Ship Resistance and Propulsion

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Lecture - 13
Ship Resistance Prediction Method – I

In the last class, we have been discussing about the resistance estimation using a Holtrop Mennen method and Holtrop Mennen method is normally use for conventional ships which can be either sink is screw or tens screw. Now, we want to the next method which is available for the estimation of a resistance of a small crafts mainly trawlers and tugs, so this is a put forward by Van Oortmerssen based on the experimental studies which we carried out.

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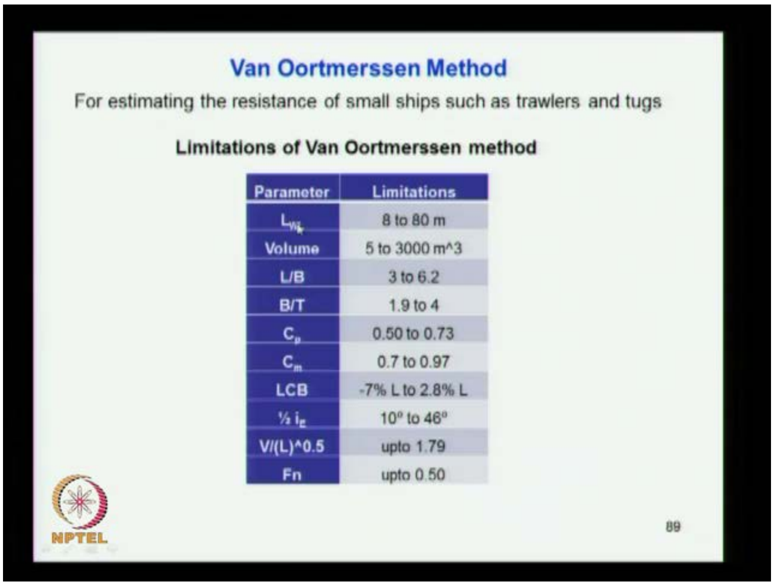

We see the limitation of this application of this method is a length on water line is between 8 to 80 meters. Then a volume at displacement is 5 to 3000 meter cube L by B length breadth ratio 3 to 6.2, breadth to draft ratio 1.9 to 4. The prismatic coefficient 0.5 to 0.73 should be a coefficient 0.7 to 0.97 LCB 7 percent from after mid ship to 2.8 percent to forward a mid ship half angle of and this 10 degree bit 46 degree and v by l power 0.5.

That is a volume displacement run raise to 0.5 is coming to 1.7 and Froude number up to 0.5, so if the vessel which you consider fall within this range and the type of vessel is also is the same. The trawlers or tugs or small crafts then naturally you can try this method for the estimation of the resistance in the preliminary stages of the ship design here.

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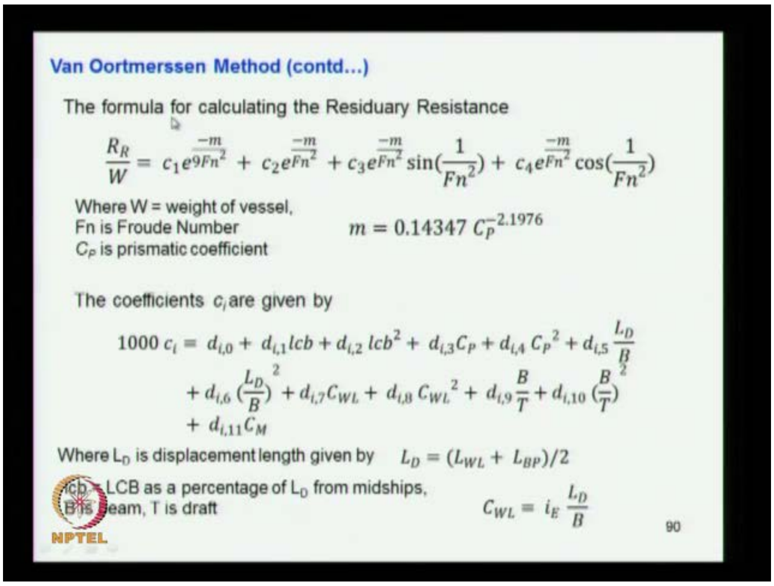

As we have discussed the total resistance using the Froude imposes splits into resigned resistance and frictional resistance. So, frictional resistance usually taken from ITTC formula and resided resistance formula is presented here. So, the reside resistance with relation to the weight of the ship, here both the forces force quantity is here, so which is represented by this expression.

You can see that c 1 into exponential minus m by 9 f n square plus c 2 into e power minus m by f n square plus e 3 into e power minus m by f n square into sign of 1 by f n square plus c 4 into e power minus m by f n square and cos an of one by f n square. So, this a expression put forward by Van Oortmerssen base on the recreation analysis carried out on the experimental data obtained through the model tests. So, here it is all clear F n is the Froude number, it is a length Froude number used C P is a prismatic coefficient where is you stay m brought up is here.

Now, represented by using this formula which were the prismatic coefficient is a parameter the coefficient c i, you can see that c 1, c 2, c 3 and c 4. So, c i varies from 1 to 4 is given by this expression over here that is this expression which depends on LCB depends on prismatic coefficient depends on LD. There is a displacement length by B, then you have the L by B here, then what plan area coefficient B by T ratio and also m should be a coefficient. So, it depends on the major geometric Parameters of the vessel at this stage if the design you are expect it to have all this things known.

So, then you can find out you can find out what is the c i from the table appearing in the next slide and this c i values you can just put it here to find out c i and m and Froude number. We get what is R R by W, so here LD is the displacement length given by this formula LD is equal l W l plus l b p its average of that may of that one CB. We already know that which is appearing here if the LCB here it is l c that is a naturally send of known buoyancy c with a reference to the mid ship can see that so B is set B by T is a draft and CWL, it can be taken as i as a half angle of entrances by LD by B.

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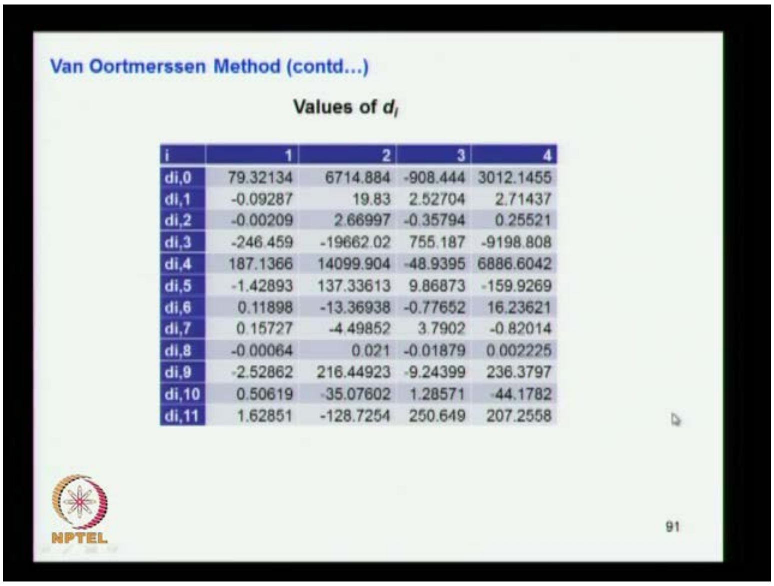

i	1	2	3	4
di,0	79.32134	6714.884	-908.444	3012.1455
di,1	-0.09287	19.83	2.52704	2.71437
di,2	-0.00209	2.66997	-0.35794	0.25521
di,3	-246.459	-19662.02	755.187	-9198.808
di,4	187.1366	14099.904	-48.9395	6886.6042
di,5	-1.42893	137.33613	9.86873	-159.9269
di,6	0.11898	-13.36938	-0.77652	16.23621
di,7	0.15727	-4.49852	3.7902	-0.82014
di,8	-0.00064	0.021	-0.01879	0.002225
di,9	-2.52862	216.44923	-9.24399	236.3797
di,10	0.50619	-35.07602	1.28571	-44.1782
di,11	1.62851	-128.7254	250.649	207.2558

So, once you get all this parameters and use the coefficients which has already prescribed by Van Oortmerssen based on the analysis, so you can see that for d i that is 1 2 and three are values is a 5, so if you look back you can see that here c i 1,00 into c i. So, here one i c 1 that is c 1 goes here, so if you want to find out c one use this expression with i is equal to 1 for i is equal to 1. That means you have need one d 1 0 d 1 1 d 1 2 like that for that first c 1, so fit for c 2, then you need c 2 1000 c 2 is equal to d 2 0 d 2 1 d 2 2 like that. So, since you get all the c values, then you can go to this expression and put the values and get this resided resistance.

So, that is what you get here, so when is when is equal to when we want to c 1 use this values when you want c 2 use this values you want c 3 this values and c four this values. So, these are the coefficient regression coefficient and based on which you will able to find out knowing other parameters this resistance reside resistance, so once c of r obtain the resize resistance, then you follow the ITTC formula.

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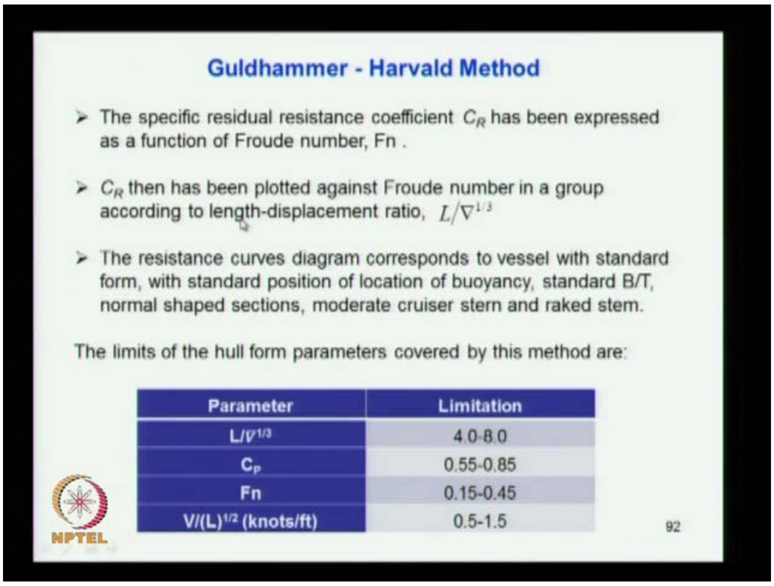

To find out the friction resistance and also use the form factor from which you will get the total resistance and that total resistance we have to add the correlation allowance. Other air allowance and wind allowance and all that from which we get the total resistance of the ship which you design and from which would be able to find out the power requirement. Subsequently, the power of the ancient required for the ship, so the next method what we look into it is like Guldhammer Harvald method. This is also a popular method again use for conventional ships and generally use for both at simple and tones curve ship.

So, here the specific Resistance coefficient here C R has been expressed as a function of Froude number which is obvious because why its relative C R is related to Froude number. Then the raisers resistance coefficient is plotted against Froude number in a group, we have already seen that if you know the chart the series diagram normally put for the Guldhammer Harvald cannot good is the diagram.

Here, you just explain this on the regression expression so this starts that is for each value of one by l by delta up of one third a certain data is available. So, the charts Guldhammer Harvald charts are meant for l by delta up of one-third values of 0.45, sorry 4.5, 0.55. It goes up to 8, so these are the charts which are available base on the studies performed by Guldhammer Harvald. So, the resistance curves diagram corresponds to vessel with standard all the test have been done with the standard is form. So, the test have been done for the standards position of LCB location of buoyancy, then standard B by T the shape is taken as normal section and cruiser stern is taken as moderate.

It has not concert transom stand here it run cruiser system which is moderate shape and raked stems, so this are the assumptions or theses are the values which have been used for the models preparation of the models. Such models have been tests and data have been obtained, so whenever there is a deviation from this value you have to apply correction to the values of the C R values which we get to use for a ship which is not deviating from this standard values used to by Harvald.

So, the limit of the application of this method you can see it is l by delta power one-third 4 to 8 that is what I said it starts from 4. Then with the 0.5 increment 4.5, so you have the charts available for these values, then the prismatic coefficient varies from 0.5 to 0.85 Froude number 0.15 to 0.45 and v by square root. It is taken and feet varies from 0.5 to v knots and the line fit, it varies from 0.5 to 1.5, if the ship falls within this range. Then there is a normal conventional vessel you can use the Guldhammer Harvald method.

So, the rake system where I think you know that what is rake system there is no bulbous bow considered here it is a normal rake system straight system. The section shapes normally it is divided into normal section then u section and v sections, so if you have deviating from the normal shape or if you using u section or v section then you have to give a correction for the change in the section shape.

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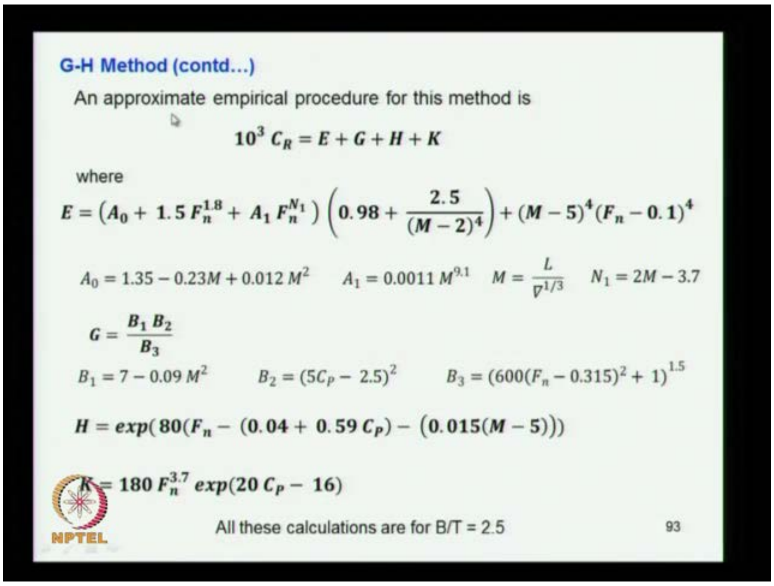

So, this is a expression coming from that in place of chart this been putting this form, so the empirical formula here is 10 cubes C R because C R is the small quantity. It is a coefficient is a non dimensional parameter and hence it is usually very small, so it is here says present often by 10 power 3 C R. So, that is equal to e plus g plus h plus k each terms are define below once in you are favour evaluate these terms. Then you can find out and get the total resizer resistance coefficient, so here the e term if you look it is given by this parameter say 0 and f n a.

Then, you have the m coming here m and f n, so you will see that what are the coefficient are parameters here a 0 given by this expression it depending on the m alone a one also depending on m alone see m is defined as l by delta power one third. So, once you know l by this value you can just substitute it here and also n 1 which appears here. You can see it represents again in terms of m, so you have this values all the values are known from here and then substitute it here.

You get E, then g the second term here design by b 1 and b 2 by b 3, so the terms are explained here b 1 depending on a b 2 depending on C P prismatic coefficient and B 3 depending on the Froude number and once you get all this parameters, you can find out what is g and g will go here. Then you have h exponential C Power of this quantity is here f n C P m all this quantities are known.

We put here then k value is depending on Froude number and prismatic coefficient, so this values again, so you that the standard that is as per the Guldhammer Harvarld standard what is the 10 cube C R. That is the resizers' resistance coefficient of the vessel which you are considering for the design. So, whenever there is a deviation of course the B by T here assumed this 2.5 that is the standard B by T assume by Guldhammer Harvald the vessel which you consider the design is deviating from this.

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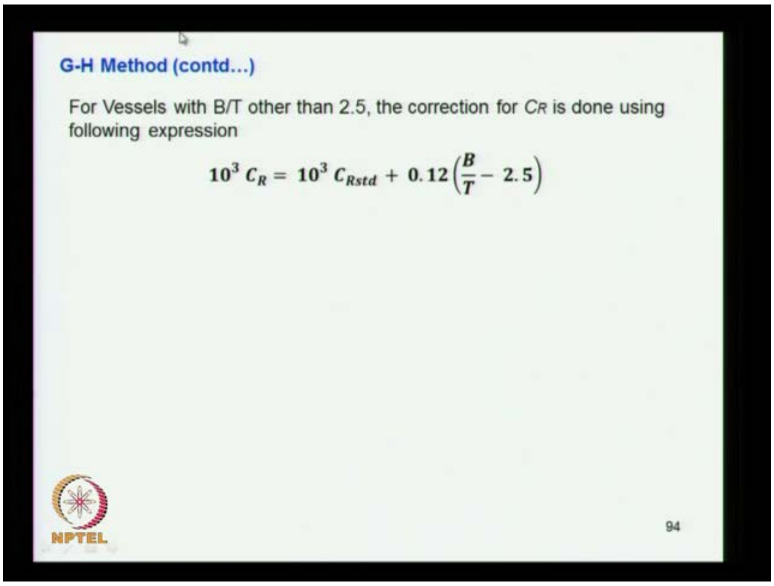

You have to give a correction in 10 cubes C R for the B by T, so here I can see the B by T correction 10 cube C R is equal to 10 cube C R standard. That is the one which we have seen before plus point 1, 2 B by T minus 2.5, so which implies that if B by T is less than 2.5, then it can be negative if it is more than 2.5. Then you have to add just physically correct when the beam of the ship increases resistance increases. So, when B by T is more than 2.5 resistance C R will increase or if the most lender that is the b is that reduce resistance comes down.

So, this quantity become negative, so which is taken care of in the correction in this the similar corrects are also available for LCB where it deviates from the standard value. Then also the form if you are using not the normal form u or v, then they will be a correction for that.

So, considering this if you are having not a cruises stern and you have a transom stern there will be correction for that. So, including all this correction the small correction which are not covered here, so you will get the corrected 10 cubes C R, so once you achieve that corrected 10 cubes. Then again you estimate the frictional resistance using the ITTC formula and get the form coefficient with the form factor and using that you will find into total resistance by putting the other model ship correlation allowance and that is c a which you put 0.0004. Then the air resistance and other things you put, then you get the comparing the resistance of the ship and tug design.

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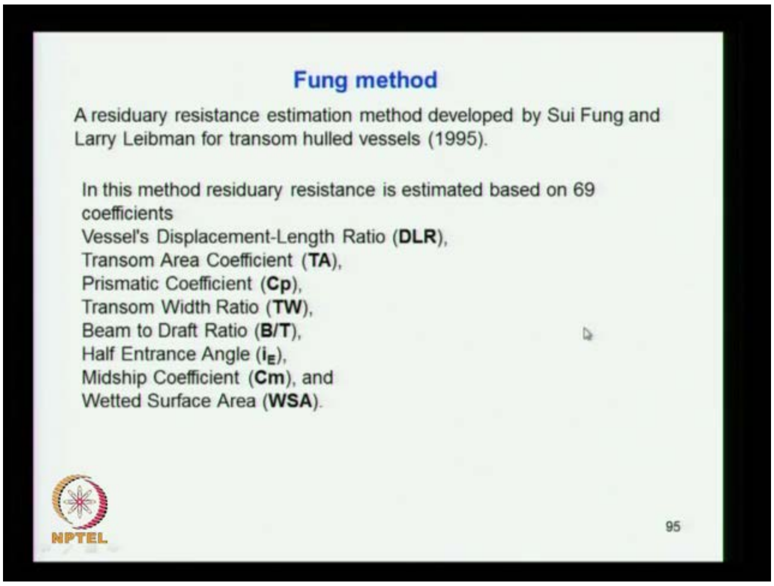

The next method here is the Fung's method, so here we can see these. Basically, resist for the transom hull vessels is carried out this are relatively new method 1995. Various parameters used in this are explained here where it consider transom area is a transom ship which is consider transom area with relation to mid ship area may be consider prismatic coefficient transom width and the B by T ratio. Half angle of entrance mid ship area coefficient wetted surface area all these are consider in the estimation.

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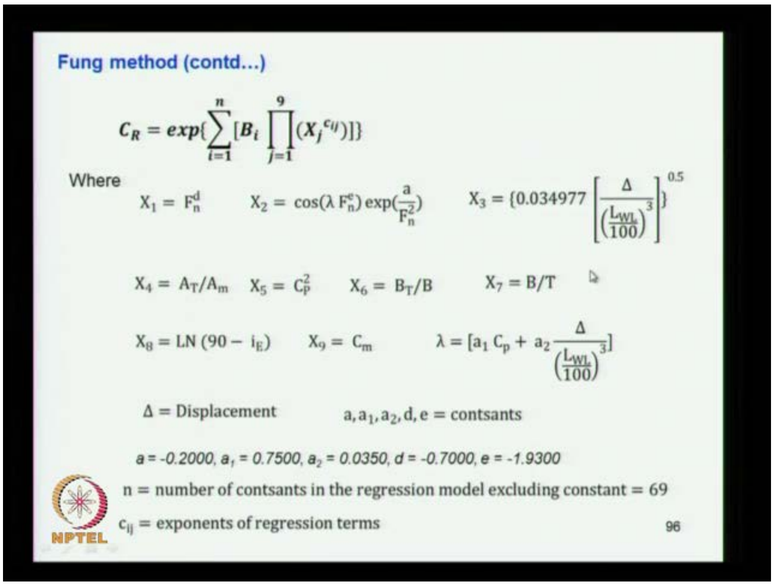

Fung method is represented and put the resizer resistance coefficient C R is equal to exponential of summation of this one. It is the product sign, so you have this the quantity over here and now you know n a thing is coming up to 16 n is a total number of constant 69 coefficient. We will see the coefficients later n value, so i is equal to 1 to n and j is equal to 1 to 9, so what so you have is the j here 1 to 9. So, you get x 1, x 2 up to x 9 see how this x one are represent x one is equal to Froude number raise to d. So, x 2 is equal to given by cosine as lambda into Froude number raise e exponential a by f n square x 3 given by this formula.

This is the mass less placement of the ship x 4, it is the area of the transom that a submerged area of a transom divided by area of mid ship section under water. Then x 5 is the prismatic coefficient curve x, the breadth of the breadth of the transom at the water line and b is a breadth of the ship. So, once you know all this parameters, you can then this is x seven is a B by T and x 8 is a length into 90 minus i e, x 9 is C m.

Then, lambda which appears here is given by this expression it depend up on C P again mass displacement l W l. So, this coefficient which appear here you can see that in d e a and also may be other a one and all that you can say this coefficient are given like this, this are the values for the this parameters other coefficient this parameter. So, finally what you need is, now you know what is x 1 x 2 up to 9 you have these values and what do look for its b values then you have the you need the c i j, so we say that we look into what how do you get b and c i j and based on which you find out.

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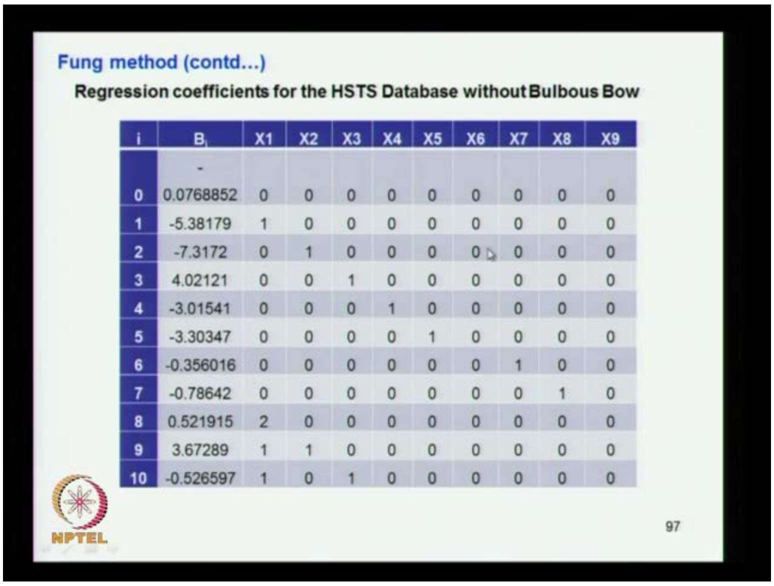

Fung method (contd...)

Regression coefficients for the HSTS Database without Bulbous Bow

i	B_i	X1	X2	X3	X4	X5	X6	X7	X8	X9
0	- 0.0768852	0	0	0	0	0	0	0	0	0
1	-5.38179	1	0	0	0	0	0	0	0	0
2	-7.3172	0	1	0	0	0	0	0	0	0
3	4.02121	0	0	1	0	0	0	0	0	0
4	-3.01541	0	0	0	1	0	0	0	0	0
5	-3.30347	0	0	0	0	1	0	0	0	0
6	-0.356016	0	0	0	0	0	0	1	0	0
7	-0.78642	0	0	0	0	0	0	0	1	0
8	0.521915	2	0	0	0	0	0	0	0	0
9	3.67289	1	1	0	0	0	0	0	0	0
10	-0.526597	1	0	1	0	0	0	0	0	0

So, here this is B you can see i is the total number of terms, we have seen 69, so this column will go up to 69. This column is up to 10 and may be next slide for that goes to 69, so for particular i what is the value of the excess. So, the power of that is given here that is you have seen that it is x power C i j, so what is the power given for the x corresponding x that power value is given here. So, once you get the b i particular row you get all this quantity you can see that sorry this is the first this all 0 is here.

So, if you go only you have b, all this are 0, so it becomes 0 then you have here B i B 1 is equal to minus 5.3817 and only x 1 will have a power other terms are not significant. So, you get goes like that the power the powers will be and the other powers means 0 means x says to 0, 1 x 2 x or 3 raise to 0 again its 1. So, other terms are become 1, so only the x 1 will have the power, so you just continue with that you have the similar diagram from regression coefficients you goes up.

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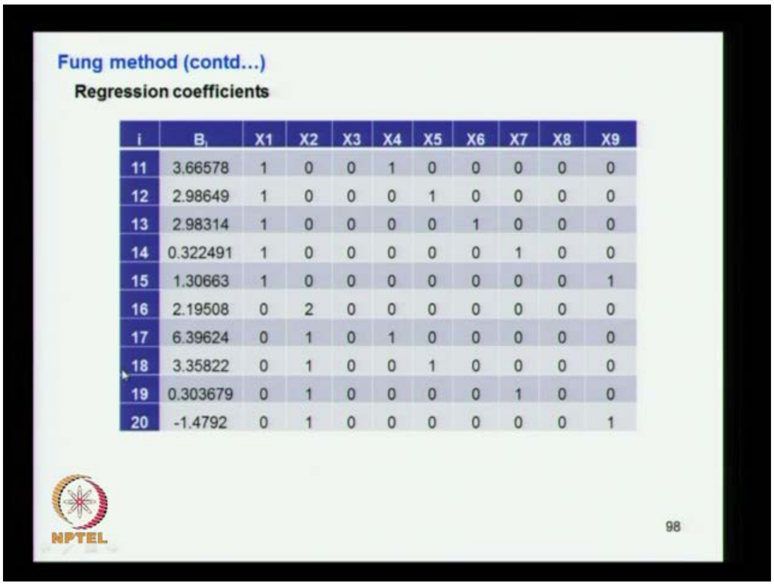

Fung method (contd…)

Regression coefficients

i	B_i	X1	X2	X3	X4	X5	X6	X7	X8	X9
11	3.66578	1	0	0	1	0	0	0	0	0
12	2.98649	1	0	0	0	1	0	0	0	0
13	2.98314	1	0	0	0	0	1	0	0	0
14	0.322491	1	0	0	0	0	0	1	0	0
15	1.30663	1	0	0	0	0	0	0	0	1
16	2.19508	0	2	0	0	0	0	0	0	0
17	6.39624	0	1	0	1	0	0	0	0	0
18	3.35822	0	1	0	0	1	0	0	0	0
19	0.303679	0	1	0	0	0	0	1	0	0
20	-1.4792	0	1	0	0	0	0	0	0	1

Similarly, 20, now 30, here 40, here 50, here 60 it goes up to 69.

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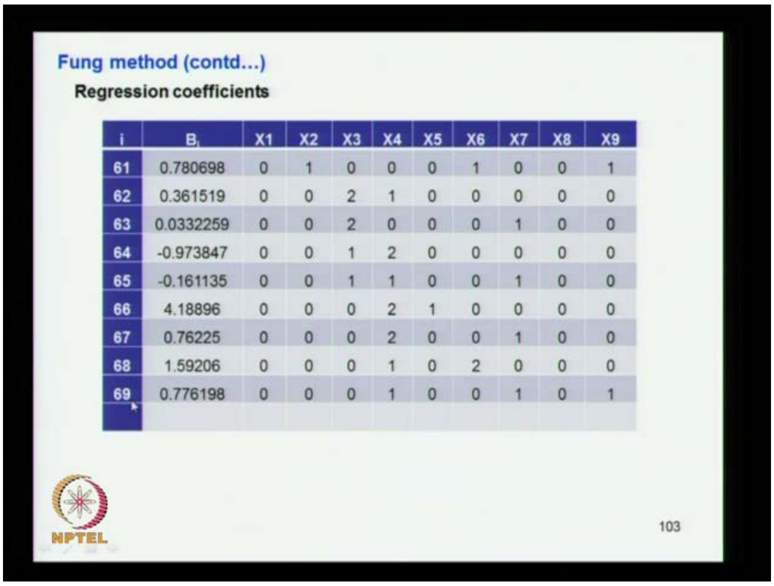

Fung method (contd…)

Regression coefficients

i	B_i	X1	X2	X3	X4	X5	X6	X7	X8	X9
61	0.780698	0	1	0	0	0	1	0	0	1
62	0.361519	0	0	2	1	0	0	0	0	0
63	0.0332259	0	0	2	0	0	0	1	0	0
64	-0.973847	0	0	1	2	0	0	0	0	0
65	-0.161135	0	0	1	1	0	0	1	0	0
66	4.18896	0	0	0	2	1	0	0	0	0
67	0.76225	0	0	0	2	0	0	1	0	0
68	1.59206	0	0	0	1	0	2	0	0	0
69	0.776198	0	0	0	1	0	0	1	0	1

So, that is a total number of coefficients, so all the coefficients are given here the power keep changing may be 2 here you can see that some powers are different.

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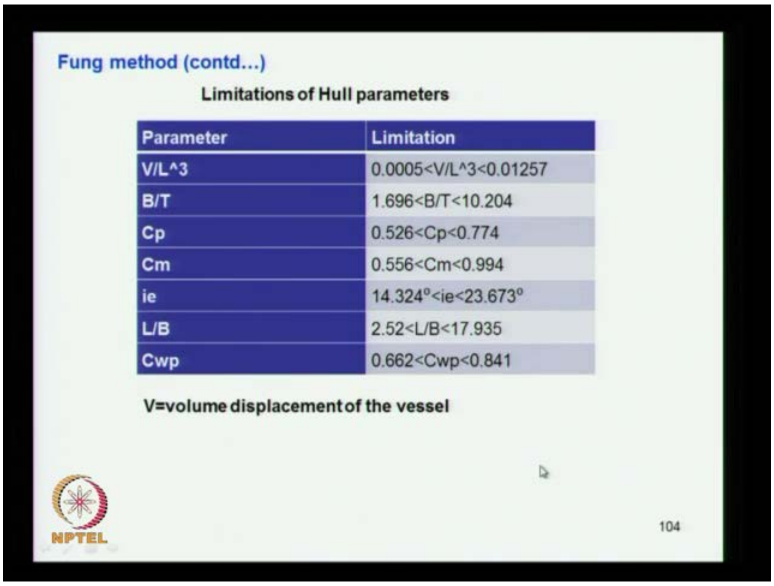

So, it is a straight forward method, now you know you will able to find out the C R using Guldhammer Harvald, you say chart the data presented in a chart form has been used. I clearly explain is based on the regression expression and using the regression coefficient. So, whole chart is now convert into regression because when you convert it in regression computer section become easier calculation become easier to programme the expression is easier than programming the chart values. So, that is the reason here, so the limitation what this is the applicable of what all what is the limitation of it is the Fung method.

It is volume displacement by l cube this the range B by T, the range prismatic coefficient against c this the range mesh coefficient this the range half angle of entrance this the range L by B length by breadth ratio this it and water plain coefficient is this. So, just look to our ship if it falls within this range, then you can use the false method so the all this methods basically are meant only for design purpose the final thing you have to perform a model tests.

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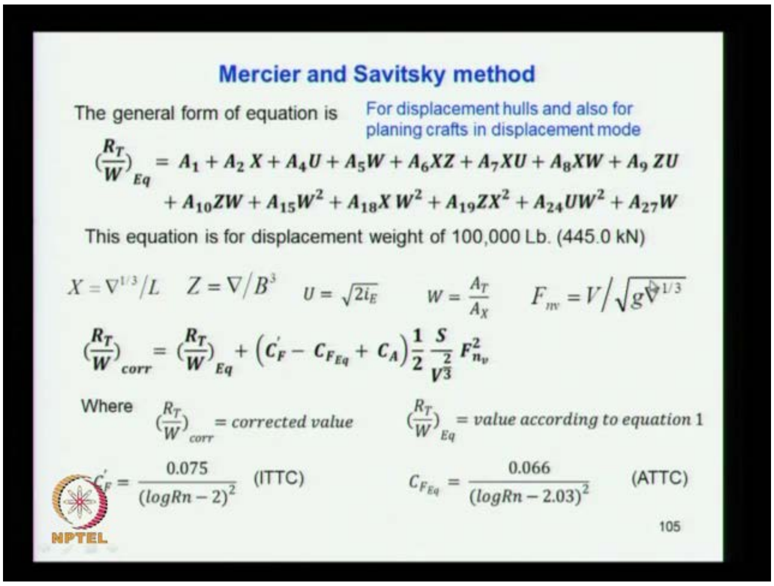

Then, you have estimate the resistance before finalizing the resistance and subsequent selection of the determination of the engine power of the selection of it. So, the next method is Mercier Savitsky method, whenever you say this method obviously refer to it is a plain hull here for displacement hulls and also planning crafts in displacement mode. So, this can used for displacement hull for usually smaller vessel and also for planning crafts and displacement planning craft plans only at a higher speed. So, the initial speed the lower speed it operate as a displacement mode, so when the speed reaches at crush hold point then it start planning.

Then, you consists it is a planning vessel and the resistance is determined separately, so here this method is applicable only for displacement ship and for planning crafts in the displacement mode not in the planning mode. So, general form of the equation is given by this total resistance by weight of the ship is given by this one a 1 plus a 2 x plus a 4 u plus a 5 W a 6 x z.

So, it goes like that, so it goes up to a twenty seven many x are missing in between look at this are form it has been used. This equation is based on the developmental study carried out for a displacement weight of 100, 1,000 pounds are equal to 445 kilo Newton's. So, here the x which appears here is explain this volume displacement power one third divided by L, so that is the x definition the set which appears here is define as volume displacement b power third as a breadth of the ship power. Then u is equal to square root of 2 time half angle length of entrains it is u appearing here it define like this W which appear here is area of the transom divided by area of the mid ship again below the water line then the Froude number is depending volume.

So, this is the demonstration of volume the Froude number definition v by square root of g into volume displacement raise to one-third. So, this is the Froude number used this is not the length of Froude number used here is the volume displacement based a Froude number so then you have the r t by W correction. If is a correction deviation from this it r t is equal to this value plus this is the correction applied here c f prime which is coming from ITTC formula minus c f E q that is coming from the Hook's formula.

I think you remember that plus the correlation allowance so all this put together and multiply half s by V power two-third into the volume Froude number square. So, the flow this you get the corrected total resistance to eight ratio, so once you get this, then you get the total resistance straight from here.

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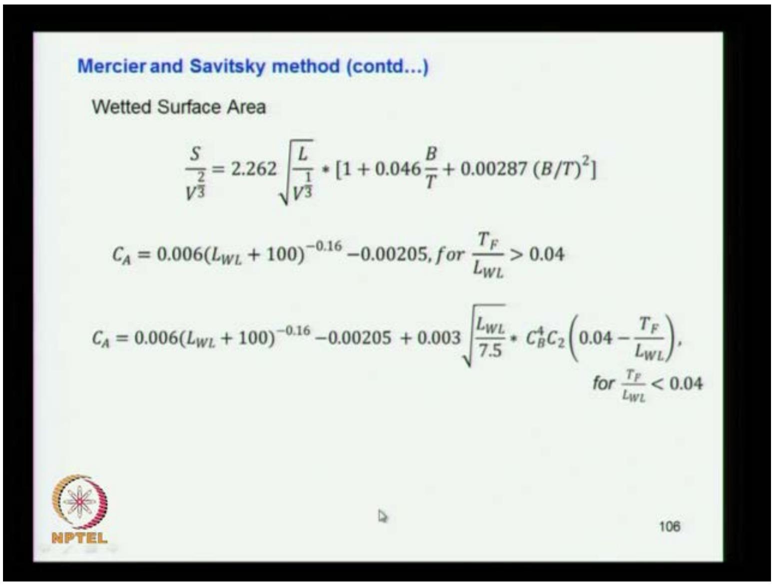

It is not that you have split this formula, the total resistance is handle unlike the previous expression where only they resizer resistance was canceller where as in this case you have consider resizer resistance also the c f values is also taken care. So, the wetted surface area is given by s by v raise to two-third is equal to 2.2 l by v power one-third B by T and B by T square. So, once from this expression by knowing this parameters you will be able to find out the wetted surface area the correlation allowance is normally taken as 0.0004, but the expression is given here base on length of water line.

This is the expression t f the t f by l W l t f is the draft at the forward perpendicular draft at the forward perpendicular by length of the water line. If it is greater than 0.04, use this if it is less than 0.04 use this expression and for at 0.04, you can use any of us both will come to the same expression.

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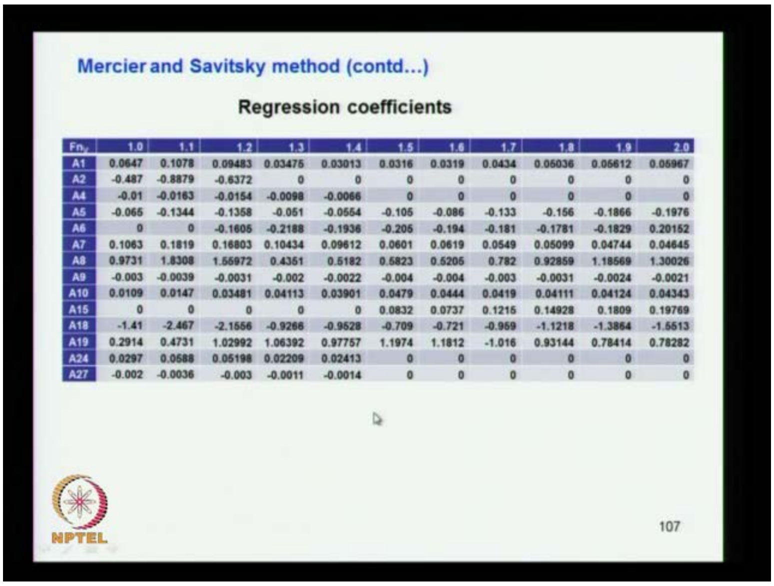

Fn_∇	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
A1	0.0647	0.1078	0.09483	0.03475	0.03013	0.0316	0.0319	0.0434	0.05036	0.05612	0.05967
A2	-0.487	-0.8879	-0.6372	0	0	0	0	0	0	0	0
A4	-0.01	-0.0163	-0.0154	-0.0098	-0.0066	0	0	0	0	0	0
A5	-0.065	-0.1344	-0.1358	-0.051	-0.0554	-0.105	-0.086	-0.133	-0.156	-0.1866	-0.1976
A6	0	0	-0.1605	-0.2188	-0.1936	-0.205	-0.194	-0.181	-0.1781	-0.1829	0.20152
A7	0.1063	0.1819	0.16803	0.10434	0.09612	0.0601	0.0619	0.0549	0.05099	0.04744	0.04645
A8	0.9731	1.8308	1.55972	0.4351	0.5182	0.5823	0.5205	0.782	0.92859	1.18569	1.30026
A9	-0.003	-0.0039	-0.0031	-0.002	-0.0022	-0.004	-0.004	-0.003	-0.0031	-0.0024	-0.0021
A10	0.0109	0.0147	0.03481	0.04113	0.03901	0.0479	0.0444	0.0419	0.04111	0.04124	0.04343
A15	0	0	0	0	0	0.0832	0.0737	0.1215	0.14928	0.1809	0.19769
A18	-1.41	-2.467	-2.1556	-0.9266	-0.9528	-0.709	-0.721	-0.959	-1.1218	-1.3864	-1.5513
A19	0.2914	0.4731	1.02992	1.06392	0.97757	1.1974	1.1812	-1.016	0.93144	0.78414	0.78282
A24	0.0297	0.0588	0.05198	0.02209	0.02413	0	0	0	0	0	0
A27	-0.002	-0.0036	-0.003	-0.0011	-0.0014	0	0	0	0	0	0

So, this is the Mercier Savitsky method, so here the coefficient what we need a 1 a 2 x of draft t is 27 that is what you need here a 1, a 2, etcetera up to 27. These quantities are given here you can see that this is a 1 values, so a 1 values are given for particular Froude number volume, Froude number is equal to 1 displacement Froude number is equal to 1. You get use this values if displacement number is one point one use this values if the displacement Froude number is in between.

You do both and then take interpolation of that for that value, so this is given for a range of Froude number 1 to 2, then increment of 0.1. So, the values are we have to take the appropriate values for a 1 to a 27 and use the previous equation, then you get the total resistance.

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So, these are the different number, there after different other methods may be some of the resistance calculation methods for advance vehicle high speed vehicle sent may be soft. We will be discussing later, so this are generally for this all meant for mainly displacement type of vessel what we have seen the method what we discuss Holtrop Mannen method. Then Fung's method Gudlhammer Harvald method all this are meant for displacement type vessels even it including the Mercier and Savitsky method. So, it can be applied to planning vessels, but only for the case when it is in the displacement mode.

So, this are the conventional methods or you know the data availability you base on the experiments carried out by various research screw and these information is very much use full for the in the designs area of a ship. So, when you design you have to have an idea about the engine power requirement, so you have to know how much the power required for the vessel.

So, the power requirement is now depending on the resistance of that, so once you get the resistance at the several speed, then resistance into the several speed that gives the effective power. Then you consider the transmission losses due to shaft baring gear and all that then you will come to know what is the power required at the engine side now you consider engine is not operated at hundred percent power always. So, the maximum continue rating is remain usually it continues rating of the injuries about 85 to 90 percent of the maximum power. So, then you will know with the non curating, what is a break power of engine, once you arrive at the that break power, then you go through the engine carried law from which you will find out you can choose an engine.

Therefore, another parameter come into picture what is the fuel efficiency what is the size what is the weight what is the reliability regarding maintains. So, cost of maintenance availability of surveys after sale surveys, so any factors you consider then you select the engine. So, once you select the engine you know what the weight which will go as so as in input into the design because when you do the weight estimation the initial stage of the design.

You might have assume a weight for the engine the engine plan mass we might have assumed. So, here you have obtain a correct mass which you substitute and proceed with design further so that is how that is why this up methods are useful. So, typical example this method have been applied to a LPG cylinder carrier, we just see that how what is it compared.

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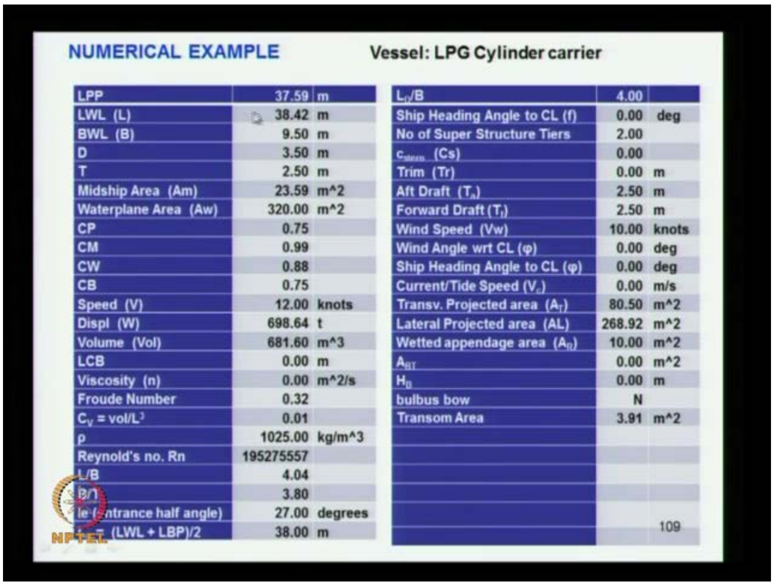
NUMERICAL EXAMPLE

Vessel: LPG Cylinder carrier

LPP	37.59	m
LWL (L)	38.42	m
BWL (B)	9.50	m
D	3.50	m
T	2.50	m
Midship Area (Am)	23.59	m^2
Waterplane Area (Aw)	320.00	m^2
CP	0.75	
CM	0.99	
CW	0.88	
CB	0.75	
Speed (V)	12.00	knots
Displ (W)	698.64	t
Volume (Vol)	681.60	m^3
LCB	0.00	m
Viscosity (n)	0.00	m^2/s
Froude Number	0.32	
C_V = vol/L^3	0.01	
ρ	1025.00	kg/m^3
Reynold's no. Rn	195275557	
L/B	4.04	
B/T	3.80	
ie (entrance half angle)	27.00	degrees
L = (LWL + LBP)/2	38.00	m

L_D/B	4.00	
Ship Heading Angle to CL (f)	0.00	deg
No of Super Structure Tiers	2.00	
C_{stern} (Cs)	0.00	
Trim (Tr)	0.00	m
Aft Draft (T_a)	2.50	m
Forward Draft (T_f)	2.50	m
Wind Speed (Vw)	10.00	knots
Wind Angle wrt CL (φ)	0.00	deg
Ship Heading Angle to CL (φ)	0.00	deg
Current/Tide Speed (V_c)	0.00	m/s
Transv. Projected area (A_T)	80.50	m^2
Lateral Projected area (AL)	268.92	m^2
Wetted appendage area (A_B)	10.00	m^2
A_{BT}	0.00	m^2
H_B	0.00	m
bulbus bow	N	
Transom Area	3.91	m^2

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So, these are the vessel parameter we have concern numerical example vessel parameters here this 37.59 metre LPP. This is the very water line length breadth 9.5 depth, 3.5 and draft 2.5 meter. This is other or other information’s about the vessel, so then you have all this parameters coming here, then you can just go through this what all different area given and speed given. And so finally, a transom area is given, so all this parameters are available.

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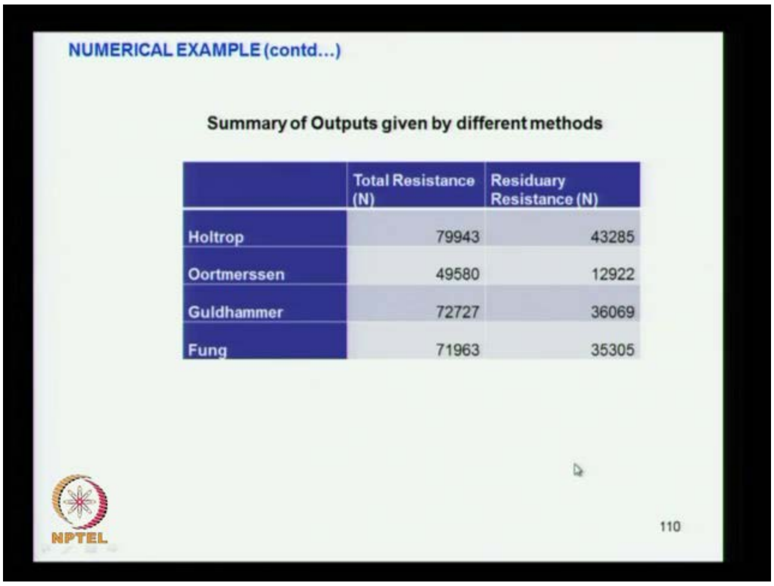

	Total Resistance (N)	Residuary Resistance (N)
Holtrop	79943	43285
Oortmerssen	49580	12922
Guldhammer	72727	36069
Fung	71963	35305

So, based on which use all this methods to find out the resistance that is Holtrop this total resistance is the retire resistance is all in Newtons Oortmerssen is given it is under predicting very high and here again say Guldhammer and Fung. They are coming closer, so this method is half it may be the vessel is not falling in the range of Oortmerssen because that mainly meant for trawler sent tugs here the vessel is the batch.

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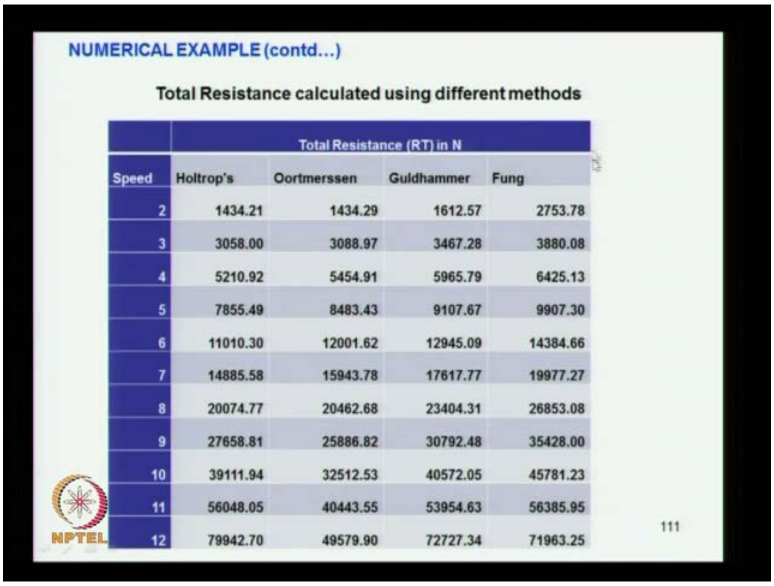

	Total Resistance (RT) in N			
Speed	Holtrop's	Oortmerssen	Guldhammer	Fung
2	1434.21	1434.29	1612.57	2753.78
3	3058.00	3088.97	3467.28	3880.08
4	5210.92	5454.91	5965.79	6425.13
5	7855.49	8483.43	9107.67	9907.30
6	11010.30	12001.62	12945.09	14384.66
7	14885.58	15943.78	17617.77	19977.27
8	20074.77	20462.68	23404.31	26853.08
9	27658.81	25886.82	30792.48	35428.00
10	39111.94	32512.53	40572.05	45781.23
11	56048.05	40443.55	53954.63	56385.95
12	79942.70	49579.90	72727.34	71963.25

So, the resistance calculating for the various speeds using the different methods are given here starting a speed of 2 meter it goes up to 12 meter.

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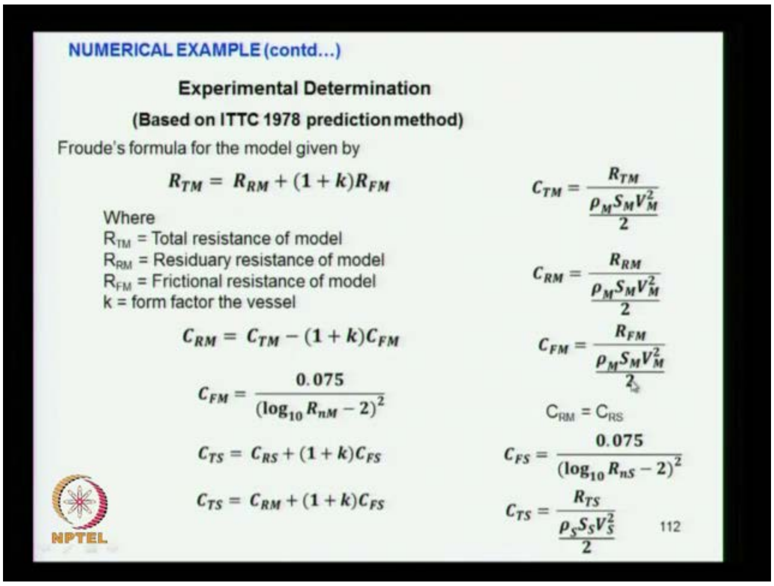

So, you can see this is the variation over that and later just plot it to find out you know take a feel of the variation of resistance prediction. So, here you already know what is a method adopted in the ITTC 1978 approach to predict the vessel resistance where the total resistance off the model is represent by the resizer resistance of the model plus the form factor into the flat plate formula expression. Use ITTC 1957 for the friction resistance, so convention thing you know that the C R M is equal to C T M minus 1 plus k into C F M, so that is the resizer resistance coefficient of the model.

From this, it is same as the C R S because it is satisfying the Froude number C F M you have is coming from the ITTC formula. So, C T s total resistance is equal to C R S plus one plus k into c f s, so you can say this c f is coming from here this formula and then the C T s you put C R s is equal to C R m. So, you get the total resistance coefficient for the ship to that you add the correlation allowance and winter air factors and all that.

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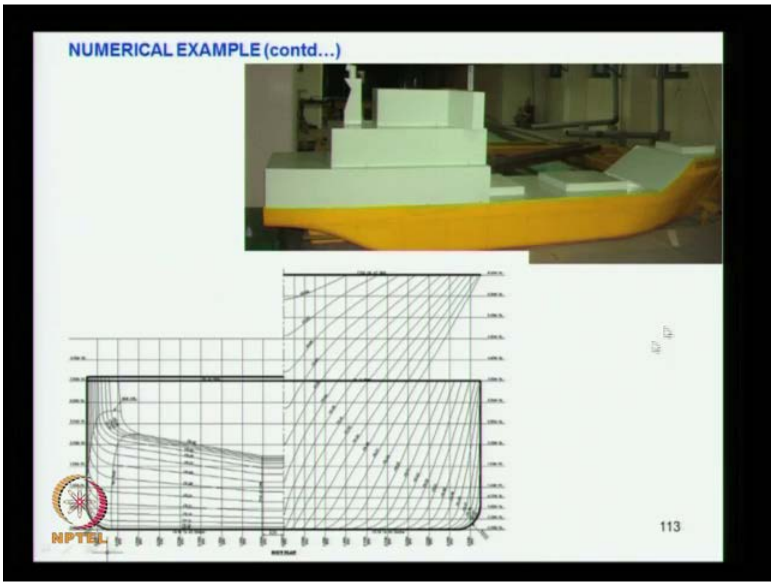

So, this is a geometry of the model and this is a geometry so the experiments also have been done using this ship and in that towing tank in a t Madras. So, the expand results also available we have also performed CFD analysis for the same vessel and all the results are compared.

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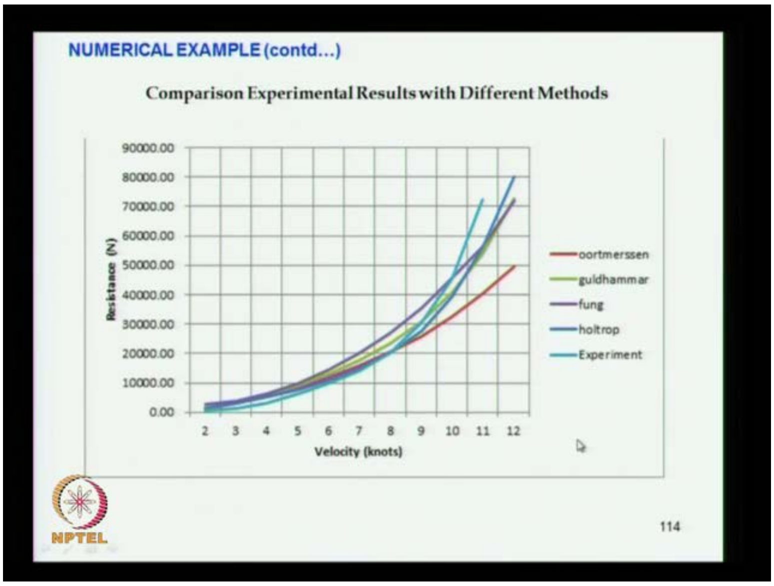

You can say here first you comparing with the experimental results with a different methods. You can see the experimental method is given by this line this line shows the experimental method and Oortmerssen is under predicting a lot, then Guldhammer is coming this is a line Gudlhammer line this is the Holtrop Mannen method. This is the Fung's method, so this is I think a service paid, you can this is a variation and Fung method. You can see the experiment getting closer to Guldhammer method and survey speed you can say it is very close. So, that is a prediction sought of prediction we have got from the different analysis using the regression expressions and also using the experiment.

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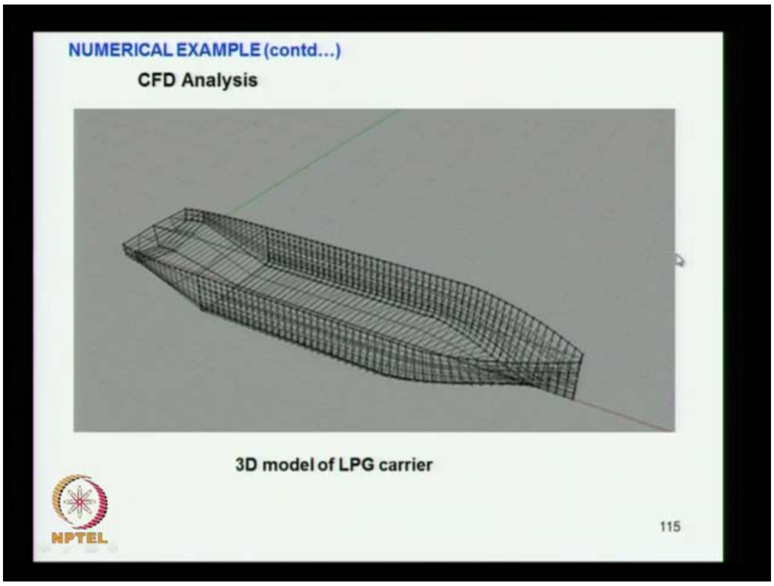

So, later I say before a CFD analysis carried out using that is the model of the vessel and computation domain.

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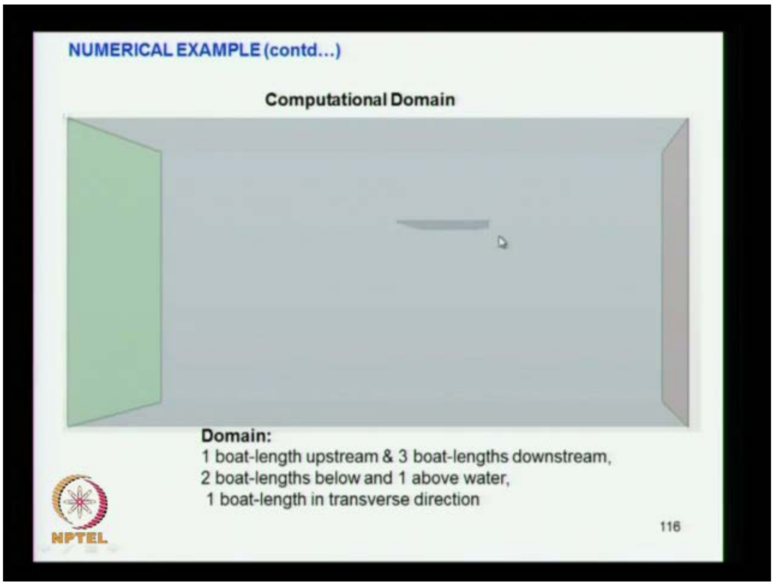

This is the vessel here and if identified domain for the computation and it is taken as boat length upstream is three times a length one boat length upstream and the side and the three times this side downstream and two boat lengths below. That is deport a condition and one above it include air part, then one boat length into transverse direction. So, usually you mould at only half of it because it is C P metric, so the boundary conditions use that inlet velocity inlet wall of fraction in component.

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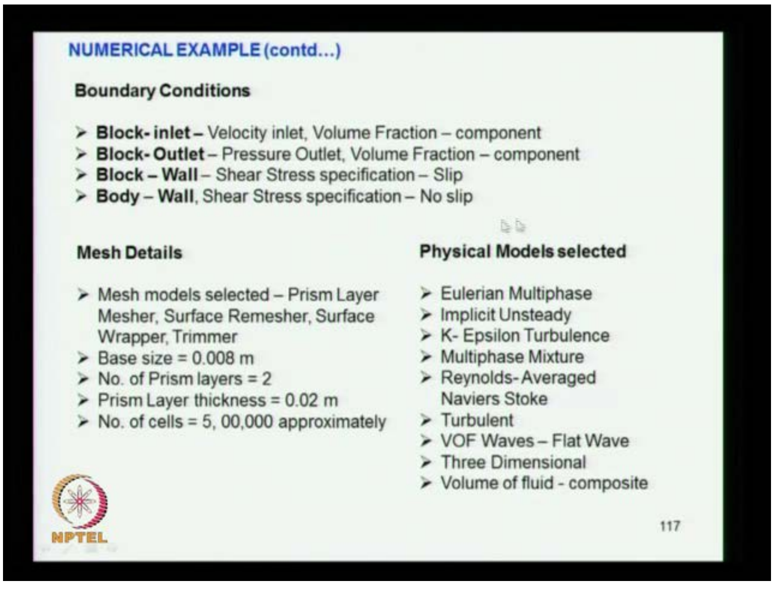

So, here this is an inlet boundary and this is the outlet boundary pressure out let volume fraction method used then the wall the shear stress whether the slip is used and body you have use in no slip condition. So, mesh details are given here and physical models selected keeps one model used then ranks used turbulent model it is tab that is what it is a capriole volume of wave waves are units some other duos for that.

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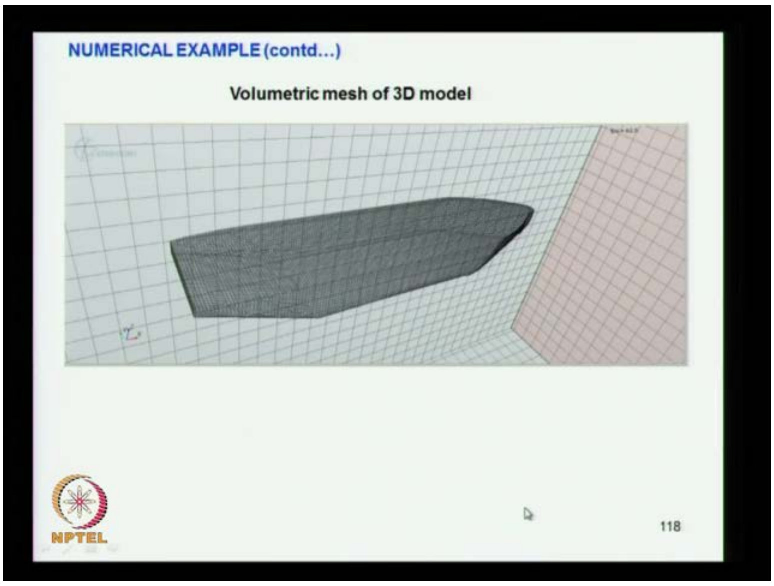

Then, you have this of the methods and closer the view of the body and determine it.

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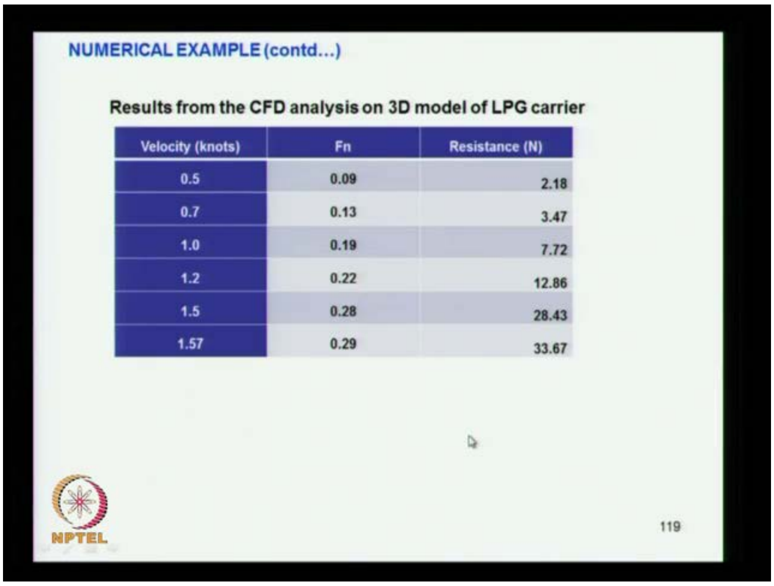

CFD analysis the for this vessel for this velocity there are some model sizes been generate in the CFD analysis. So, it is the model speed in corresponding Froude number and these are the model resistance update in neutrons.

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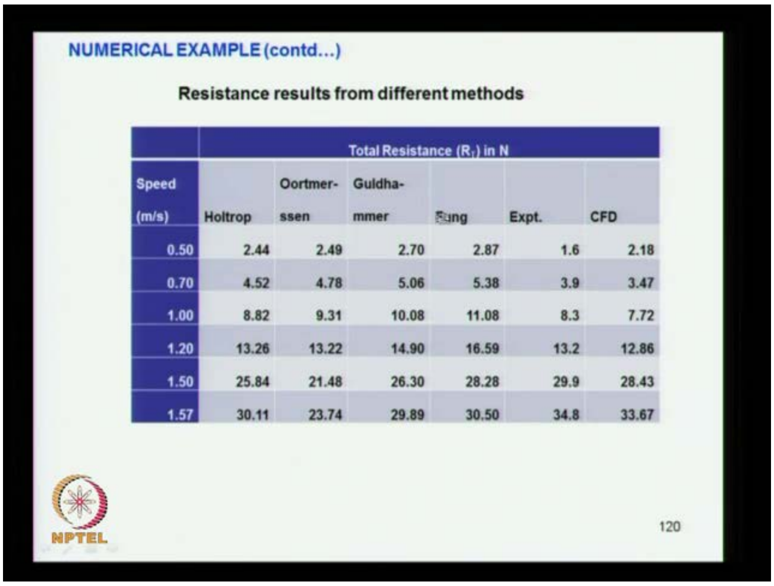

Speed (m/s)	Total Resistance (R_T) in N					
	Holtrop	Oortmer-ssen	Guldha-mmer	Fung	Expt.	CFD
0.50	2.44	2.49	2.70	2.87	1.6	2.18
0.70	4.52	4.78	5.06	5.38	3.9	3.47
1.00	8.82	9.31	10.08	11.08	8.3	7.72
1.20	13.26	13.22	14.90	16.59	13.2	12.86
1.50	25.84	21.48	26.30	28.28	29.9	28.43
1.57	30.11	23.74	29.89	30.50	34.8	33.67

So, now the total resistance compare all this CFD and you can see that Holtrop method for the model case Oortmerssen Guldhammer Fung experiment and CFD. This is I think this the survey speed and there you get the values coming reassembly close you can see here except this Oortmerssen method.

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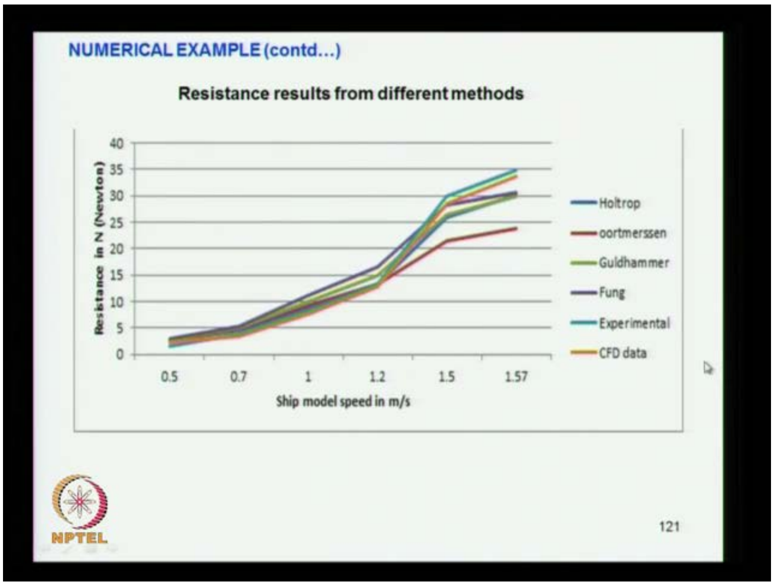

We just out play, so this is the plot of that for different methods.

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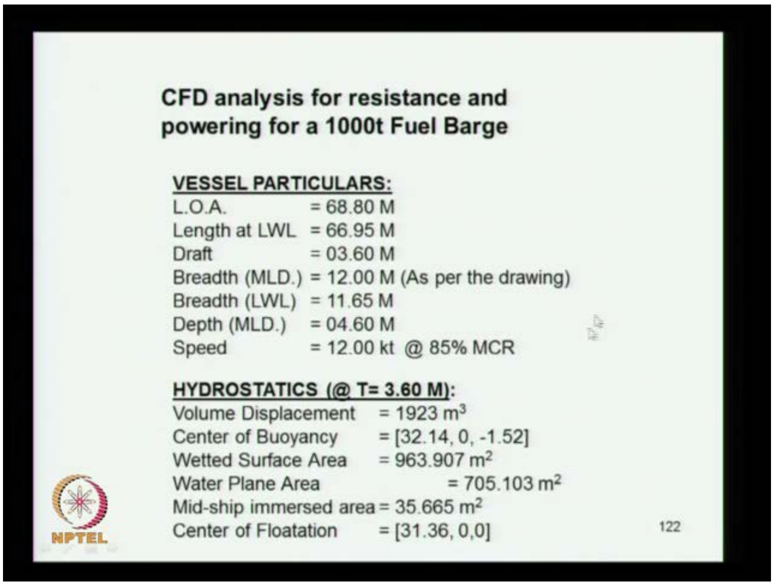

So, it is subsequent to this.

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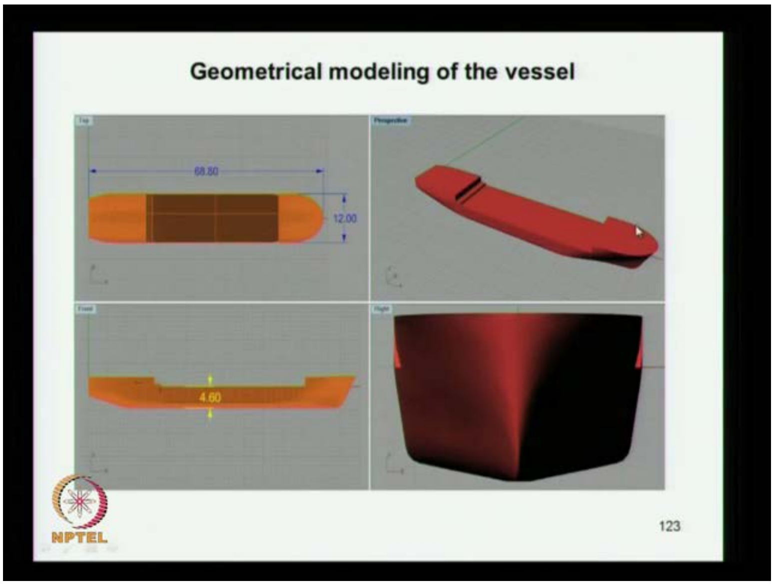

The lower vessel was also considered for the CFD analysis for 1,000 fuel barge, these are the particulars of that 68 meters, 66, nearly 67 meters length that tenth that water line. So, these are main particulars of the vessel and this are the hydrometric Parameter said this have design draft of 3.3 metres. So, the volume displacement centre point C position wetted surface everything obtain for that vessel and the same has been used for further analysis this is the model 3 D model of the vessel. You see this different views, sorry top view is a profile view is a symmetric view and sufficient view only again only half the model is consider because of symmetry.

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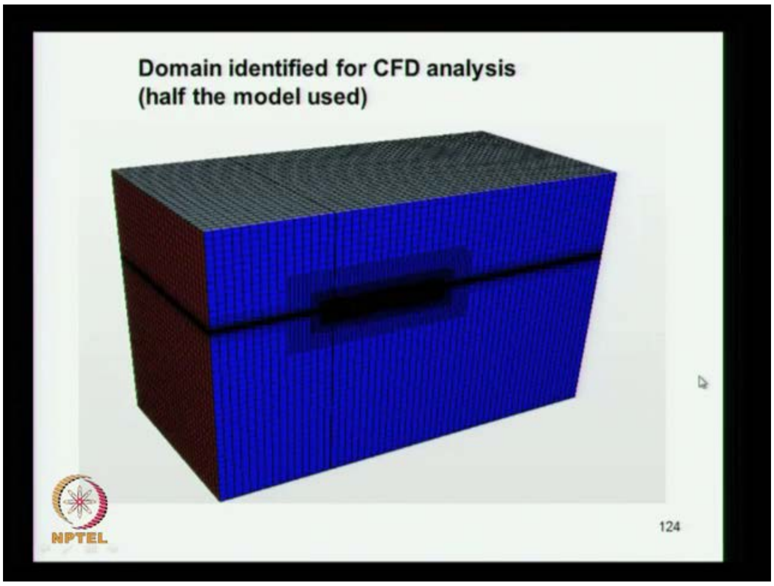

You can see here, so symmetry planed here and then domain is unless fixed this on the standard you know dimensions, so closer view of the machine.

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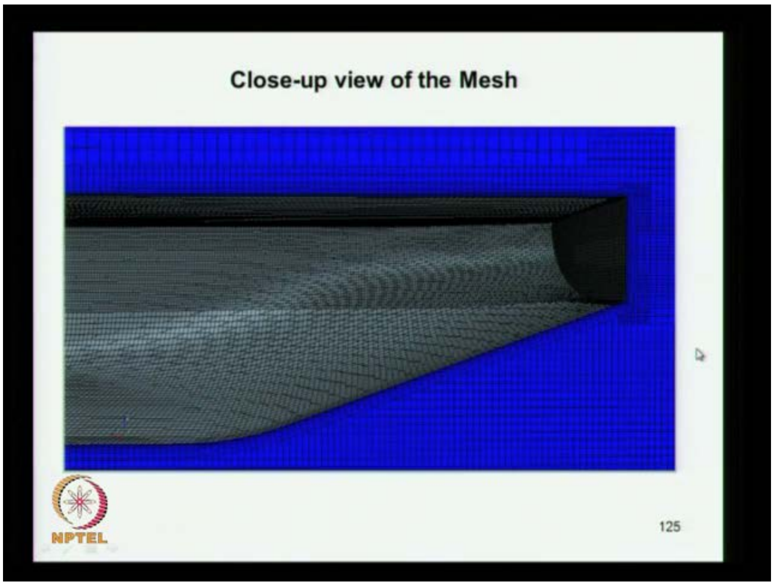

You can see the mesh around that and this is the total resistance.

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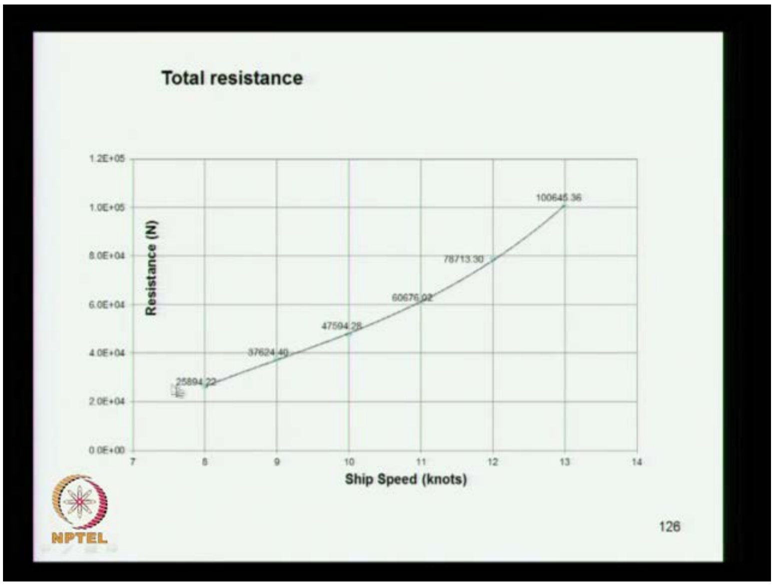

This has been obtained based on the CFD studies, so you can see this has been checked with data with Guldhammer Harvald method which has coming getting very closer to that within a deviation of a 5 to 10 percent. So, this is a speed resistance in neutrons, you can see for various ship speeds for the prototype is plotted. Here, the modelling is done for the prototype not for the model size dissolved for the model a prototype dimensions.

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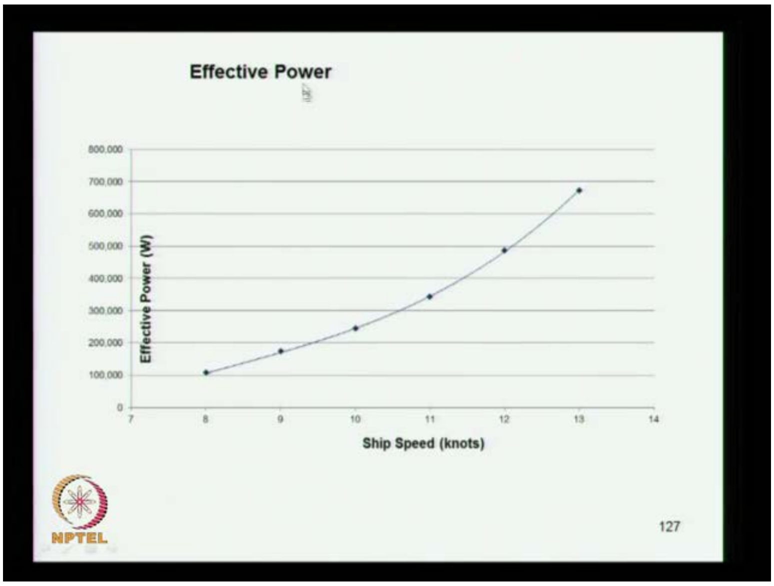

Finally, you get resistance into velocity is the effective power, it is effective power obtained from the computation.

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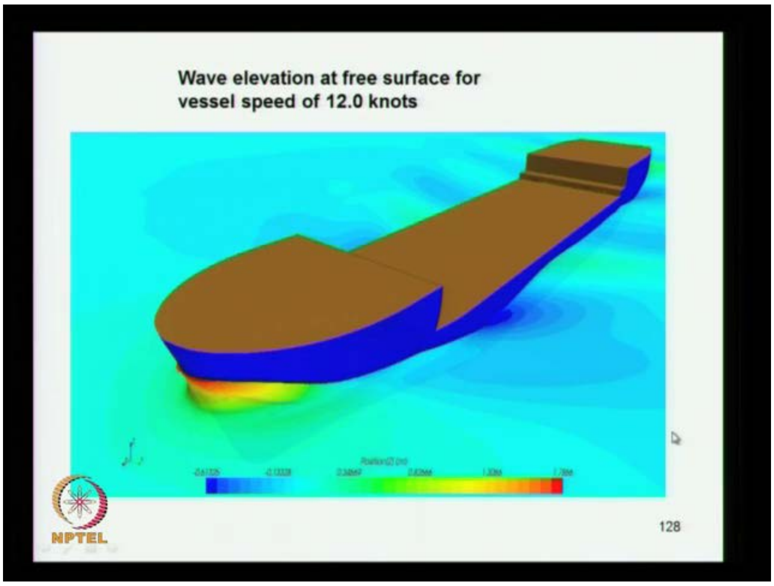

Here, you can see that wave valuation a free surface for a vessels speed of you can say it is the survey speed is 12 knots in this case see the wave valuation here. You can see the wave is coming to we looked the scales is coming to 1.7, you can see it is a draft of 3.6 metre the bow wave is going up to 1.7 metres above the water level. You can see here the wave size is there and here is a deep excreta forming here, you can say this scale is low extra formed here.

So, generally this shows as that this region is having a high wave which increase are resistance of the ship. So, if you read is say in the form reduce the shoulder you may be you provide a bulbous bow, this is a vessel without a bulb avoid a bulbous bow and obviously it is going to reduce the wave size and reduce the resistance of the ship. So, the safety analysis through light on to this aspect, so what would be the reason information about the wave formation or you input the flow pattern the velocity around the flow.

The body which increase the friction resistance and all that, so that is this helps in doing that, so this is actually meant for a dual project which obviously the Schlichtings the design stage. So, there is a scope for correction for the form as I said before inclusion of bulb properly designed is going to dink down the bow way and also a proper a fine tuning of a form here the shoulder also reduced the wave size.

The resistance is expected to come down, you can see that the model also shows that you say is sub one without bulb. You can say it is a raked step, there is no bulb here. So, provision of the bulb obviously will have a positive influence and the resistance of the vessel. So, I think with that we conclude this lecture, and we will continue in the next class.