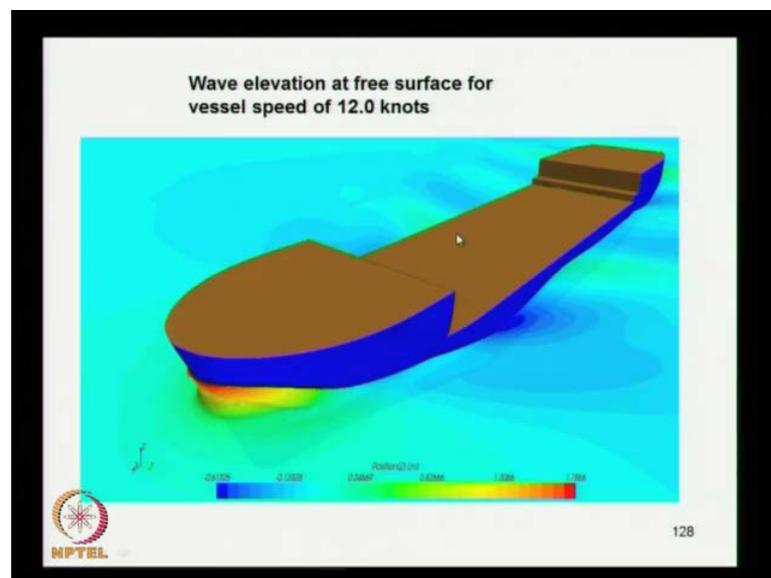


Ship Resistance And Propulsion
Prof. Dr. P. Krishnankutty
Ocean Department
Indian Institute of Technology, Madras

Lecture - 14
Ship Resistance Prediction Methods – II

We have been discussing about resistance estimation using relations, which have been evolved through experimental analysis carried out by different groups.

(Refer Slide Time: 00:28)



We have already seen the methods put forward by ((Refer Time: 00:32)) valued person ((Refer Time: 00:39)) and Seveskis method and all that. Also, we have seen the resistance estimation carried out for a typical shape that is an LPG carrier, which has been analyzed using CFDN method. We have seen that comparison of the resistance results or plane using different methods, second the experimental values and also the CFDN resistance.

Later, we have discussed about the CFDN analysis, of a thousand tones bars or it is an oil bars using CFDN for this estimation enough resistance of the vessel. So, this is the one, which we have discussed in the previous class, which I have shown the, which shows the water elevation. What is shown here, which we had discussed also about that the elevation of water is high at the forward side. It comes about 1.76 meters.

So, this results in higher wave resistance. Also, you can see there is a change in the water elevation. You can see here is a trough formed and here is a crest formed. So, the size of the wave is high and hence the energy associated, with that is going to be high wave making resistance will be high. So, this is addressed we have a form change for this vessel. This vessel is not having barabos bow. So, one can think of introducing about the barabos bow. So, that is to reduce the resistance at the bow wave and bring down the size of the bow wave, also the wave along the ship which subsequently subsequently reduces the wave making resistance, also possible wave breaking resistance.

(Refer Slide Time: 02:55)

Taylor Gertler Standard Series
(Gertler, 1954)

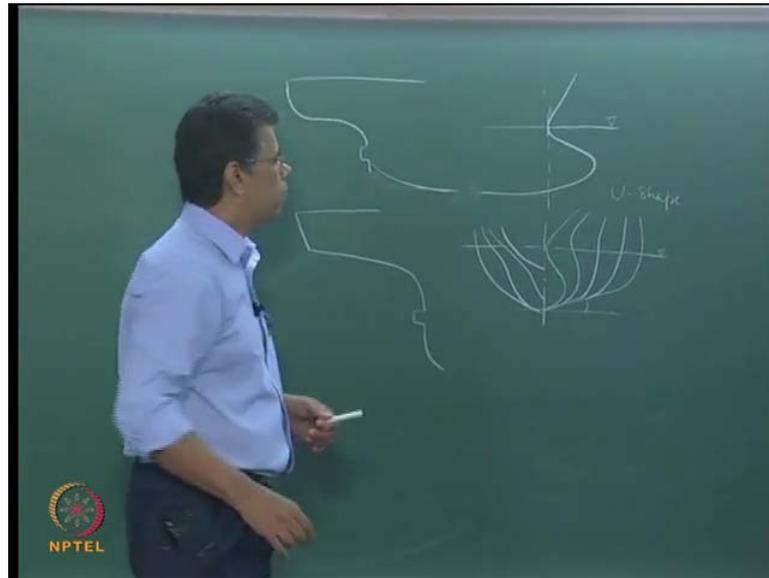
<p>Features:</p> <ul style="list-style-type: none"> Twin-screw vessel. Cruiser type stem. Bulbous ram bow extended on a raised forefoot. Midship section - small deadrise and relatively large bilge radius. Forward sections - U-shaped. Aft sections - V-shaped. Keel flat, rising at the extreme stern. 	<p>Taylor Gertler Series - Range of Application</p> <p><i>BIT</i> = 2,25 to 3,75 <i>Cp</i> = 0,48 to 0,86 <i>V/L</i>³ = 0,001 to 0,007 <i>Fn</i> = 0,15 to 0,60</p>
--	--


129

So, now we look into another sum of the other methods resistance, estimation methods again here, there are based on the experimental data, obtained for resistance ship resistance by performing model test. This result this method what is a Taylor Gertler standard series, which came up in 54, which has the models ships, which have been tried for model test and twin screw vessel. Twin screw vessel you can see that there, may be form variation in the after the vessel to accommodate the twin screw.

So, that f of x that contributes to or changes the resistance of the vessel. So, that is why the importance, why is Pacific twin screw vessel. Then the type of stem used the cruiser stem that cruiser stem. Then I just explained how that stem before scale the cruiser stem. If you consider these are type of stem, which is called cruiser stem.

(Refer Slide Time: 04:04)



This is a cruises stem, where as when it comes to transform stem. You will see this another type, it will be like this. So, this is the transform stem, so here what the modally considered is transform stem, is relatively new involvement or evolution of the ship formed craft. That is the cruises is to be the conventional type. So, here this transom the ship, what is used is a cruises stem ship, then you use bulbars bow. So, here ram bulbars bow. So, the bulbars bow the form goes like this this are type of bulbars. So, here is a water lane, so the bulb is of this type. So, that means its extended on a four fourth. You can see here it is a four fourth raise to four fourth.

So, four fourth is this range n this is a region for four forts. So, this region is not that it is the raise of four fort. So, that is the type of shape thanks to the vessels based on which the model tests models have been prepared. Test have been have conducted for the estimation of resistance type also the med ship section, which shows that it is consider the med ship section its having a dead raise. It is a dead raise of a raiser flow, you can see that it goes like this, then it has got a large bulk radius.

So, that is the type of mid ship section. So, it has an angel if you consider the base got an angel here and this is a bildge radius. That radius is a large radius that I, what it is explained here. You can see here in this a midship section is small dead rise, also, relatively large bilge radius, then the forwards the section ship and forward and draft. Usually, if you take a section ship here the forward. If you take a section, it may be

something like that you take the forward section here. This is the bulb section, which come like this. This is a section of the if you take a section at the forward side. This is a U shaped this sections coming in the forward. So, what do you have is you have other sections coming like this.

So, you have the section shapes coming like this, this is the shape, which is going to process. So, this is of u shape in the forward side this is U shape. So, the here the v shape is directly narrow over in the bottom and upper. So, here this is the water level you can see, where as when it comes to the as said there are few v section. So, a section may be, so just goes like this. So, this is a type of section used for the shape and the keel flat rising at the extreme stem here is the keel flat raising at the extreme stem. So, if you consider a keel bottom. It may have a flat possession you can have a flat possession. This is going and usually comes when it here its goes like this keel raises up. Also, the keel raising at the ends.

So, this is the type of form of the vessel they have tried. So, here you can see the breadth of the draft ratio is 2.25 to 3.75 b by 2 ratio. That is the dimension ratio used for the vessel then the prismatic coefficient range form. It is a wide range 0.48 to 0.86 v by 1 cube. This is the range 0.001 to 0.007 and fluid number 0.15 to 0.6. So, this is the vessels specification. Now, you explained that I have also reported by Fisher you consider B by T.

(Refer Slide Time: 09:03)

C_R by Fisher (Fisher, 1972)

For $B/T > 3.0$

$$C_R = \{C_{RB} + 0.12(B/T - 3) + 50(\nabla/L^3 - 0.007)\} / 1000$$

For $B/T < 3.0$

$$C_R = \{C_{RB} - 0.2533(3 - B/T) + 50(\nabla/L^3 - 0.007)\} / 1000$$

where

$$C_{RB} = -1.83 + 14.02 S_{LX} - 27 S_{LX}^2 + 18.32 S_{LX}^3$$

$$S_{LX} = (3.3613 F_n) + C_p - 0.7$$

Schoenherr skin friction line is used for C_f

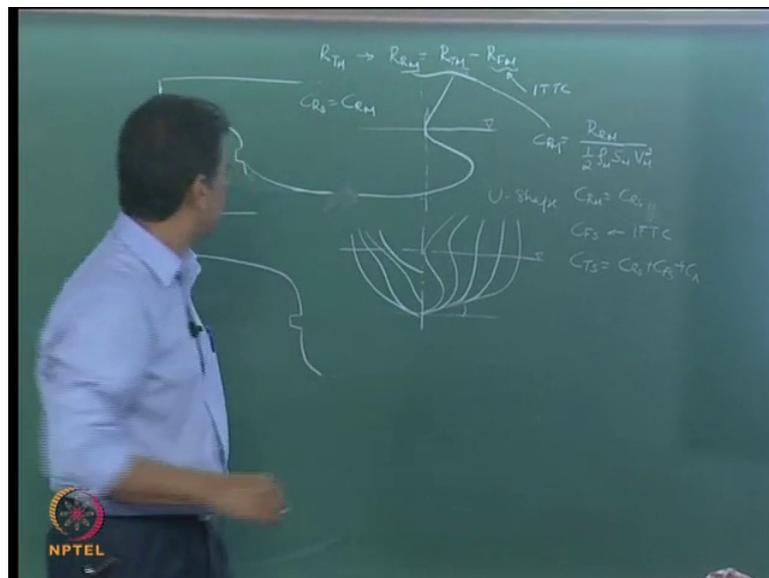


130

Suppose, the vessel B by T is greater than 3 in that above, you can see that it is ranges from 2 to 2.25 to 3.75. Now, it is putting a clause here your B by T is greater than 3. Then the residuary resistance coefficient is given by this expression its C R B. You can see the B and T are used here volume displacement by L Q. These are the parameters used and if B by T is less than three. Then you use this expression for the estimation of residuary resistance. So, you know that when you perform the model test, you have to meet the fluid. You can meet the fluid condition and meeting the Reynolds number is not possible.

So, usually you prefer to run the model under the condition of fluid the proposed by the fluid. That is where the model speed is equal to the ships speed divided by square root of S K L of the model. So, that is what you do, so what you get what you measure from the total resistance. You know the procedure we have already discussed about that from the procedure. You get the total resistance and that is you find out what is the total resistance, for the mofernbern of the model.

(Refer Slide Time: 10:45)



Then you from this you find out what is the for this condition you find out the residuary resistance of the model. You get it by total resistance of the model minus frictional resistance of the model. So, this you get from ITDC or any similar formula. So, that is the procedure then you can non dimensional this value RTM. So, what you do is which we have already discussed. So, from here you get coefficient for this CRM is equal to r

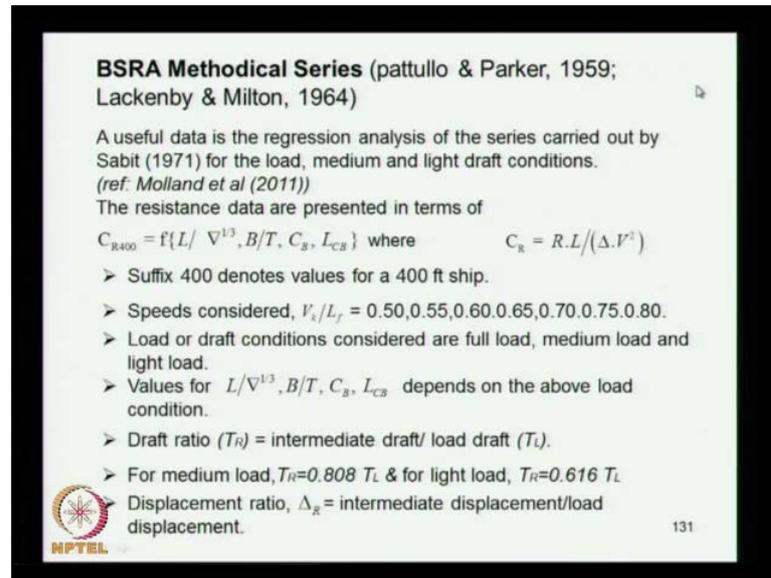
from here residuary resistance of the model divided, by half row of model weather surface of the model into model. That is why you get $c_{r,m}$ and from this you will get CRM is equal to $C_{R,S}$ and from, which you after this you find out what is a c of of ship.

Again using ITDC formula or any similar formula and from once you get $C_{F,S}$. You put along that C_T of the ship is equal to C_R of the ship plus C_F of the ship. That is what you get plus relevant source C_A . So, that is what you find out the total resistance of the ship is equal to the residuary resistance of the ship plus, which is same as $C_{R,S}$. You know that it is same as CRM. So, you get this and this value and that is into the sense getting R here. So, you get the C_R , which is actually the same for non dimensional coefficient for residuary resistance for the ship in model. Since, you followed the fluid type of the resistance or fluid condition for model test. So, here depending on B by T you decide which is appropriate.

Then you choose a corresponding formula and where C_R will be the parameter. Here, you can know that $C_{R,B}$ is given by this expression. This expression got the parameter s of $6 l x$ gives $l x$ here $l x$ as a s for here and s cube here. So, this parameter is given by this expression, which is in terms of fluid number, this matic coefficient. So, you know the speed of the vessel. You know the speed of the this fluid number for that condition, the prismatic coefficient of the result. So, you get this value, so you get $s l x$. Once, you get $s l x$ you get it with this formula here and substitute here you get $C_{R,B}$. Once, you get $C_{R,B}$ get over to the corresponding formula appropriate formula, which you use depending on B by 2.

Then you get you know all these quantities you find out what is $A C_R$. Once you get C_R next component, which you look forward is estimation of the frictional resistance coefficient. So, frictional resistance coefficient here, what I suggest here use the Schoenherr skin friction line, which we have discussed, when we discussed about the frictional resistance. We have discussed about Schoenherr formula hooks formula and I D D C formula. So, here you use a Schoenherr formula for this estimation of C_F . So, once I get the frictional resistance coefficient. So, then you can find out the C_R plus C_F S is equal to the total resistance coefficient for the model. Then I have already explained how to x applied due to the ship.

(Refer Slide Time: 15:03)



BSRA Methodical Series (pattullo & Parker, 1959; Lackenby & Milton, 1964)

A useful data is the regression analysis of the series carried out by Sabit (1971) for the load, medium and light draft conditions. (ref: Molland et al (2011))

The resistance data are presented in terms of

$$C_{R400} = f\{L/\nabla^{1/3}, B/T, C_B, L_{CB}\} \text{ where } C_R = R.L/(\Delta.V^2)$$

- Suffix 400 denotes values for a 400 ft ship.
- Speeds considered, $V_s/L_f = 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80$.
- Load or draft conditions considered are full load, medium load and light load.
- Values for $L/\nabla^{1/3}, B/T, C_B, L_{CB}$ depends on the above load condition.
- Draft ratio (T_R) = intermediate draft/ load draft (T_L).
- For medium load, $T_R=0.808 T_L$ & for light load, $T_R=0.616 T_L$
- Displacement ratio, Δ_x = intermediate displacement/load displacement.

NPTEL 131

Next method, which is also a widely used is a B S R A method methodical series B S R A stands for the British ship research association. So, they have done expensive experimental studies quite some time back you can see 15 n, this is the time what they have done. This is generally done for full of ships and like balkarous and tanker results. If you have designing a balkarous or tanker results to form itself is available based on this series. Since, the form is already available. It is also a proven form you can use it and for which the resistance data is provided in as in you know expression form. So, based on that experimental data the regression analysis is created.

It is forwarded it is created this a habit and its 71. Also, you can see this reference by the book by milton. So, the resistance data that is residoury resistance co efficient is a function of l by delta raise to one one third B by T block coefficient, procession of center of point eventual position center of points. So, here C R is defined using this expression R into l by mass displacement into p square. This is the expression usually we put C R is equal to R by half row s c square, but here you use another s. You know expression for the non dimensional essentials. You can see here this is a 400. So, for this 400 denotes value of a a of 400 feet ship. So, that is what is giving speed considered here is V K L of V K means the speed in nods divided by l f means length in feet.

So, that is what we have to put, so this ratio b by l where v should be nods and l should be in feet that the ratios are given for, so much 0.5 to 0.8 with an increment of 0.5, 0.05.

So, the load or draft conditions considered of full load. So, they have considered the vessel tested the models for three loading conditions. One is when its fully loaded, which means that the ship of model is floating at the desired load water lane. Then two other conditions one is a medium condition or the intermediate load condition, the another one is a light condition. So, they have already explained how they treat this.

So, the value of this quantities that is the parameters coming here for G_r depends on the load condition is obvious. When the ship floats at different water lane, it is going to have different resistance characteristic, which in turn depends on this parameters that is l by Δ power third B by $T C B$ and $L c b$. So, it is going on depending on that, so there will be a change when you consider $C R$ value for different loading condition. The $C R$ what you get at full load condition, medium load condition and light load condition are going to be different are not going to be send.

So, here the draft ratio intermediate the draft ratio $T R$ is equal to intermediate or any draft, which you measure or at that draft drafted, which the model test is performed, which is less than the designed load water lane. Or designed draft divided by the load draft that is the maximum draft permissible for the vessel. So, this ratio is called the draft ratio for medium load. We have seen the conditions here full load medium load and all that. Light load for medium load the $T R$, which is the draft ratio is take as 0.808 of the maximum load of full load draft. For light condition is taken as 0.616 times the load draft. So, this is the way how they defined the load the draft conditions depending on the respective load condition. So, displacement ratio there is another term defining ΔR is equal to intermediate displacement by load displacement.

So, the vessel is now floating at a lower draft, so you have to identify what is the or you have to estimate what is the displacement at that lower draft. That displacement divided by the displacement of the vessel. When its floating at the dips unloaded water lane, that is called the displacement ratio given by ΔR .

(Refer Slide Time: 19:53)

BSRA (contd...)

Note: Use these expressions to get Δ and $L/\Delta^{1/3}$ at any intermediate draft.
 C_B is the value at load displacement.

For $C_B=0.65 - 0.725$, $\Delta_R = 1.0 + (T_R - 1.0)[3.776 - 7.16C_B + 4.8C_B^2]$

For $C_B=0.725 - 0.80$, $\Delta_R = 1.0 + (T_R - 1.0)[-1.1245 + 6.366C_B - 4.533C_B^2]$

Use the following expressions to get L_{CB} at any intermediate draft.

For $C_B=0.65 - 0.725$,

$$L_{CB} = L_{CBLoad} - (1 - T_R)[-1.24335 + 328.98C_B - 218.93C_B^2 - 10.553L_{CBLoad} + 27.42(L_{CBLoad} \cdot C_B) - 18.4(L_{CBLoad} \cdot C_B^2)]$$

For $C_B=0.725 - 0.80$,

$$L_{CB} = L_{CBLoad} - (1 - T_R)[-1.69.975 + 449.74C_B - 298.667C_B^2 + 3.855L_{CBLoad} - 12.56(L_{CBLoad} \cdot C_B) + 9.333(L_{CBLoad} \cdot C_B^2)]$$


So, use these expressions to get delta and one delta at any intermediate draft C_B is the value at load displacement. So, what you do is C_B you keep it at the load displacement. So, here you consider C_B you consider C_B for range of 0.65 to 0.725, then the delta r is given by this expression. So, you can find out delta R that is the displacement ratio is equal to 1 plus T R. We have already seen its a draft ratio. We have seen that the value T R is equal to 0.808 in the previous slide. I think 0.08 for into t 1 for medium load condition and 0.616 into T L for the light load condition. So, you know this T R value from that. Also, you know the C_B of the vessel says a C_B , at the load displacement is not changing, then you have put C_B cube.

So, you find out what is the displacement the ratio of the displacement at the water line at which the model test has been carried, divided by the maximum displacement of the model of vessel. So, here if that is the expression for C_B , which if it falls within this range. If the C_B fall within this range that is 0.65 to 0.8. Then the displacement ratio is given by this expression. So, you can just you know all these values here C_B and T R substitute you get the delta R value displacement ratio. So, you use the following expression to get L_{CB} .

Now, the other thing what you need to know is L_{CB} , because the L_{CB} is the parameter inside to find out the C R value, so L_{CB} again at any intermediate depth intermediate draft. You consider again two expression given for L_{CB} same C_B , which

given 0.65 and 0.725. The first case will C B is equal to L C will get load condition L C get load condition is known.

So, you find out the L C B load condition from the right statics. So, L C B load condition T R is known C B is known. So, you know C B then this is known. Now, L C B load condition for all these quantities are known. So, you substitute the values here of the various quantities. Then you get what is the L C B at a intermediate depth. So, intermediate depth is determines the T R that intermediate depth is reflected in T R, because T R is equal to the intermediate draft divided by the maximum draft. So, that is what reflected here. So, the that is how you get the L C B for the intermediate draft. If the blockage coefficient is following in this range 0.725 to 0.8. Then you have the L C B given by this expression only. This data changes, which comes from a regression expression the coefficients changing according to that.

So, you have L C B all the T R C B all these values are known, so you get L C B here. So, depending on the vessel L C B you select, which expression need to be used and using that expression, you get the L C B here. Now, we have seen, how to get T R, how to get delta R, how to get L C B for intermediate.

(Refer Slide Time: 23:27)

BSRA (contd...) $C_R = R.L/(\Delta.V^2)$

FULL LOAD CONDITION
Limits of parameters in the full load condition are:

$L/V^{1/3} = 4.2 - 6.4, B/T = 2.2 - 4.0, C_B = 0.65 - 0.80, L_{CB} = -2.0\% \text{ to } 3.5\%$

$C_{R400} = (Y_{400} \times 5.1635) + 13.1035$

where

$Y_{400} = a_1.X_1 + a_2.X_2 + a_3.X_3 + a_4.X_4 + a_5.X_5 + a_6.X_6 + a_7.X_7 + a_8.X_8$
 $+ a_9.X_9 + a_{10}.X_{10} + a_{11}.X_{11} + a_{12}.X_{12} + a_{13}.X_{13} + a_{14}.X_{14} + a_{15}.X_{15} + a_{16}.X_{16}$

$X_1 = 1; X_2 = (L.V^{1/3} - 5.296) / 1.064; X_3 = 10(B/T - 3.025) / 9.05;$
 $X_4 = 1000(C_B - 0.725) / 75; X_5 = (L_{CB} - 0.77) / 2.77; X_6 = X_2^2;$
 $X_7 = X_2^3; X_8 = X_4^2; X_9 = X_2^2; X_{10} = X_2.X_3; X_{11} = X_2.X_4;$
 $X_{12} = X_2.X_5; X_{13} = X_3.X_4; X_{14} = X_3.X_5; X_{15} = X_4.X_5; X_{16} = X_2.X_4^2$

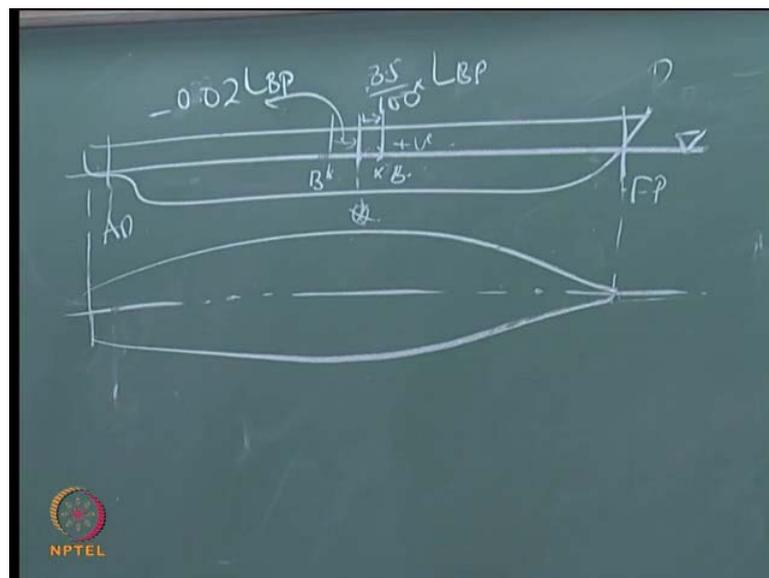
Values of a1, a2, ... are given in the reference

133

Now, you see full load condition, now we have said this B S R A method is applied for three loading conditions. That is a full load condition intermediate condition and light condition is not it? So, first we consider full load condition full load condition L by delta

power one third is given by is that is it. You consider the range of a application is 4.2 to 6.4, B by T range of application 4.2, to 4 C B 0.65 to 0.8. So, 0.8 means the full form, which comes then L C B minus 2 percent to 3 plus 3.5 percent. So, here L C B possession, there are considered the form of the ship changes. So, the form of the ship that is there is concentration of volume of the form of the ship. So, you can see that, if the ship if you consider the form here, the ship is floating at this water lane.

(Refer Slide Time: 24:38)



Now, if you consider it will be a water plane, where you may get a ship like this, so such a ship, so depending on that. So, if you consider with this is the after perpendicular. It is a forward perpendicular, somewhere the middle the middle length, you call it is a mid ship. So, the longitudinal possession of set of gravity is or the center, not the center gravity, the center of point C center of point c is the centroid of the underwater volume of the ship. So, the depending on the fullness of the vessel to a forward draft the possession of center point C changes. Suppose, the ship is full on this region forward side, if you take the fullness of the form the center point C, may be somewhere here if its full. So, L C B this side is taken as positive.

So, that means if you consider range what we discussed that is L C B from minus 2 to 3.5 percent the plus three point percent means it is X C B. This is 3.5 percent means three 3.5 divided by hundred of L B P. So, it is 3.5 percent of L B P, so that is what it means. So, if the if the ship is fuller towards the half then L C B moves to the after mid shape. If

that is the case this may be possession. So, here what is given is maximum distance is two percent of L C B two percent of length. So, this will become point zero to L B P. So, that is what it means, so it is going to be this side is negative upside is negative and forward is taken as positive.

So, why you define L C B in resistance is that determines the fullness of the form. If L C B is forward the body or the ship under water form is more full in the forward side. Usually, that offers more resistance for the ship, because more of full that means you get more hydrodynamic. You know flow variations, which leads to increase in resistance. So, if the form is fuller in the draft and find there is forward the resistance usually decreases. So, that is importance of providing L C B specifying L C B in the resistance estimation. So, here this resistance coefficient again 400 associated that 400 feet long. So, it is given by $y = 400$ into this. So, what is $y = 400$ it is given here this is equal to a 1×1 plus a 2×2 . Then it goes up to a sixteen $\times 6 \times 16$.

So, all these a_1 , a_2 , etcetera are given in the reference, which you have seen in the book by Molant. You can refer that the values of a_1 and a_2 all these are given there, where as the $x_1 \times x_2$ are different like this x_1 is equal to $1 \times x_2$ is equal to that L by delta power one third minus. So, this is the expression for that x_2 , x_v is given by this expression all are known B and T known delta known L. So, all these quantities are known, so you can estimate this $x_1 \times x_2$ you can see that x_4 depending on C B $\times y$. Depending on L C B is known from hydro static. So, $x_6 \times 2$ square, so all these quantities are coming from the previous x values. Hence, you would be able to estimate all the x quantities x_1 to x_{16} . Also, you know the coefficients, which comes from the regression expression of the data.

So, then you find out y and then you find out once you know y you get C R. Once you get C R you can see you can find out what is the resistance from this expression. So, that is procedure adopted in B S R A method this regression expressions have been given by Sarbit. You have seen that originally it was given in a chart when with that test were done in fifties, which was created as chart designed chart later for easier. To make it easier for computational job, that is why you need a expression.

So, carried out a regression analysis and came out with a regression expression. This is the regression expression, which has been evolved from that. So, this is the expression,

which has been given for the fully loaded condition B S R A. At the estimating resistance for the vessels coming under the range of applicability's specified by the in the fully loaded condition. So, that is the this one.

(Refer Slide Time: 30:06)

BSRA (contd...) $C_R = R.L/(\Delta.V^2)$

MEDIUM LOAD CONDITION
Limits of parameters in the medium load condition are:

$L/\nabla^{1/3} = 4.6-6.9, B/T = 2.6-4.9, C_B = 0.62-0.78, L_{CB} = -1.6\% \text{ to } 3.9\%$

$C_{R400} = (Z_{400} \times 6.449) + 15.010$

where

$Z_{400} = b_1.R_1 + b_2.R_2 + b_3.R_3 + b_4.R_4 + b_5.R_5 + b_6.R_6 + b_7.R_7 + b_8.R_8$
 $+ b_9.R_9 + b_{10}.R_{10} + b_{11}.R_{11} + b_{12}.R_{12} + b_{13}.R_{13} + b_{14}.R_{14} + b_{15}.R_{15} + b_{16}.R_{16}$

$R_1 = 1; R_2 = (L\nabla^{1/3} - 5.7605) / 1.1665; R_3 = 10(B/T - 3.745) / 1.125;$
 $R_4 = 100(C_B - 0.7035) / 8.05; R_5 = (L_{CB} - 1.20) / 2.76; R_6 = R_2^2;$
 $R_7 = R_2^2; R_8 = R_2^2; R_9 = R_2^2; R_{10} = R_2.R_3; R_{11} = R_2.R_3;$
 $R_{12} = R_2.R_3; R_{13} = R_2.R_3; R_{14} = R_2.R_3; R_{15} = R_2.R_3; R_{16} = R_2.R_3^2$

 Values of b_1, b_2, \dots are given in the reference

134

Now, you consider same the medium load condition the medium load condition, we have seen the three conditions. So, this is second condition medium load condition ship may not may be operating at a at the design for hundred thousand tones D W T. It may be operating at may be 50,000, because depending on the load and all that. So, there may be a variation. So, you would like to know what is the resistance chance due to the change in the loading condition. So, medium load condition here it say L by delta power one third 4.6 to 6.9. That is the range B by T 2.6 to 4.6 a b this is the range L C B, you can say this. So, this parameters are deferred now on based on which how do you get the residuary resistance coefficient.

So, again put another parameter it said and then you find out this set is equal to b 1 R 1 b 2 R 2, same as what you have seen before a 1 x. Here, it is a b 1, R 1, so you have the same up to 16. So, you have 16 terms here, so again R 1, R 2 all the parameters explained here all depending on the known parameters, which is B T L displacement volume displacement all L C B. So, all these are known C B, so everything is known. So, you just substitute the values you find out R 1, R 2 etcetera up to R 16. The b 1 b 2 and all given in the reference coefficient, which is obtained from the regression analysis.

So, once you get all these quantities, then you can find out what is asset here, then substitute here you get C R value. So, use that to find out the residuary resistance coefficient of the vessel. So, here the third loading condition light load condition.

(Refer Slide Time: 31:57)

BSRA (contd...) $C_R = R.L/(\Delta.V^2)$

LIGHT LOAD CONDITION
Limits of parameters in the light load condition are:

$L/V^{1.3} = 5.1_{\text{to}} 7.7, B/T = 3.4 - 6.4, C_B = 0.59 - 0.77, L_{CB} = -1.1\% \text{ to } 4.3\%$

$C_{R400} = (S_{400} \times 7.826) + 17.417$

where

$S_{400} = c_1.T_1 + c_2.T_2 + c_3.T_3 + c_4.T_4 + c_5.T_5 + c_6.T_6 + c_7.T_7 + c_8.T_8 + c_9.T_9 + c_{10}.T_{10} + c_{11}.T_{11} + c_{12}.T_{12} + c_{13}.T_{13} + c_{14}.T_{14} + c_{15}.T_{15} + c_{16}.T_{16}$

$T_1 = 1; T_2 = (L.V^{1.3} - 6.4085) / 1.3085; T_3 = 10(B/T - 4.915) / 1.475;$
 $T_4 = 100(C_B - 0.679) / 8.705; T_5 = (L_{CB} - 1.615) / 2.735; T_6 = T_2^2;$
 $T_7 = T_2^2; T_8 = T_2^2; T_9 = T_2^2; T_{10} = T_1.T_3; T_{11} = T_1.T_3;$
 $T_{12} = T_1.T_3; T_{13} = T_1.T_3; T_{14} = T_1.T_3; T_{15} = T_1.T_3; T_{16} = T_1.T_3^2$

Values of c_1, c_2, \dots are given in the reference

135



We have already seen that the draft is 0.616 times c full load draft. So, here you can see the range 5.1. You can see the previous one this starts from 5.1, that is 4.6, that is 4.2. So, there is a difference due to the displacement variation because it denominator changes. So, here you have this values V by T given by this and C B this is the range. So, when it comes towards the lower draft naturally the C B, also comes down is not it? Its more fine towards the bottom. So, when they consider lower draft like draft midst the C B value will be less. So, it is more fine towards the bottom and also same thing the breadth also breadth and draft. If you compare there will be a variation the draft is coming down.

So, I think this ratio goes up D is coming down you can see that here is 3.4 here is 2.6 and here is 2.2. So, that which implies that the T values going down for different loading condition, that why the B by T ranging is changing from that. Similarly, here also as I said the displacement also lowers.

So, this value keep going up with the lower draft. Now, this residuary resistance that the load condition is given by this expression, the same way what we did before this parameters are different here the S quantity is given by this expression starting from c 1 t

1 c 2 t 2 and going up to c 16 t 16. So, here this again the c 1 c 2 coming from the regression coefficients from the analysis and t 1, t 2, etcetera are given here, which are depending on the known parameters of the vessel that usually displacement. That is then B T, L C B same parameters what we have seen before. So, all these parameters are known for the vessel. So, you just substitute you get all three values c 1 c 2 are the regression coefficient, which is available in literature. So, you can just find out what is this quantity.

(Refer Slide Time: 34:09)

Series 60

Series 60 - developed in 1950, Lackenby and Milton (1964).
A regression the data was carried out by Sabit (1972).

Range of speeds & hull parameters:

$$V_k/L_f = 0.2 - 0.9, L/B = 5.5 - 8.5, B/T = 2.5 - 3.5,$$

$$C_B = 0.60 - 0.80, L_{CB} = -2.5\% \text{ to } 3.5\%$$

$$C_{R400} = (Y_{400} \times 8.3375) + 17.3505$$

where

$$Y_{400} = a_1 \cdot X_1 + a_2 \cdot X_2 + a_3 \cdot X_3 + a_4 \cdot X_4 + a_5 \cdot X_5 + a_6 \cdot X_6 + a_7 \cdot X_7 + a_8 \cdot X_8$$

$$+ a_9 \cdot X_9 + a_{10} \cdot X_{10} + a_{11} \cdot X_{11} + a_{12} \cdot X_{12} + a_{13} \cdot X_{13} + a_{14} \cdot X_{14} + a_{15} \cdot X_{15} + a_{16} \cdot X_{16}$$

Values of a1, a2, ... are given in the reference

$$X_1 = 1; X_2 = (L/B - 7.0) / 3.0; X_3 = 2(B/T - 3) / 9.05;$$

$$X_4 = 10(C_B - 0.7) / 75; X_5 = (L_{CB} - 0.515) / 2.995; X_6 = X_2^2;$$

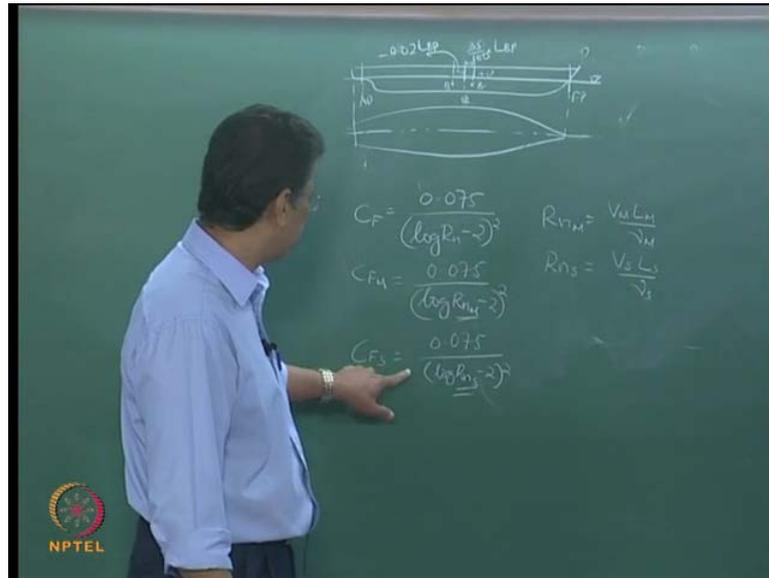
$$X_7 = X_2^2; X_8 = X_2^2; X_9 = X_2^2; X_{10} = X_2 \cdot X_3; X_{11} = X_2 \cdot X_4;$$

$$X_{12} = X_2 \cdot X_5; X_{13} = X_3 \cdot X_4; X_{14} = X_3 \cdot X_5; X_{15} = X_3 \cdot X_6; X_{16} = X_4 \cdot X_6^2$$


138

So that is the one, so once you get all these the C R values. Then you can find out the residuary resistance of the ship, that the co efficiencies remains same for the shipping model. Then you use I D D C formula to find out the frictional resistance. So, I D D C you know that. So, C F is equal to point of 0.075 by log R N minus 2 the whole square. So, you know this formula.

(Refer Slide Time: 34:37)



So, if you use the parameter or Reynolds number of the model. You get the residuary the frictional resistance of the model. The frictional resistance coefficient of the model or if its use the parameters of the or the Reynolds number of the ship. You get the frictional resistance coefficient of the. So, you can see that difference here this is one, which makes the difference, which implies that $R_N N$ is equal to $V M L M$ by μm . That is the Reynolds number of the model is equal to models speed into length of model divided by kinematic viscosity of water in the tank. Usually, its pressure and breadth of the ship is equal to Reynolds number of ship is equal to $V S L S$ by μ .

That's the velocity of ship or speed of the ship. This is the length of the ship and μs is the kinematic viscosity of c power terms. So, you can find out on this Reynolds number go to I D D C formula. So, you get G F or C F s and from this you will get the C F value. So, as we discussed you have a total resistance or you say C T s is equal to C T. For C R s plus C F s plus alleviants, may be correlation alleviants. Other expenditure alleviants and all that plus air resistance everything come here.

(Refer Slide Time: 36:42)

$$C_T = C_{R_S} + C_{F_S} + C_A + \dots$$
$$R_{n_M} = \frac{V_M L_M}{\nu_M}$$
$$R_{n_S} = \frac{V_S L_S}{\nu_S}$$

So, you have the other components here. So, here C_{R_S} is equal to similar C_{R_M} , which is coming from the $B_S R_I$ expression, what we have discussed here and C_F the frictional resistance come from its coming from the $I T T C$ formula. You have to choose the Reynolds number according to it. So, next type is, so we have seen that a for n. Now, so next type of vessel is called a serious $X T$ formula is where, you known very popular from lot of research have been done on the particular type of vessels series 60. This also got evolved during the sixties. So, the range of the speed the vessel ranges is very important that you have to have an idea about, the validity range of application of this methods.

So, here you have series sixty, so here the validity range is $B K$ by $L F$ of the result should be within 0.2 and 0.9. That is the speed in nods divided by length in feet should be in this range by B , should be in this range B by T in this range $C B$ in this range. Its more full here $L C B$ in this range. So, you have a vessel, which form in this range. You can use this relation or this method here again, $C R$ procedure resistance given by this expression over here. This one is given by this expression here. So, here you can see that all these co efficiencies are given in the literature. That is a reiteration co efficiencies and $x 1 x 2$ and all these are given here. So, same has been did in the $B S R$ anything and the same or the he also, he will did the regression for $B S R I$ and also for series 16.

So, here $x_1 \times x_2 \times x_3$ are all these parameters are given here. All the quantities which appear in this expressions are known. So, you see to estimate this expressions. Then finally, you substitute back here you get y and this back to here you get c here. So, that is the method used in series sixty type of vessels.

(Refer Slide Time: 39:17)

Hollenbach (1998) - Single-screw and Twin-screw Vessels
Resistance tests on 433 models at the Vienna Ship Model Basin.

Length over surface L_{os} is used & it is defined as below:

- for the design draft, L_{wl} is used.
- for the ballast draft, length of WL in ballast condition is used.

Froude number used in the formulae is based on the length L_m , as follows:

$$L_{fn} = L_{os} \text{ for } (L_{os}/L) < 1$$

$$= L + \frac{2}{3}(L_{os} - L) \text{ for } 1 \leq (L_{os}/L) < 1.1$$

$$= 1.0667 L \text{ for } 1.1 \leq (L_{os}/L)$$

 137

So, here we move onto to next its relatively new 1998, which is applicable for single screw and twin screw. So, both type of vessels you can use this. So, see the number of models they have done 433 models, the test have been done on that. It has been done at Vienna ship model basin. So, the length over surface this is a parameter l_{os} is used. It is defined below l_{os} for designed draft L_w is used for L_{os} for ballast draft. The length of water line in the ballast condition is used. So, the L_{os} depends on L_w L is $L_w L$. If it is at the designed full load condition or in the ballast condition L_{os} is the water line, which you have to measure for the ballast condition. So, that is the difference the fluid number used the formula, you based on length is the length L_{fn} is the fluid number that is length base to fluid number.

So, L_{fn} that the length what length is used for the definition. That fluid number is defined as B by row $G L$ and that L which you have to use is defined by this. So, L_{fn} is equal to L_{os} , if this ratio is less than one. You have already known L_{os} here due to the length of the ship. So, if this is less than one use this expression. If it's between 1

and 1.1 use this expression for the length, which used the fluid number or use this, if for this one less than or equal to this quantity. So, that is what is the definition of L of X.

(Refer Slide Time: 41:19)

Hollenbach (contd...)
 The residuary resistance coefficient

$$C_{R_{std}} = C_{R_{std}} C_{R_{FRK}} k_L (T/B)^{0.5} (B/L)^{0.5} (L_{02}/L_{WL})^{0.5} (L_{WL}/L)^{0.5} \\
 \times \left\{ 1 + (T_A - T_F)/L \right\}^{0.5} (D_P/T_A)^{0.5} (1 + N_{rud})^{0.7} \\
 \times (1 + N_{br})^{0.5} (1 + N_{boss})^{0.5} (1 + N_{str})^{0.5} \quad \text{where } k_L = e_1 L^{0.2}$$

T_A is the draft at AP; T_F is the draft at FP; D_P is the propeller diameter;
 N_{rud} is the number of rudders (1 or 2); N_{br} is the number of brackets (0-2);
 N_{boss} is the number of bossings (0-2); N_{str} is the number of side thrusters (0-4)

$$C_{R_{std}} = b_{11} + b_{12} F_r + b_{13} F_r^2 + C_B (b_{21} + b_{22} F_r + b_{23} F_r^2) + C_B^2 (b_{31} + b_{32} F_r + b_{33} F_r^2)$$

$$C_{R_{std}} = \max \left[1.0, (F_r / F_{r, std})^{0.5} \right]$$

where $F_{r, std} = d_1 + d_2 C_B + d_3 C_B^2$

Use ITTC formula for C_F



138

So, here what you can say is the residuary resistance coefficients C_R is given by this expression C_R standard into C_R for the another parameter here k_L by B raised to a $1/B$ by L raised to L^2 . So, you can find out the ratios here all these T_A is the draft at perpendicular T_F is drafted forward perpendicular, if this is a dip it will be different. So, that is why it is given here then $L D_P$, D_P is shown here is a propeller diameter. Then this is a number rudder. Then this is the now I think number of brackets. That is the propeller brackets.

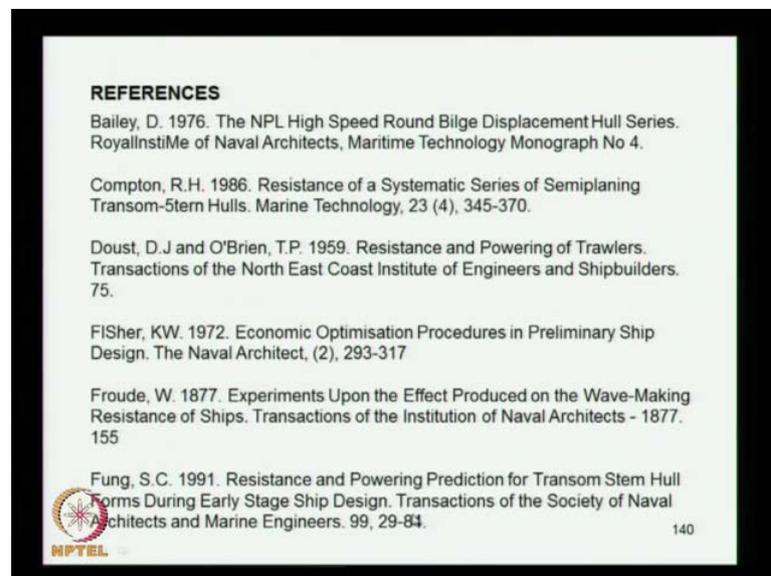
Then the propeller boss number of bossings bossing for the propeller and this is the number of thrusters. So, you know all these parameters from the vessel. What is the draft of forward, what is the length what is the breadth. Then what is the breadth I mean load water line length. Then all these you know number of rudder bracket boss and everything. So, you have all these information for that vessel. So, then you what is need to know is a 1 a 2 a 3 all these quantities, which obviously you have to it, must be given there. You just see that and here you have the k_L is given by e_1 into L power e_2 , you just see how do you how do you get this?

So, this are the values obtained then C_R standard. That is a residuary resistance for the standard model of standard vessel is given by this expression $B L^{-1} + b_1 L^{-2}$ into fluid

number plus b^{-1} into fluid number square plus a/b into this quantities over here. There the fluid number here and C/B square again, the same expression here how can say. So, here this is a expression for the residuary resistance coefficient. Then you are looking to this one C_R/F orchid. That the maximum of $1/F_R$ by F_R . This quantity this is this quantity is given by this expression this expression, which gives a to find out this ratio fluid number. You know from this you get F or K_R . So, you get the ratio and then raise to c^{-1} . So, you take one and this value maximum of you take assigned for this quantity.

So, once you get this then all these co efficiencies $b^{-1} b^{-1} 1/2 a^{-1}$ everything is given in the literature, which comes out of the regression analysis of the data. So, once you get all these co efficiencies. You just substitute here including $a^{-1} a^{-2}$ everything is coming from there. So, then you get you can find out A_R standard. Then put it here this is already estimate all the quantities are known to find out the residuary resistance C_R . Then use as I explained I did the formula for C_F . So, once you get C_R and C_F then you can find out the C_T of the ship. Then you can find out the total resistance of the ship. So, these are the total you know different methods normally used for conventional vessels.

(Refer Slide Time: 44:34)



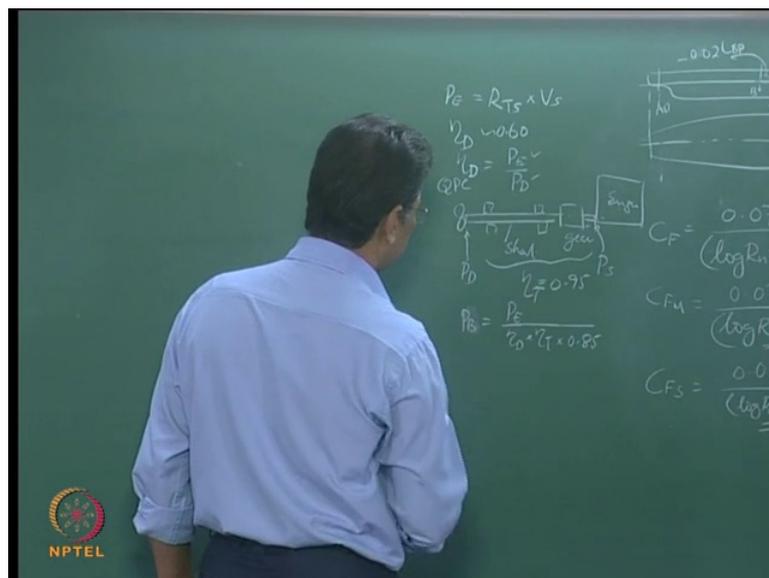
We will see them in the next class about more details about the in advanced way marine way, till about the resistance are estimated, so the methods what you have seen in the residuary. That is mainly on depending residuary resistance or estimations different methods, we have seen and naming it all top menon Van load person method

Goldhammer Havold method Viskis method. There is a massive of Viskis method, then we have seen the catalog method. Then other methods you know B S R I method series sixteen method, then the last one called back I think. So, all these different methods are there. So, a designer has to choose the method required for the resistance estimations appropriately.

So, he has to understand what is the vessel data what type of vessel is designing. Once, you know the type of vessel and see what is the parameters like what is the L B B ratio what is L by delta power to one third. What is the B by T? What is L C B possession? What is C B range? So, all these parameters you have to look what is the fluid number. So, all these matters, so considering this look to the this different methods. You identify, which method is more appropriate for the vessel, under consideration and choose the method estimate the resistance.

So, one thing you have to keep in mind is that these methods are used all the resistance value, which you estimate using these methods are only for the preliminary designed of the vessel, which give information about the power requirement. Once you get the total resistance of the vessel then you can roughly arrive at the power requirement of the required for the engine. So, what you have to do is you have to you get R T of the ship from any of these methods.

(Refer Slide Time: 46:44)



So, once you get $R T$ into the speed of the ship that gives the effective power of the ship. So, the effective power of the ship is given by this. Then you know you have to find out, what is the effective power. Then you have to find out what is the assumed propulsive efficiency $E T A D$. Normally, you assume may be approximately 0.6, 16 percent $E T A D$. So, once you get η_d is equal to the effective power by delivered power. That is the effective power is given by this relation $P D$ is the power delivered, at the end of the propeller. So, if you have a propeller you have the shaft going. Then it's going through a gear box. Then finally, to the engine this is the gear engine. Then you have the shaft propeller. Then you may have some support bearings and all that for the shaft.

So, Once you know this, this $P D$ is a power required at this propeller. At this point this is power required at that point $P D$. So, from the engine you get power its coming here. This is the power at this point you have this called the shaft power shaft available the power available at the shaft end. So, from the engine you get the power, then this are shaft power gear, where you have a loosens the gear bearings and all that. Finally, there is a power delivered in that. So, this ratio between effective power and delivered power is the only $E T A D$. That is the called also called $Q P C$, this is called propulsive coefficients. So, now transmission loss is usually five percent taken with the gear. So, you have an idea, what is $P D$.

So, you know $P E$ value, so you know $P D$. So, from that you can find out $P D$ is equal to $P E$ divided by $E T A D$ from here. Then you have the transmission loss of into $E T A D$. That is the power coming at this, then if you are giving at during d of the engine. Usually, 15 percent given 0.85, so this is a $P B$ engine power engine power is equal to $P E$ by $E T A$. This is $P D$ divided by transmission efficiency and divided by due 80. So, from, which you will get what is the break power required for the engine. So, that is the advantage. So, when the initials at the initial stage of the design of the vessel, you would like to have a rough estimate of the engine power. Also, once you get the engine power, then you will be in a position to take an engine or you know select an engine, from the catalog of the other engine manufacturers.

So, there are different manufacturers, so you choose that various other parameters, also come into picture this gives an information. This gives a engine power, which will go as a further input into the designed finalization, for the improvement in the design of the ship. So, this method what you have discussed is they are good. May be at that stage or at

later stage, it is advisable to have a may be model test and make sure that its matching the requirement. Then you may have to relook it into the engine, which you select it. Finally, make the propeller design and you know finalization of that, with that we conclude this class.

Thank you.