only information about resistance in powering it also gives the information about flow condition around the model which will go as an input into the alteration of the design if you recollect. So,

this are general things what we have done all this things are done only for depart a condition. But, you know that in actual life for the ship the ship may encounter shallow water it may have to it has to go through shallow water region. And also there are vessels which are decent exclusively for shallow water of operation like inland water vessels and all that. So, next we will say how the water way restriction influencing the resistance of the ship which we will take up in the next class.