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

Lecture - 17
Resistance of Advanced Marine vehicles - III

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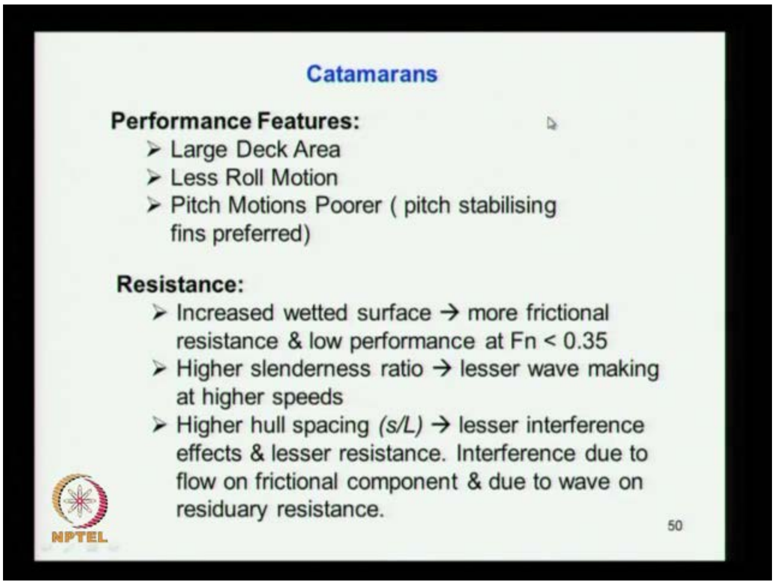

Now, we are continuing with the resistance of same advanced marine vehicles and next a degree of that is a Catamaran. Catamaran is you know it is a well known having two handles the same displacement is being placed into being supported by two herbs and advantage of that performance, which is you can see that a large deck area. A vessel which needs a large deck area in this option less roll motion, because of these two herbs kept apart and pitch motions poorer, so pitching is the power with the Catamarans.

So, generally you need a pitch stabilizing fins for Catamarans, if you need a more stable clarification when it comes to resistance for Catamarans, you know that increased wetted surface because more with the same displacement is now split into two halts. Naturally, the vessel surface is going to be more weather surface and the frictional resistance will be more. Hence, it has been estimated or evaluated that its having a low performance from resistance point when the fluid number is less than point 3.5.

So, from the resistance point it is going to be bad if it operates the fluid number less and may primarily contributed by higher wetted surface and higher frictional resistance. Then it is the same length if you consider this going to be slender and even it is a high slenderness ratio that is breadth or length and breadth of the hull is going to be higher compared to mono phone. Hence, most slender and less wave making resistance at higher speeds, so that is an advantage, so the fluid number is high, then you says 0.35.

So, then major contribution to the total resistance is coming from wave making and now you have two hulls with center in shape formed and which produces less wave making resistance. It will have an advantage if you opt Catamarans higher hall spacing that is the distance the two hulls s by L.

Then, less interference is the hulls when they are moving, when they are side by side, two hulls are moving, these hulls generate waves or there is a flow across the or along the hull. This flow may interfere if the two hulls are close by and if these two hulls are sufficiently apart, interference effect will be reduced. So, that is the importance for having the space area higher s by L ratio lesser will be the interference effect.

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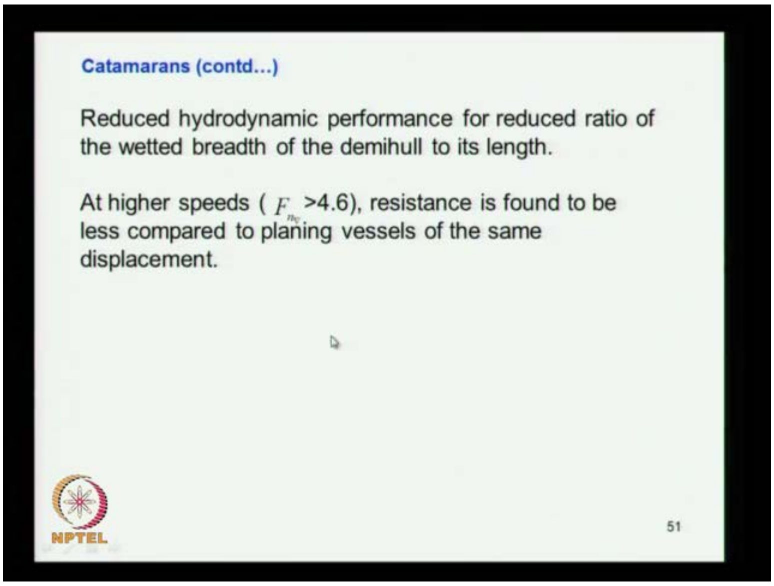

The reduced hydrodynamic performance for reduced ratio is of the wetted breadth of the demy hull to its length. So, it is related to wetted breadth that is underwater maximum breadth to its length, so the hydrodynamic performance should be reduced for this ratio is plus at higher speeds that is volume fluid number.

If it is greater than 4.6, the resistance is found to be less compared to the planning vessels of the displacement type of the same displacement planning vessels. So, if you can consider the planning vessels in the Catamarans. If you consider the Catamarans operates at this fluid number range high speed Catamarans found to be half resistance is found to be less compared to the planning vessel which operates at that.

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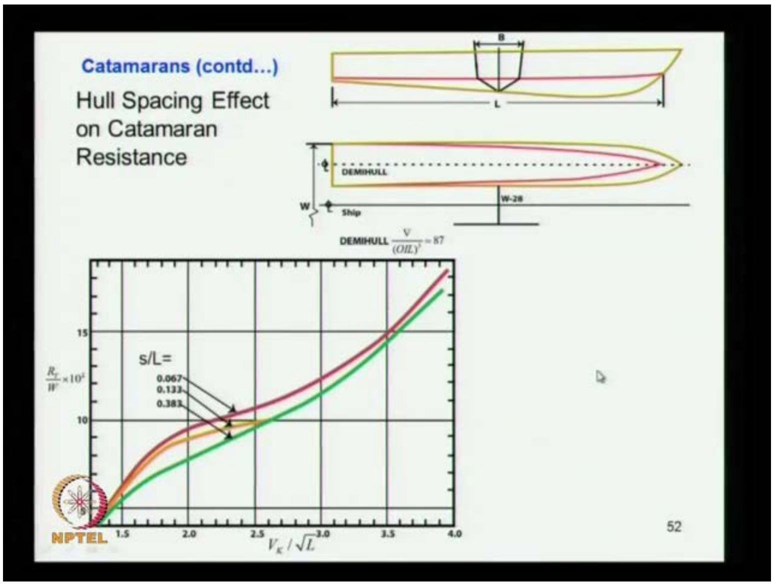

So, if you properly design and place it, then the resistance will be not greater in even Catamarans, you can see that these are resistance, you can see R T by W. It is displacement into 10 square that is what is total area and you can see this is for different s by L spacing, there is decimal spacing. So, if the spacing is less, interference effect will be more and resistance will be more if the spacing is more between the hulls interference effect will be less.

Naturally, you see the red line here resistance is less, so that shows the effect of the spacing of the dummy hulls in catamaran on the total resistance of the vessel. So, these are same thing you can see it is a different things different forms, which reflects the effect of spacing on the total resistance.

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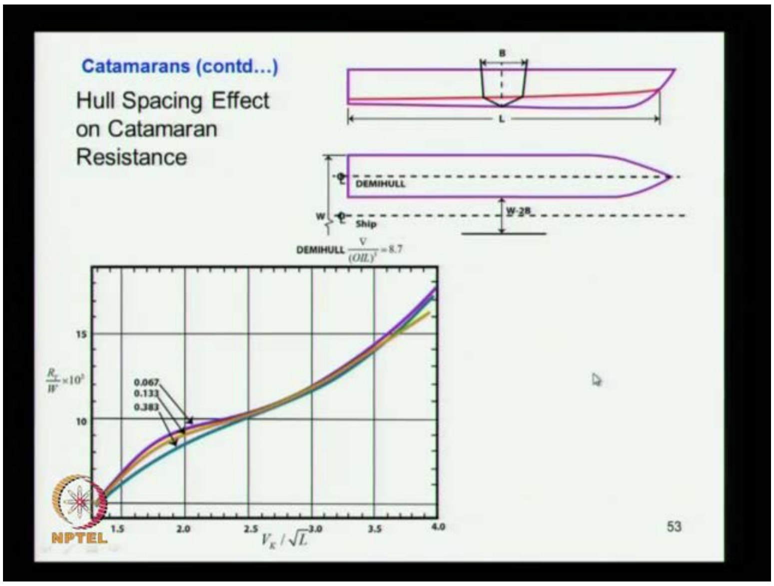

Now, we consider round bilge catamaran series.

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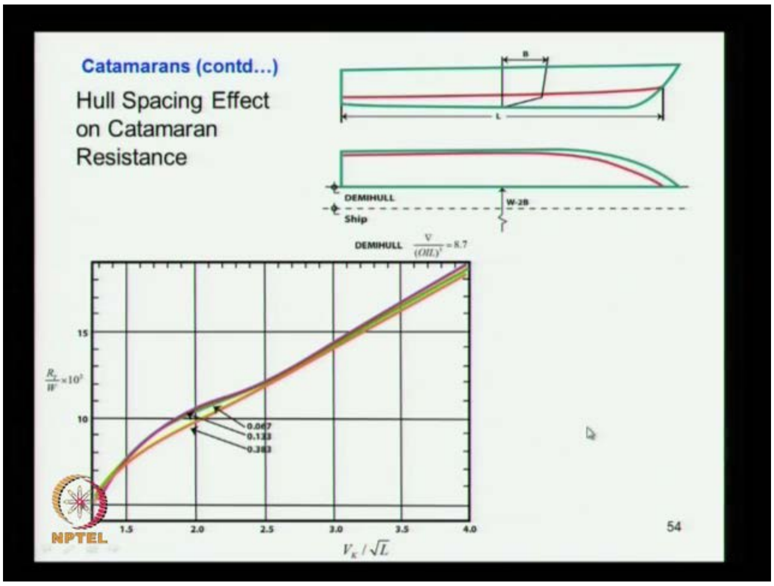

This is a high speed semi displacement catamaran hull forms.

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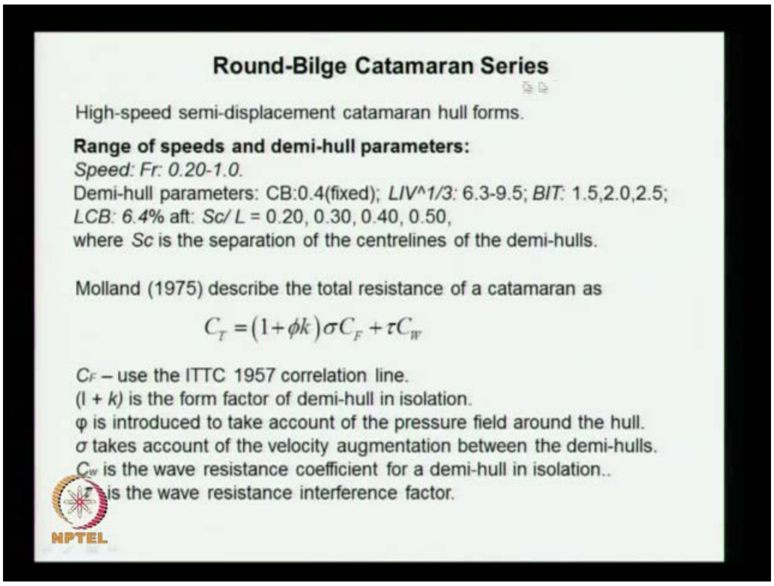

We have already discussed the semi displacement thing, now instead of mono hulls it is in the catamaran two hulls range of speed and demy hull parameters speed of fluid number 0.2 to 1 considered demy hull parameters. That is CB block coefficient 0.4 length to volume by this or length volume ratio or displacement ratio is given by this one B by breadth draft ratio given by this LCB 6.4 percent draft of the mid ship. Then the spacing you can see demy hull this range, so these are parameters which are considered here in this series where s is the separation of the centerlines of the demy hulls.

So, this is demy hull spacing, so Molland based on this studies is or this Catamarans he has put total resistance co efficient is equal to 1 plus 5 k into sigma into C F plus tow into C W. So, here you can see say normally what do you see is a conventionally for mono hulls, you put C T is equal to 1 plus k into C F plus C W or C. Here, you are putting some extra parameters tow sigma phi what does it means, so these are the interference effects phi what is the interference on the form factor sigma.

What is the interference effect on frictional resistance tow, what is the interference on the wave making resistance due to the two hulls these are the additional. You know the variations appearing here when compared with that of the mono hulls C F, you can use ITTC formula and plus k L is already set form factor of demy hull in isolation. So, demy hull alone what is the form factor, then pi is introduced to take account of the pressure field around the hull that is basically what the interference effect then sigma takes account velocity argumentation between the demy hulls.

When you see there are two hulls moving, there is constriction brought between the two hulls that is the width result constriction to the flow. That means flow velocity increases, so that is the well said velocity argumentation and the flow passes through between the two hulls the velocity increases due to the constriction of the flow region. C W is the wave resistance coefficient for the demy hull in isolation the C W, you know you consider the demy hull as a independent, what is the wave making resistance coefficient C W tow is the wave resistance interference.

The wave created by one hull interference of the wave created by another hull, so these waves may build up and it builds up naturally resistance of the vessel increases. So, this tow is a factor interference factor which takes into account the interference effect due to the wave making.

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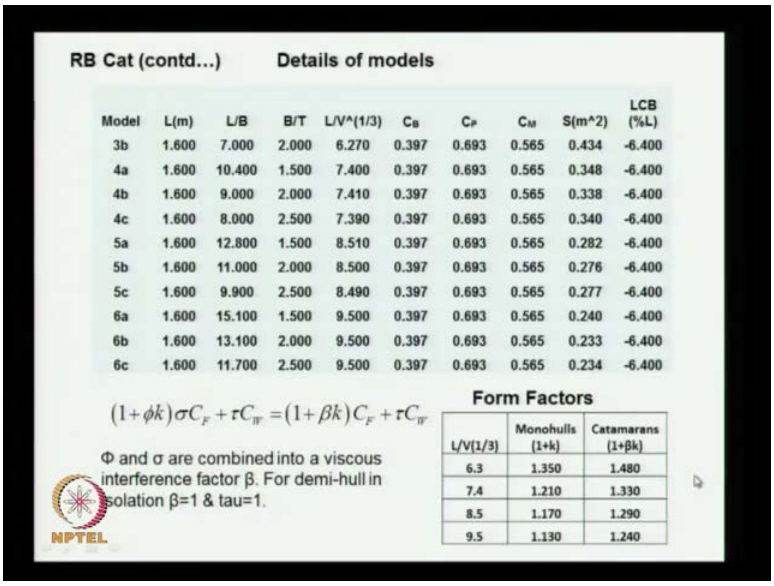

So, round bilge Catamarans same what we have discussed details of models, what they have considered, these are the different models, model parameters are given here all the form coefficients given here. Then weather surface area LCB position everything shown here, so this is you know parameters of the models they consider, so here you can see this expression what you have seen ct this is the expression for C T. It is you know rare written in this form 1 plus beta k into C F that is you just expands this, you will get this C F plus tow into C W.

So, phi and sigma this phi and sigma are comparing to give beta that interference phi beta and for demy hull in isolation beta is equal to 1 and tow is equal to 1. If you consider mono hull beta is equal to 1 and tow is equal to 1 that is the form. Now, these two takes care of the interference effect, you can see the mono hull the form factor 1 plus k and plus k for mono hull.

This is for different length to volume you can see this is form factor 1.35, 1.2, the corresponding catamaran if you consider see this is going to higher 1.48. Here, it is 1.35, here it is 1.48 that is 1.21, 1.33, so this shows that the resistance of frictional resistance or viscous resistance has gone out due the interference effect between the demy hulls same for the same vessel.

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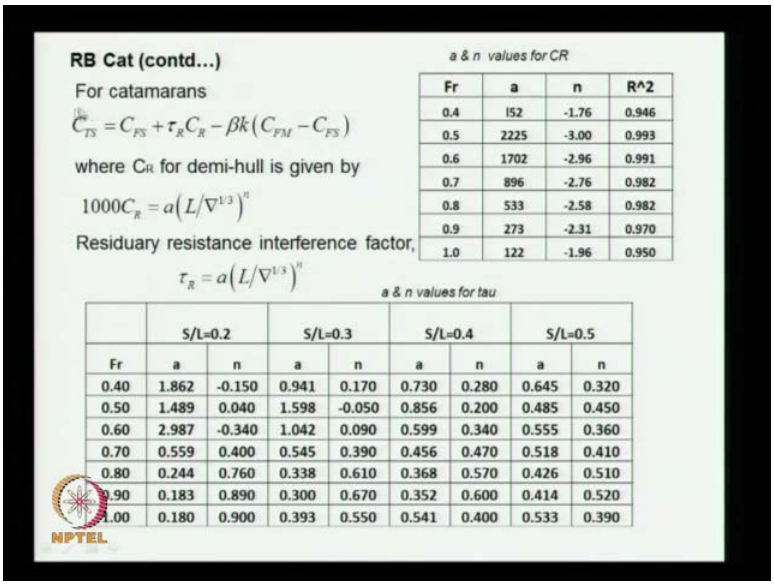

RB Cat (contd...)

For catamarans

$$C_{TS} = C_{FS} + \tau_R C_R - \beta k\left(C_{FM} - C_{FS}\right)$$

where C_R for demi-hull is given by

$$1000C_R = a\left(L/\nabla^{1/3}\right)^n$$

Residuary resistance interference factor,

$$\tau_R = a\left(L/\nabla^{1/3}\right)^n$$

a & n values for CR

Fr	a	n	R^2
0.4	152	-1.76	0.946
0.5	2225	-3.00	0.993
0.6	1702	-2.96	0.991
0.7	896	-2.76	0.982
0.8	533	-2.58	0.982
0.9	273	-2.31	0.970
1.0	122	-1.96	0.950

a & n values for tau

	S/L=0.2		S/L=0.3		S/L=0.4		S/L=0.5	
Fr	a	n	a	n	a	n	a	n
0.40	1.862	-0.150	0.941	0.170	0.730	0.280	0.645	0.320
0.50	1.489	0.040	1.598	-0.050	0.856	0.200	0.485	0.450
0.60	2.987	-0.340	1.042	0.090	0.599	0.340	0.555	0.360
0.70	0.559	0.400	0.545	0.390	0.456	0.470	0.518	0.410
0.80	0.244	0.760	0.338	0.610	0.368	0.570	0.426	0.510
0.90	0.183	0.890	0.300	0.670	0.352	0.600	0.414	0.520
1.00	0.180	0.900	0.393	0.550	0.541	0.400	0.533	0.390

Now, you see C T S, that is how the ship is equal to C F frictional resistance coefficient of the ship plus tow r that is you see that into C R minus beta 8 k into C F from minus c of x. This difference is taken; actually you are reducing this because the frictional resistance coefficient of model and frictional resistance coefficient of ship are different. You have to take the difference when you predict it from model two ships, so where C R is for a demy hull and this is given by this. So, C R is given by this expression, you can see that C R is equal to a into l by you know this quantities length of the Catamaran is known, displacement is known.

So, you know a, and the n are you can obtain from here a and n on different fluid number are given here. So, what do you do is you want to you can find out C R using this expression and from using this table. So, C R is obtained here, you need tow of tow R is given that is the residuary resistance interference effect tow R is given by this expression for which it is given for different demy hull spacing to the length. If you choose 1, you get a and 10 a and n are obtained from corresponding fluid number, so for change of fluid number you will get tow r this tow r you put and C R.

You have you get this quantity here C F of I mean has come from ITTC formula, so you know we can find out all these quantities and then C T S. So, you know it is clear the catamaran total resistance is obtained using this relation where the frictional resistance coefficient of model and ship of the proto type are obtained using ITTC formula using the corresponding Reynolds number.

Here, you consider the residual resistance coefficient is given for demy hull here and interference factor is coming from here. So, you get everything, so you can find out what is C T S another form is next type of vessel is swath, swath represents small water plane area twin hull vessels, swath is a small water plane area twin hull vessels.

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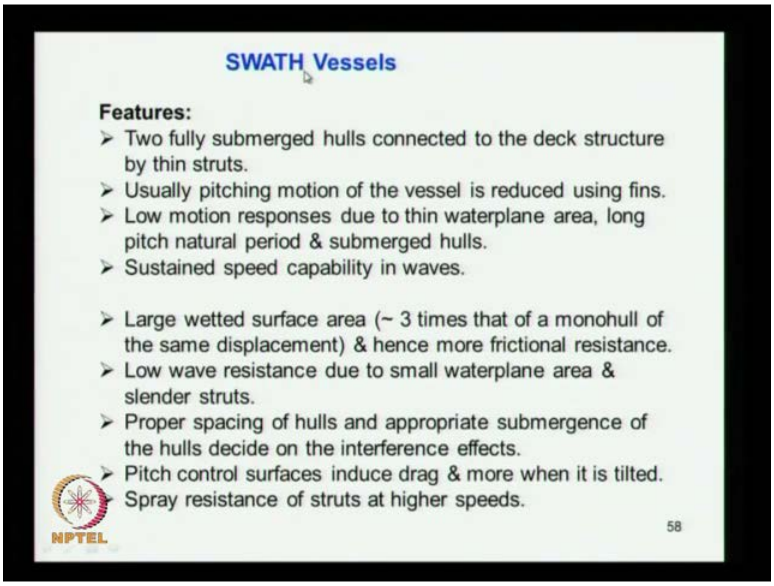

So, here the features of swath I think you understand what the swath, so I am not going give a definition sketch view of that. So, here the swath vessel the features two fully submerged hulls connected to the deck may be I will there is a diagram.

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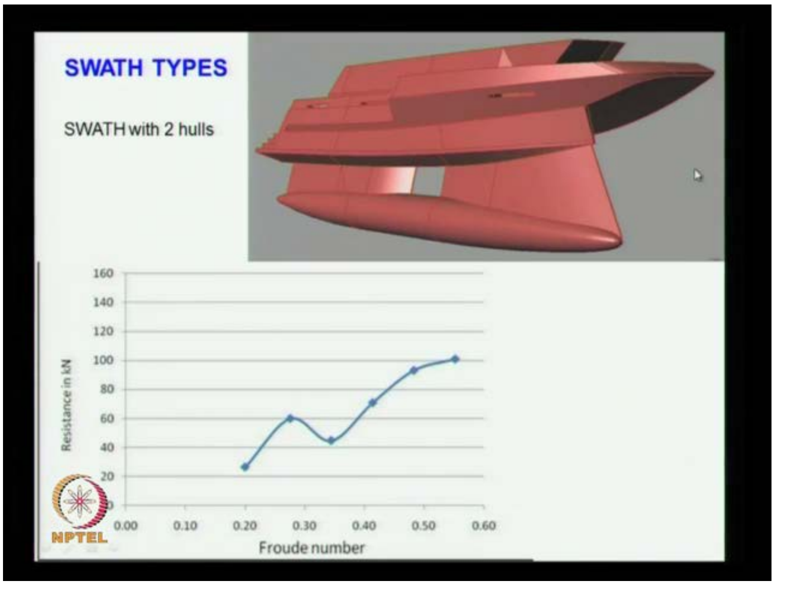

You can show here what the swath is, you can see this is the swath, it is a small is a cylindrical hull the water line may be somewhere here when it floats may be somewhere here. These two are the struts, this is a strut and this is the strut, then it is connected to the main hull, this is the deck area. So, this is the configuration of this is one hull, so similarly you have other one on this side this is the one hull and other side. So, here water plane the strut is water plane is that this position water plane going to be thin whether small water plane area twin hull.

You have one hull here, one hull on other side twin hull ship that is called the swath, so this swath stands for that small water plane area twin hull vessels. So, what you have is two fully submerged hull, you have seen that two hulls submerged which gives the point support to the decks structure. They are connected through thin struts are you know thin line shaped where cylinder usually pitching motion of the vessel is reduced using fins. Pitching motion will be reduced using fins low motion responses due to thin water plane area because the water plane area is thin you see that the motion is less.

It gives a very good stable platform for may be for research activities and all that such vessels which collects samples from sea bed and all that they need a stable plat form. So, this type of vessel helps a lot in that respect then long pitch natural period and submerged hulls, so pitch natural produce a long. So, naturally pitch motion in actual sea may be less, and then sustained speed capability in waves because the motions are less the speed can be maintained the actual for the mono hull shape.

The problem is the other types of ships or including Catamaran the motions are high that means the additional resistance due the motions become more, but in this case the motion is less. Hence, the additional resistance will be less and hence the vessel the swath vessel can retain its speed even in drowsy condition. Also, larger vessel surface area you have two cylindrical hulls the weather surface is going to be raised nearly 3 times a mono hull of the same displacement, so the surface area is huge hence more frictional resistance.

So, naturally you get more frictional resistance, low wave making resistance because the studs are at the water surface which is thinner, very fine. Wave making become less because of this slender struts proper spacing of hulls and appropriate submergence of the hulls decide on the interference effects. If you submerge the hulls sufficiently and they are kept apart sufficiently then you have less interference effects pitch control surfaces induce drag.

We are providing control surfaces to reduce pitch action, then naturally you have learnt pitch resistance due to that spray resistance of struts at higher it moves at a higher speed. There will be spray generated from the struts which add to marginally to the resistance of the vessel, so here you can see this types of a mono strut.

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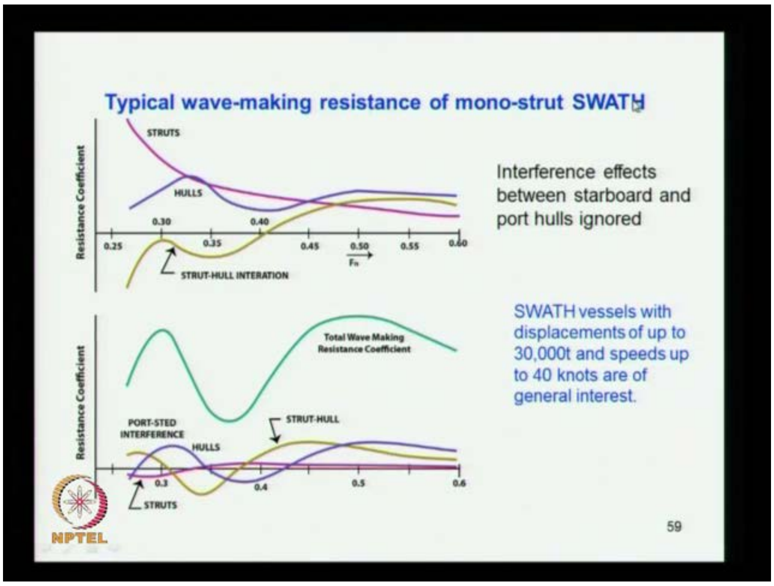

Swath is instead of two struts what you have seen here you have few using two struts, so mono strut means this is a joint together to have single strut. So, that is the mono strut, so you consider a vessel with a mono strut, then you can see the resistance given here resistance co efficient of the swath given separately. This is of the hull separately and then the difference affects separately, so from which you will get the total resistance of the vessel for different fluid number.

You can see that different fluid number, so you just add up you get the resistance this is just given for a typical presentation of it, then resistance coefficients for the vessel with displacement of the 30,000 tons and speed of 40 knots. This is another type, where the variations are given total wave making resistance strut hull interaction affect. Then the hull alone core starboard, it is starboard interference, so this are the different you know components given there.

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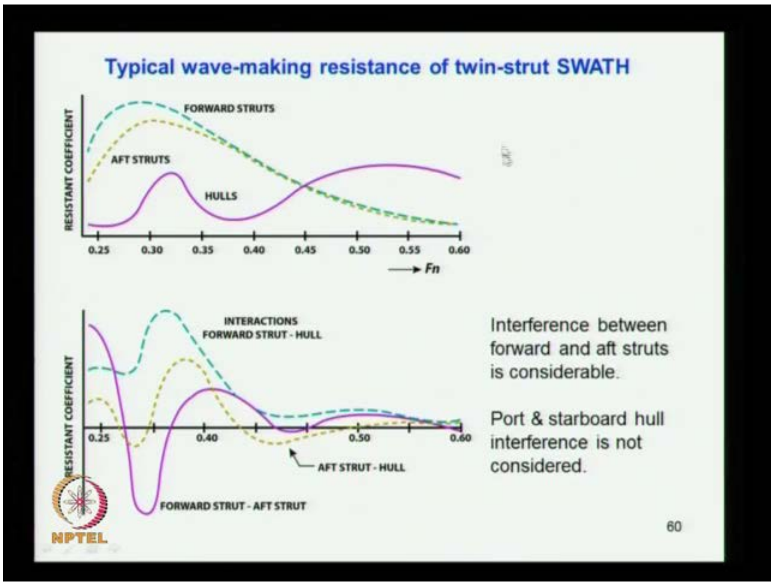

Similarly, instead of mono, you are now using what same as what you have seen, so this is a variation you can see the variation of the resistance co efficient forwards that twin struts. So, you have forwards and half strut, so you can see forward at a half strut what is the resistance radiation and of the hulls. We just sum it up you get the total resistance and here the same thing you can see that interference effects what is shown here interactions between strut and hull.

The forward strut and hull interaction between half strut and hull then forward strut and half strut interaction, so here you get the interaction effects. So, these interaction effects plus the independent affect that give the total resistance procedure resistance, so there is a wave making resistance if you look you can see that this is a tandem strut prediction.

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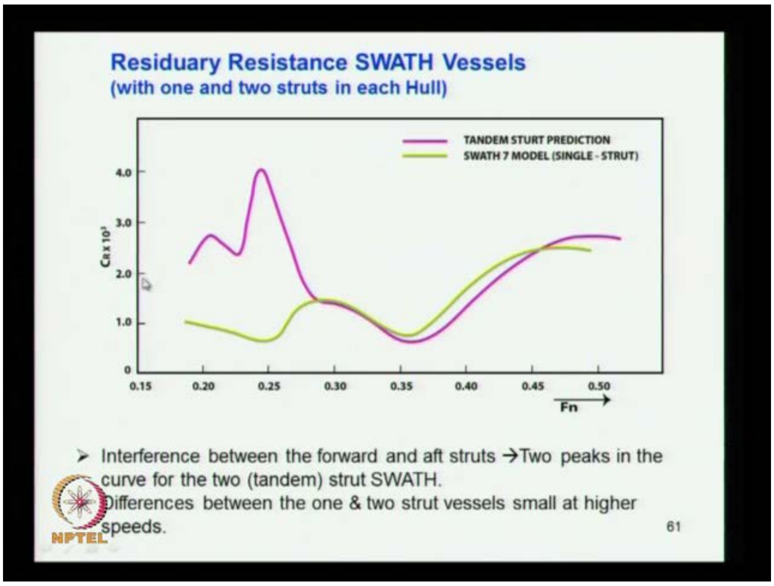

You can see interference between the forward and half struts two piece forward you can see that two piece one piece here, another piece here in the curve for two hull struts and difference between one and two struts vessels small at high speeds. So, here this is a single strut vessel and this is a twin strut vessel and here twin strut you have such a variation two pix. So, if the variation is high at low speed, but here it is less, this is a single strut, but when it comes to at high speed high fluid number, they remain more or less same defect is more or less same strut hull influence is less.

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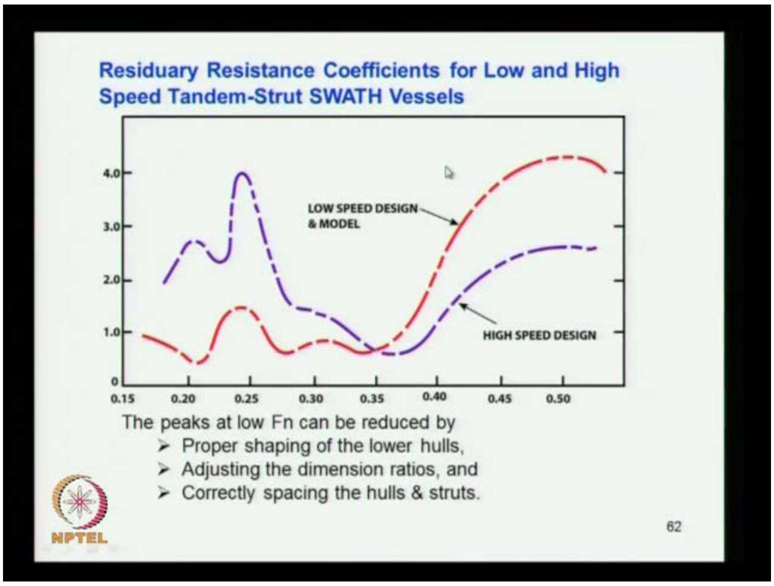

So, this is for a residuary resistance co efficient for low and high speed tandem struts swath vessels that are two struts are used. You can see the low speed design model it is a there is a particular type which it is this is for low speed and this is a particular one which is designed for the high speed. You can see that the high speed designed the resistance becomes low at high speed, whereas this is distance for low speed that is what low speed resistance is less. If you take the same vessel at high speed resistance increases, you find that this is a low speed design, the design itself is different.

So, at low speed resistance is good fine it is designed for low speed, but if you operate the high speed resistance increases where as if you design a vessel with the high speed design at low speed resistance will be high, but at high speed resistance becomes less. So, these are some of the known type of vessels which we have analyzed by using CFD, also we did some experiments you can see that resistance against the fluid. So, this is one of the configurations, we did sort with two hulls in two struts basically two struts and also two hulls.

This is one hull and other side you have two hulls, one hull and actually four struts one and other side you have two, I mean total four struts. You can see that you have a hump here and then it goes up same as what you seen before you can see it is a two humps, a hump here and also before one you can see that two struts, one hump here another hump.

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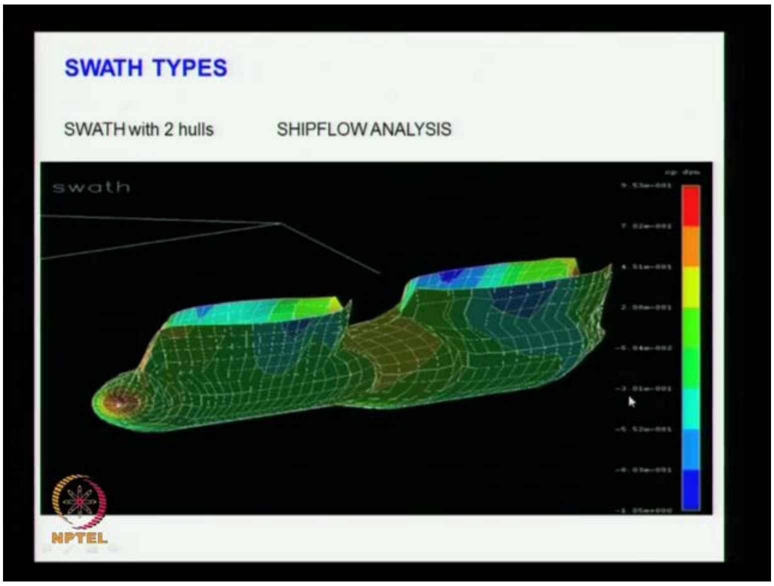

So, that is the characteristic of the resistance curve for the swath vessel, this is an analysis which has been carried out using ship flow.

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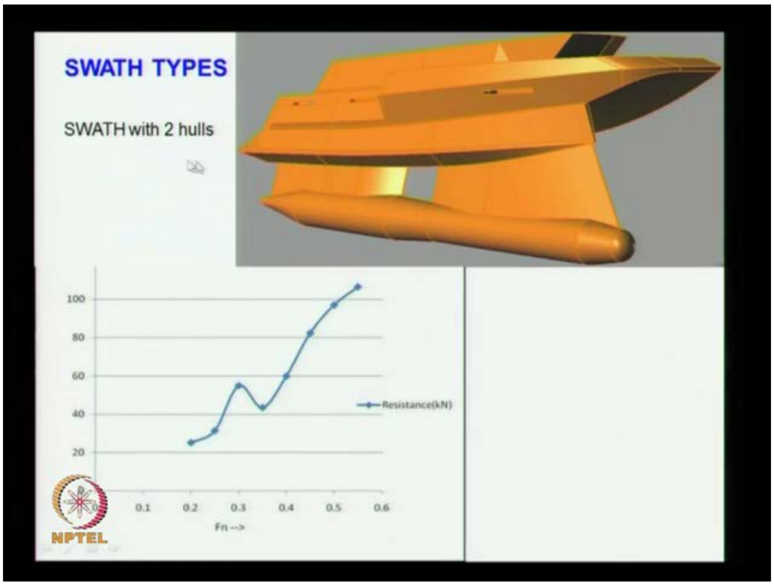

Same thing analysis of which ship flow, now another type what we consider here is another hull form you can see the hull form is different compared to the previous one. You can see here this, so this is the form where as in this case this is the form we get you can see that and what is known, resistance due to that so successively.

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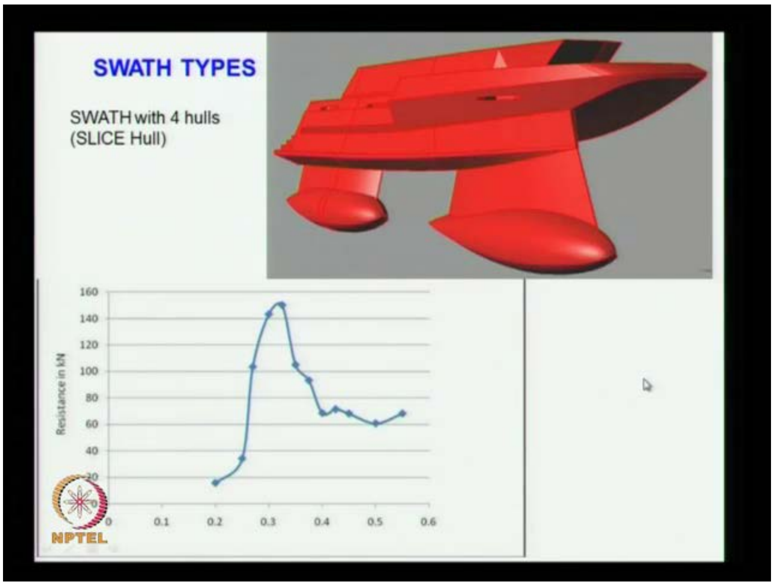

We consider the another one called four hulls, one here, two hulls here and another two hulls are this side four hulls is again the swath, you can see the variation of the resistance like it speaks up some point.

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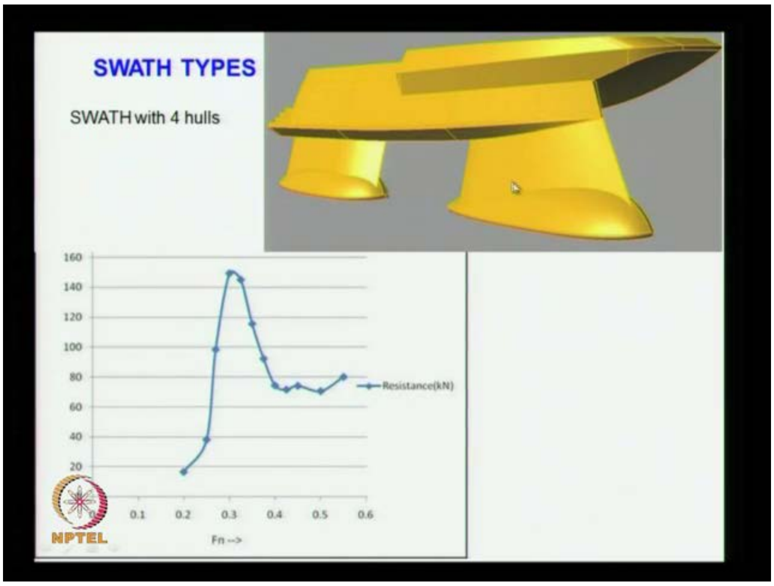

Then, it reduces and similarly, for another type the form is different same four hulls, so you get this is another, so this are the studies which have been carried out by us say F D studies and so experimental some configurations. So, this is the all about the resistance part of swath vessels, swath vessels you know the configuration

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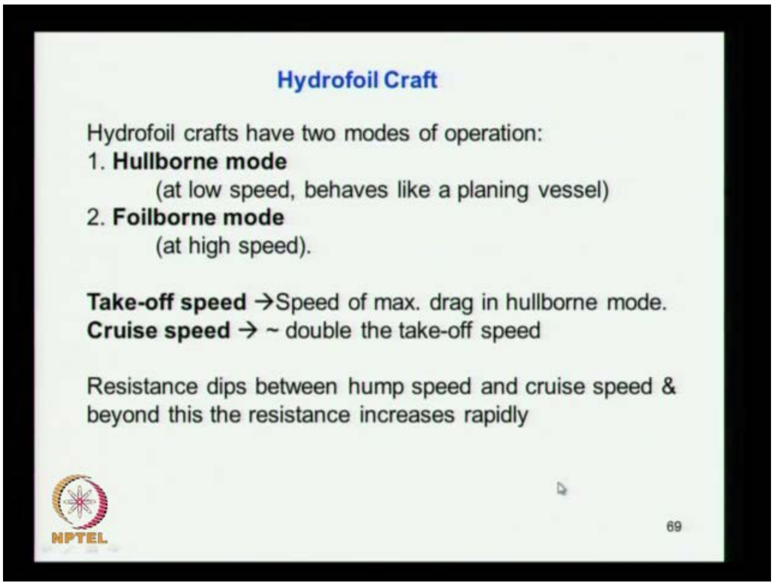

Now, you have an idea about the resistance and you know that low speed frictional resistance is going to be high because for the same displacement compared to a mono hull, a swath will have 3 times the better surface area where it is a huge one. It has got lot of advantages, more deck area more stable platform and thin struts produces less wave making resistance and which can come at higher speed and even in wave condition. The speed can be maintained next part type of vessel is a hydrofoil craft hydrofoil craft, you know this work, basically which one there are foils hydro foils which are submerged are below the vessel.

These hydrofoils moves at the speed, generate the lift and push the vessel up even above the water and thus the resistance water it become foil bond condition and resistance is reduced drastically. For the same power, the vessel can operate at a much higher speed, so that is the advantage of hydrofoil craft, so here it has good two operating modes, one is hull borne that is in the displacement mode and other one is foil borne fully supported by the foil.

The whole vessel is pushed up, so it take up speed is main border speed of maximum drag in hull borne mode, so when it moves on the displacement the hull borne mode the resistance increases with the speed and reaches a maximum. At that speed, the foils will be more active, foil will push it up when the foils push the vessel up, naturally the contact with water is reduced and resistance comes down and speed increase.

So, that is called the cruise speed, so there is a one maximum point that is which is the threshold speed and cruise hold speed is normally double. That resistance dips between hump speed and cruise speed that is reaches a maximum and then it drops and then it picks up.

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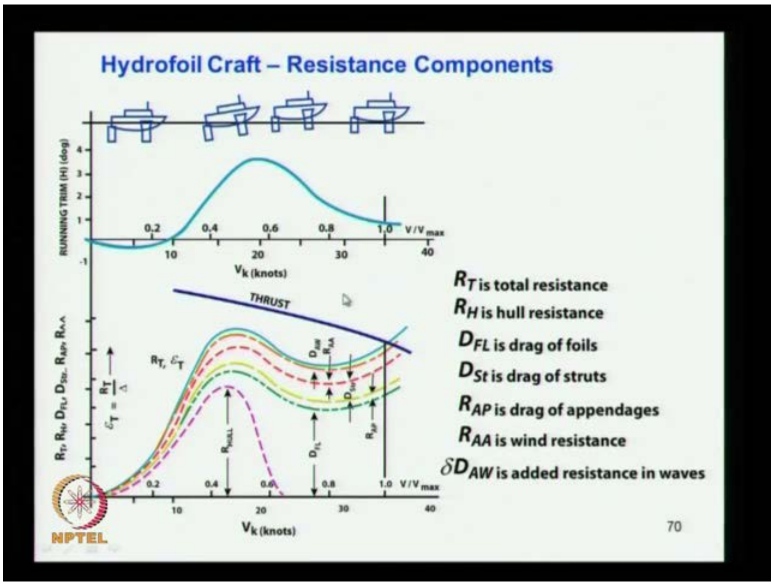

You can see here the resistance gives this is the maximum threshold point, then you see at higher speed resistance is coming down. The resistance is coming down at higher speed, then after speed, it picks up because of the high velocity. Here, you can see the trim of the vessel, the hydrofoil, you can see this is a hydro foil which comes, so this is the foil here, these foils will generate lift, this is a horizontal direction foil or may be V shape, which will generate lift and push the vessel up.

While it is moving, you can see with reference to the speed the trim of the vessel initial speed, it is almost parallel, no trim when it gives start to picking up. The trim increases at the threshold, you can see the maximum just before you know take of it reaches high trim and after takeoff, the trim reduces and in fully bulk bound condition.

It becomes event, so the trim reduces, so this is the variation of trim with reference to speed. Here, you can see the resistance various components are given total resistance is given by this blue line, and then you have hull resistance that is the foil like, and then strut drag. So, there are different all components are given here and final this is the total resistance of that you can see the total resistance increases, deeply reaches the maximum and this is the takeoff. From here, it will take off, then that means hull moves up, then resistance comes down and then due to the higher speed and high wave making it increases like this.

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So, the foil should have good lift dragged ratio when you design the foil you should have good lift, component craft must be able to operate in a stable and controlled manner lifting surface forward and draft are required for longitudinal stability. The lifting at forward, you need to have a two pairs, one is the forward draft, otherwise there will be imbalance. So, otherwise the trimming will be excess, so you can adjust the flag or the foil to adjust the lift and then the trim of the vessel a tandem arrangement.

The load is almost even between these foils, so you have to have a balancing between the foils in an airplane or conventional configuration. More load is carried by the bow foil, the bow foil usually carries more, we will see that arrangement in the canard configuration.

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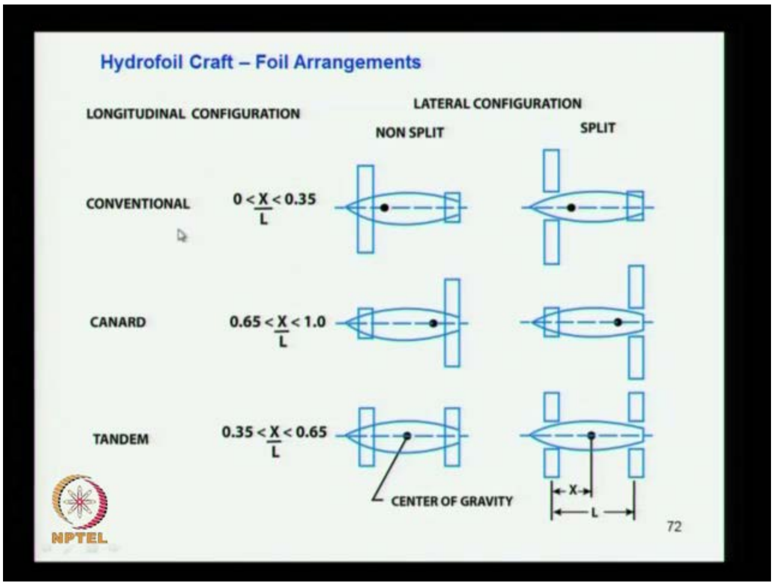

You can see that configuration here, this is a conventional, you can see that the foil arrangement this is a forward foil this is a aft foil and this is a non split type because this integral. This is split type you can see two spoils are given and this is called these are conventional arrangement, this is not called canard arrangement, you have here is a small one. Here, is a big one and here its integral one, here it is a split one and this is a tandem one, here almost we have both almost same and here both are split.

So, these are the type of you know foils, these foils are under water and you have if you take a section. Here, it is going to be a aerofoil or height of foil shape, so that means it gives a lift in the plane normal to this the vertical direction, so that is what is saying in the canard configuration the second configuration it is aft foil may take more load. So, here canard configuration this will take more loads because it is big here, whereas in this configuration, this will take more loads. Here, the more load is taken by the foil, the fore or aft lifting surfaces may be split type or reactive type or retroactive type in shallow water.

So, you can see that it may be integral or it may be a split type, so this are the configurations normally adopted for the foil arrangements of a hydro foil craft, so hydrofoil craft this is a surface piercing SP means surface piercing foils.

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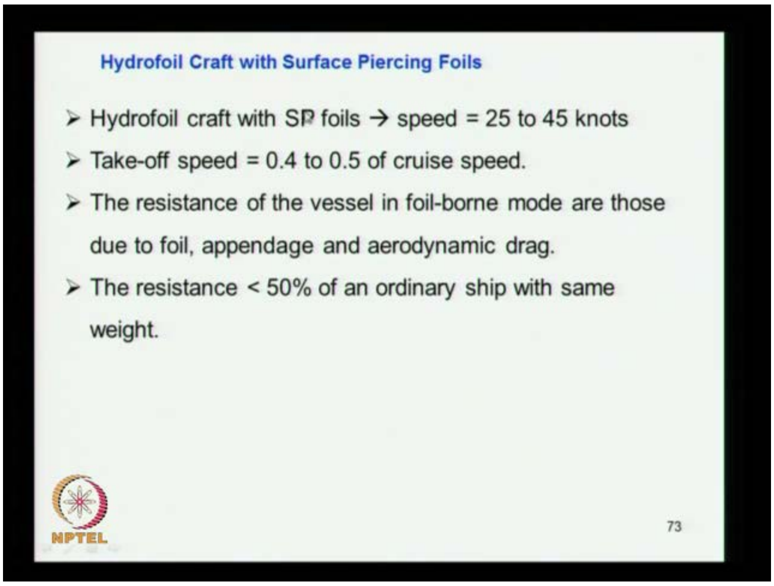

The speed achievable is about 25 to 45 knots 45 knots is a 85 speed takeoff speed comes about 0.4 to 0.5 times of this speed. The resistance of the vessel in foil borne mode are those due to foil and its foil bound condition, the ship is above water the resistance is above water. So, the resistance is coming from foil appendages pretend all that and also above water portion, you get the error dynamic track resistance less than 50 percent of an ordinary ship with the same weight. So, resistance you can find that its 50 percent less than 50 percent or ordinary.

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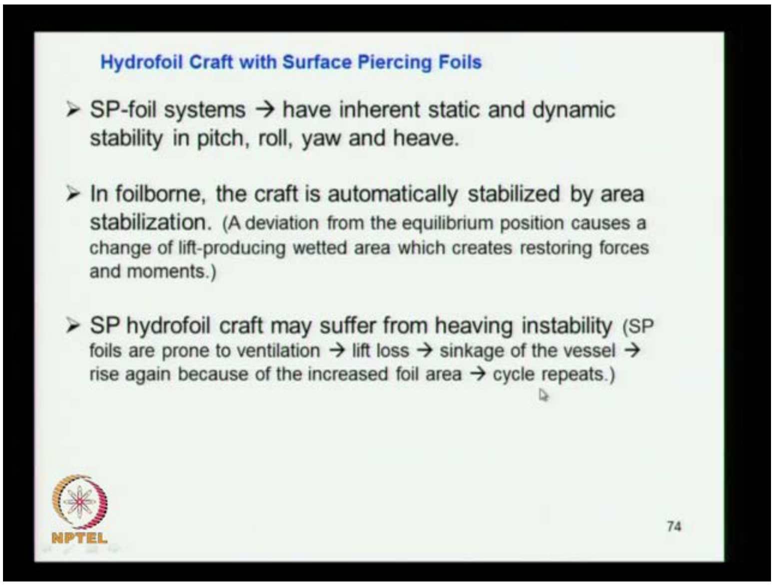

Surface piercing foils system have inherent static and dynamic stability, so they are stable all the hydro dynamic features of that have been inclined to one side. Automatically, the side which goes down will get more lift it will push it back it get generate some moment. So, its inherent automatic stabilization, so it will have in pitch role yaw and heave in foil borne, the craft is automatically stabilized by area stabilization.

That is what I said, then a deviation from the equilibrium position, this is what I said where if suppose the foil is that, if it will work inclined to one side, the foil on the inclined side, lower side will be more submerged. More sub mergence leads to more lift force that lift force generate a moment to put it back, so surface piercing hydrofoil craft may suffer from heaving instability that is another problem related to this.

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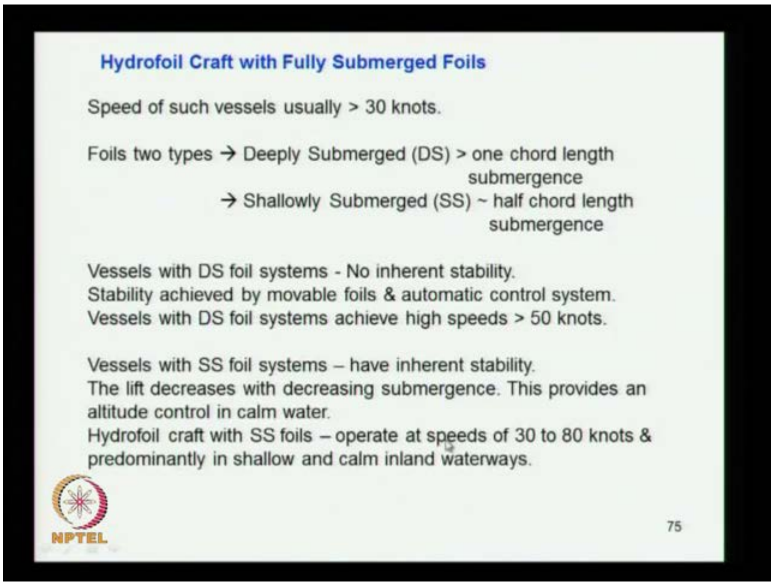

So, our concern where looking more into resistance and speed parts speed of the such vessels usually 30 nodes, we have seen that foils are two types deeply submerged that is deeply submerged. The foil is one chord length submergence shallowly submerged is the half chord length submergence vessels is deeply submerged foils system, no inherent stability because there is no variation, when it heals, stability achieved by movable foils and automatic control system, you have to have the moving you know fins which can be controlled using control system. You know to stabilize the platform, stabilize the vessel;

hydro foil craft with shallow fully submerged operates at speed of 30 to 80 knots, predominantly in shallow and calm inland waterways.

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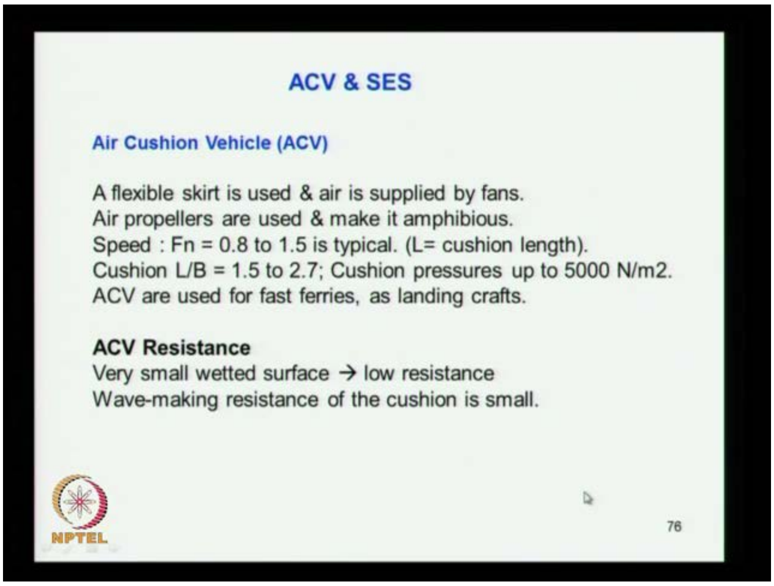

So, that is the about hydro foils, so there is no specific you know data available as such in the literature to show that what is the how you estimate that, but depends on purely on the design of the hydro craft foils. You have to look into the details and then only you will able to estimate the resistance of hydrofoil curves. Other category we are looking into air cushion vehicles and surface of the ship, both come under the almost the same class same way of operation air cushion vehicles means it is typical. The old craft which produces an aerostatic pressure between the hull and water surface, this aerostatic pressure that is created using heavy duty fans put vertically.

These aerostatic pressures push the hull up because of high pressure the hull of the vessel will be taken out of water pushed up. Now, the vessel has not got any contact with water and hence the resistance reduces and it attains higher speed and since is hull is not in contact with water propels are not used, but air propels are used in aircrafts. So, this is the air cushion vehicle we creating a cushion of air at high pressure, which pushes the vessel above the water and which will leads to reduce the resistance.

So, here the round the vessel we have a skirt, flexible skirt is used and air is supplied by fans that is what is said. So, you have a skirt, you need to have a chamber to generate pressure, so around the vessel you have a thick rubber skirt and that will gives a chamber air chamber and inside pressure are create pressure instead the chamber which push the vessel up. So, air propels are used as I said before water propels are not possible because it operates, it is coming above water and this makes amphibious. It can work even on land, it comes to the beaches and you know it can move through beaches and also move through water.

So, we say its amphibious speed is fluid number 0.8 to 1.5 typical where it is a cushion length cushion L by B, this is a L by B ratio of that cushion pressure is 5,000 Newton per meter square. Air cushion vehicles are used for fast ferries and also landing crafts because landing crafts mean it can land to the beach. So, it has been used by you know US and other for Iraq war, they have used the air craft which came from sea into the beach.

So, they have vehicles or equipments on both which can be taken directly to the land, you know you do not need a port or anything for that. It just comes to the beach and unload it air cushion vehicle resistance, very small weather surface area because it is pushed up load resistance wave making resistance of the cushion also small because it is only a body not in contact air. So, that is wave making resistance, also small surface affect of the ship the difference is surface affect ship is having a two hulls like a catamaran.

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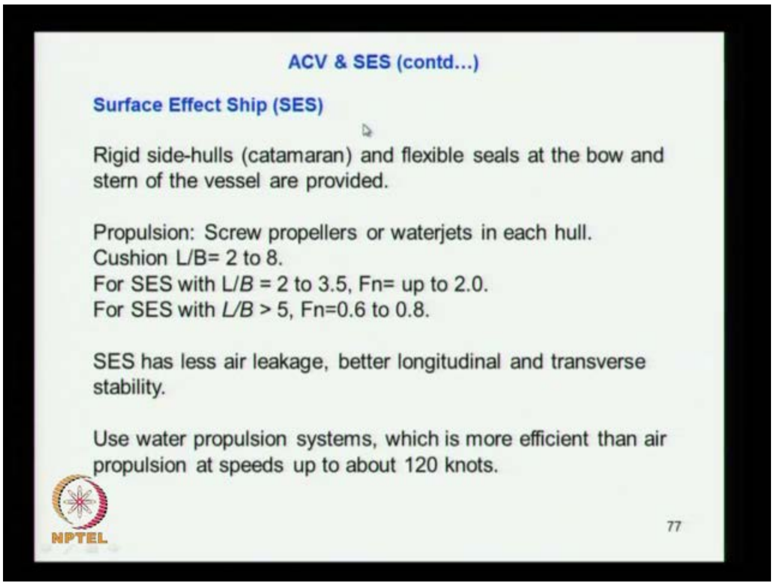

So, the only the ends are open, so what you do is you put you know screens or skirts at the ends, so it get a champ the sides are rigid hull and the end open ends, it is often forward are covered with rubber skirts where you get a chamber. Then you generate pressure inside and then it moves forward with a reduced resistance and high speed, so that is the surface affect of the ship. So, here it is says rigid side hulls catamaran and flexible seals at the bow and stem of the vessel are provided. So, you get a chamber pulls chamber propulsion you can use water jet or may be normal screw propels.

There is a cushion L by B, you can say 2 to 8 and L by B for C S with L by B is the fluid number goes up to 2 this is a range C S has less air leak because it is a rigid hull. So, air leak is less, so you have better efficiency in the creation of aerostatic pressure inside better longitudinal and transverse stability. So, because of the hulls, you have the transverse stability, it is a catamaran transverse stability is much better. So, use water propulsion system which is more efficient then air propulsion which speeds up to 120 knots surface of x ship going to 120 that is nearly 230, 2,200 and 30 kilometers per hour, I can see the vehicle moving.

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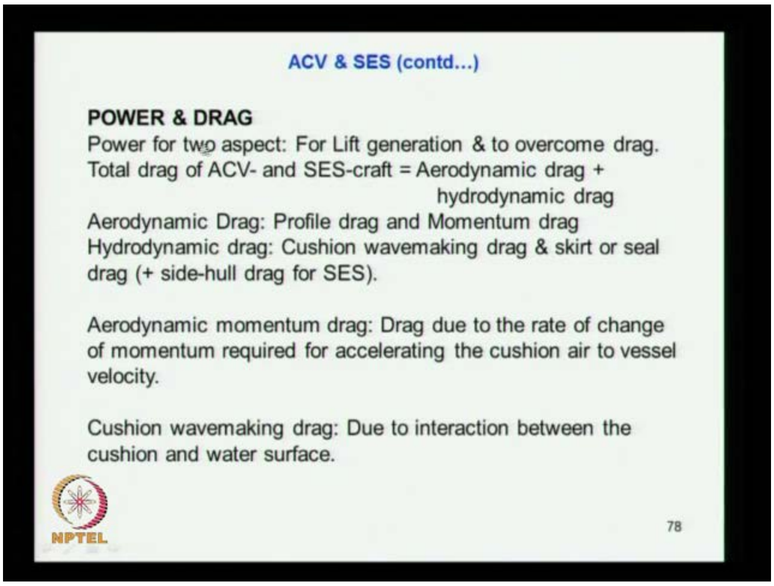

Water vehicle, marine vehicle how ran drag of this type of vehicles, power of two aspects for lift generation to overcome it need, power one for lift generation that is to generate the pressure inside for lifting that. Other one is to overcome the forward motion the draft to attain the speed, so total draft of equation vehicles and surface of a craft you have the aero dynamic craft because moving rise speed. This air bond plus side two dynamic craft you have both aero dynamic drag, you have the profile drag because of the shape and momentum drag because the air cushion also is moving.

There is momentum change when its speed changes, so there is momentum drag, so hydrodynamic drag, you have cushion wave making when the cushion is moving the cushion. The air cushion mix with it is a drag due to that the skirt which it touches the water also makes a drag or C in this C S. Then plus side hull drag of this, so you have small component coming from here another component is coming from here so here what is says aerodynamic momentum drag is explained here, drag due to the rate of change of momentum required for accelerating the cushion of air to the vehicle velocity.

So, these are the components of resistance one is the air resistance or air drag other one is a water resistance or hydro dynamic drag air drag got two components that is a profile drag due to the profile and shape and due to the air flow. Other one is due to the air cushion moment; it is a momentum drag where as hydro dynamic drag got wave making drag due to cushion.

Then wave making coming from skirt wave making, and also frictional resistance coming from the skirt or seal drag plus… In case of see the side hulls the catamaran that also contributes to that. So, cushion wave making drag due to interaction between the cushion and water surface you consider there is a high pressure chamber which is moving forward. So, that means this cushion when it moves forward generates waves, but not much, so that contributes to the wave making component of the ship, so you can see here a cushion vehicles and the surface of the ship.

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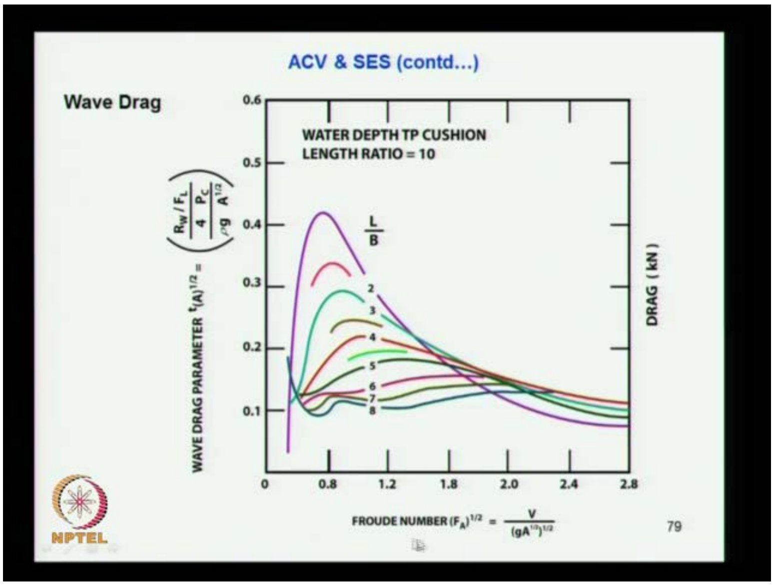

You see is the fluid number, fluid number is given by B by G a square root of A and square root of the whole thing where A is I think it is a cushion area. Let me check that A is the cushion area, so your fluid number is based on the square root of cushion area.

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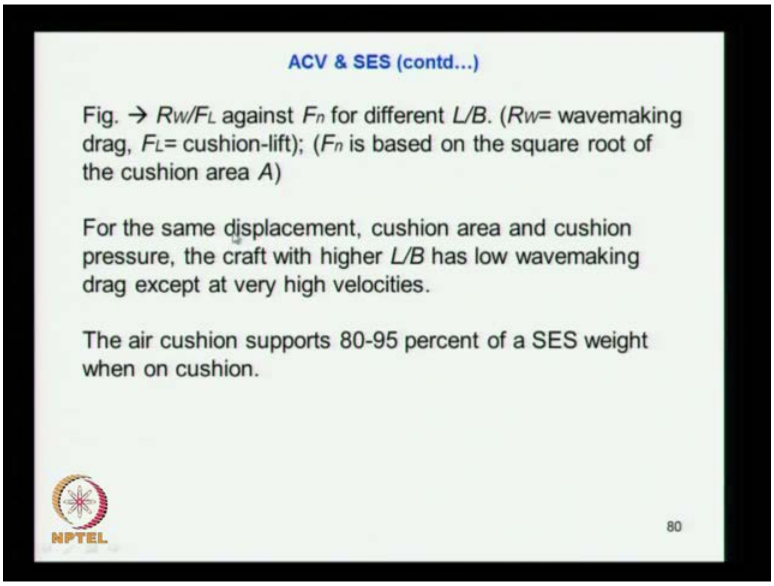

So, A is the cushion area that is you know the length of the cushion and breadth, so you get the cushion area from there, then here is the wave drag parameter given by this expression R W by F L, what do you see R W and L N. You can see R W well against the R W is the wave making resistance F L is the cushion lift, so this is the ratio of that, so if you get this ratio over here and it is done for different L by B. That is cushion length to breadth ratio, so you can see that this is the very low length and this is the high length. You can see that variation of this with respect L by B what the resistance is, you can or wave track parameter here, so for the same displacement cushion area and cushion pressure. If you consider same displacement same cushion area and same cushion pressure the craft with higher L by B has low wave making resistance. It is like if you consider that the craft with higher L by B, L by B is high here, 8, the wave making effect is less, wave making drag is less, so that is what do you prefer that help in the same.

So, accept that very high velocity the air cushion supports 80 to 95 percent of a weight, so only how much 5 to 20 percent support coming from the skirt. The side you know hull almost 80 to 95 percent of the weight is supported by air cushion, air cushion vehicle skirt drag.

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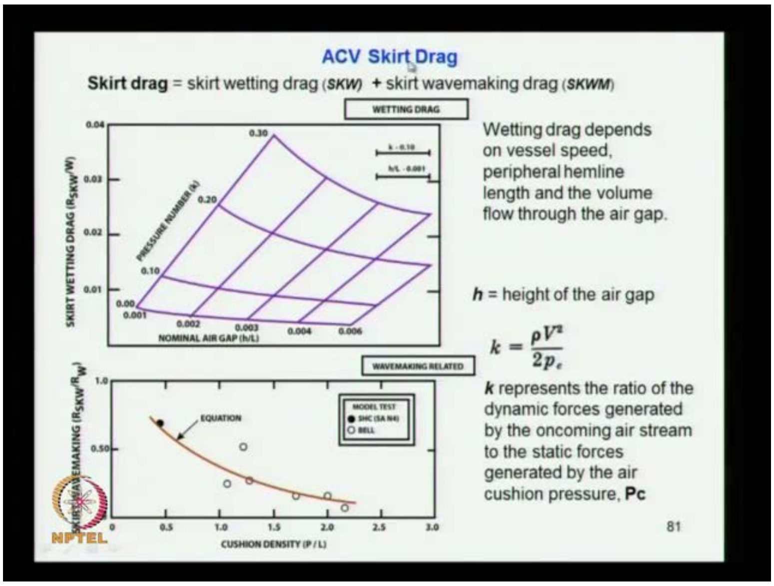

You can see the skirt, so I am not going to the details that can see the figure here this is a skirt weighting drag what is given here and this is skirt wave making drag. You can find from this this parameters values, here it is plotted against P by L P by L is I think pressure by length H by L, H is the air gap that is the chamber height divided by length of the cushion.

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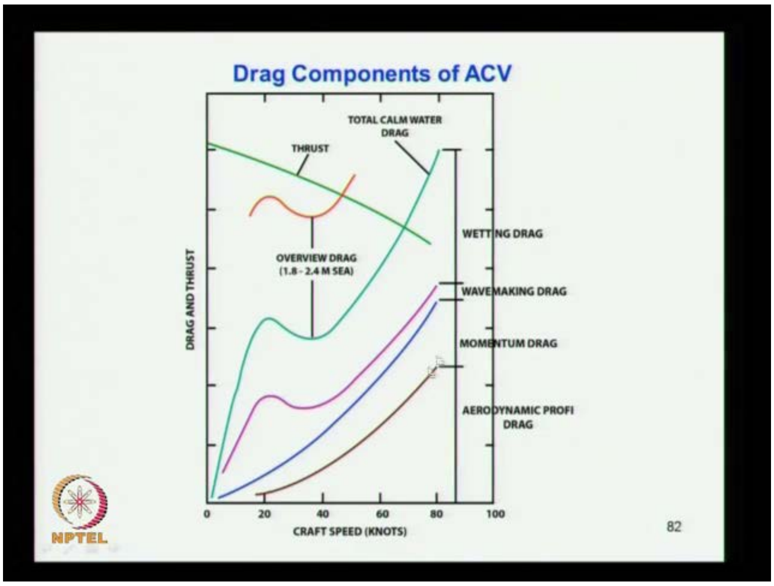

Drag components of the air cushion vehicle, you can see that drag component this is aero dynamic profiled drag. This is the momentum drag, then this is a wave making drag and this is a weighting drag that is the friction. So, the total thing you put you get the total drag and you know the thrust is the self propulsion point.

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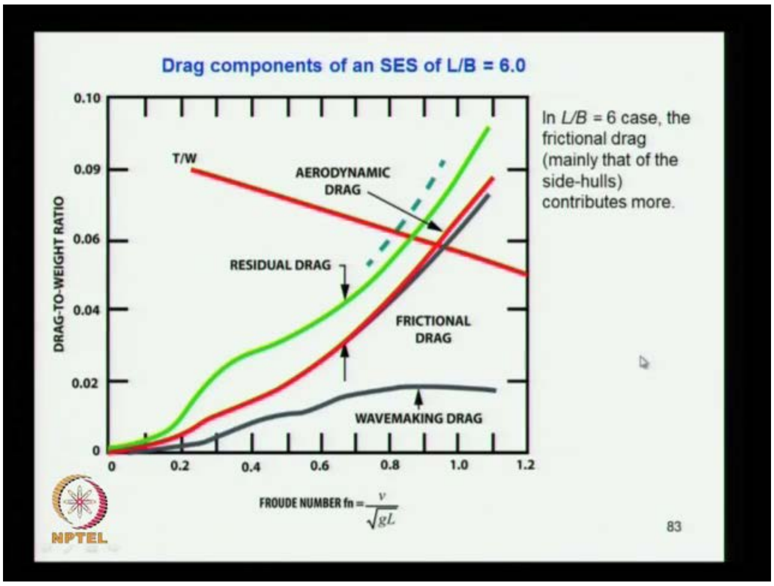

So, the resistance and thrust match here for the components, you can surface of the ship which follows L by B is equal to 6, you can see the fluid number and here its drag to weight ratio R by W, you can see that what is the wave making drag is very less, you can see the speed fluid number is very high, but see the wave making is less friction is more. May be you know even friction also here you can, then see that aero dynamic drag coming here, you adding up, this is a residuary total drag and a difference between total drag and the frictional drag.

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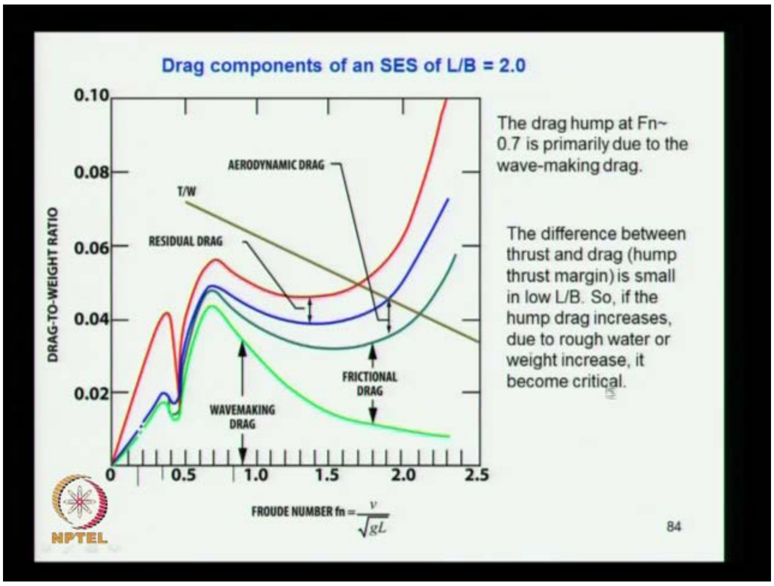

You can see this is a characteristic variation of different components wave making how its varying friction and then you have the residual drag then hydro dynamic drag. So, all put together you get the resultant one. That red line here that is the total drag to weight ratio for the surface effect of the ship having length to breadth of air cushion is equal to 2.

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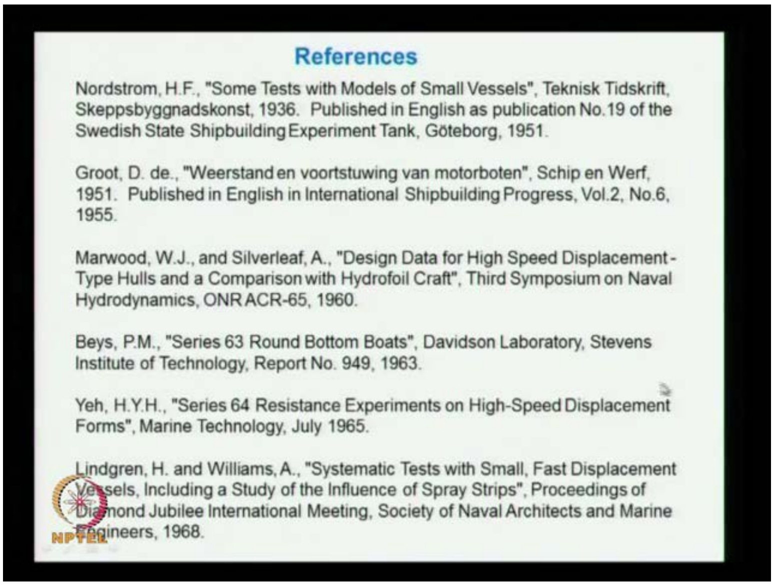

With that I think we have this is all different reference moves.

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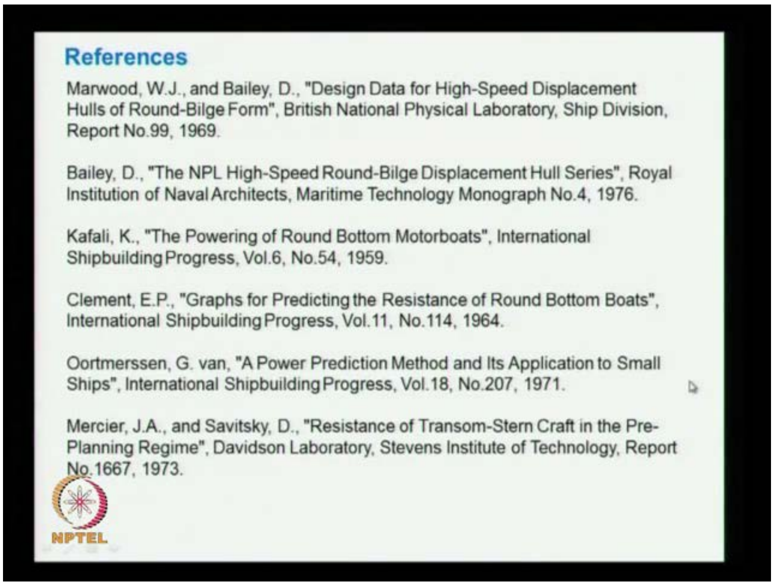

You have seen, you can see the list of references here.

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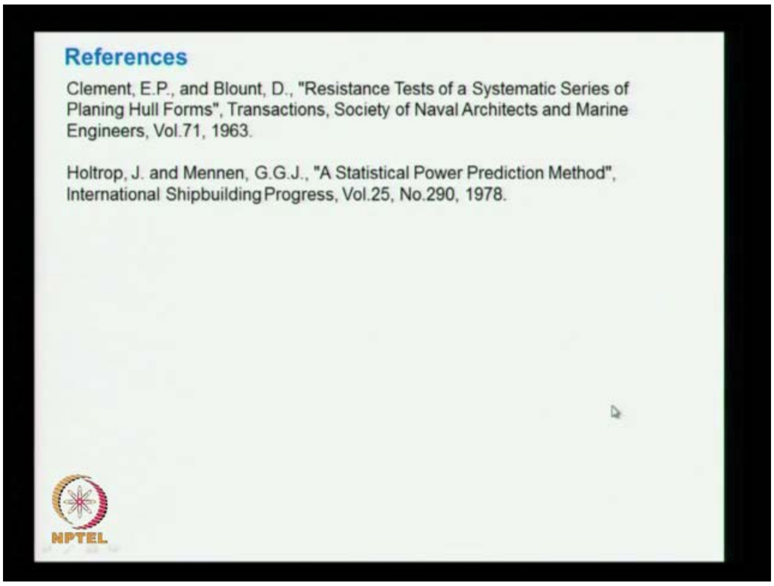

With that we conclude the all the resistance part of the course, so what you have seen if you recall you start from the beginning, you can see that we started with the basic principles of resistance components of resistance physics of the components. How to estimate the various components, what is the model test, how the proto type resistance is predicted from the model test, what are the extra plus ship methods of a double and how you know the similar it is from model to proto type are handled.

That is we had problem with the kinematical, similarity because it is not satisfying the Reynolds number between ship and model, how to tackle that where you use the frictional resistance co efficient. It is similar expression and uses the Reynolds number for the respective case of the model length proto type. You apply the corrections for these variations, and then you predict the total resistance of the accounting for roughness corrections sea wave corrections. That is the motion aspect, all these you find out the total resistance of that, then we moved on to the standard, you know series and prediction methods put forward by different research groups for different types of results.

Here, we consider normal conventional ship is mono hulls and displacement type and where we could you know find we can find out the resistance from the expression or regression expression or C D starts of various research groups. Here, one need to know the applicable to range of this and accordingly you can find out the resistance components and total resistance. Subsequently, you can find out the power requirement if you have an understanding about propels efficient and all that, so once you get the powering estimate power of the vessel.

Then, you will after considering all you know loss of transmission losses and duration allowance and all that you can arrive at the engine power which will go as and input into the design of the ship for. Once you know the engine the weight of the engine is clearer, now then performance of the engine is more, then you may have to design a propeller based on the engine. That is optimum from the engine point, then you get the total weight and everything which will add to the fine tuning of the ship design.

Subsequently, also we have seen other aspects regarding the advanced marine vehicles advanced marine vehicles, we have seen the different types including planning crafts multi hull vessels like catamarans swath shapes. Then hyper foreman vehicles like air cushion vehicles hydro foil crafts surface of the ship and all that, so with this available information, all these portions have been covered under this course and resistance part of it. The next part what you will be having is a propulsion of that, so which you will see various aspects of propulsion everything which will be covered later, with that I conclude the course.

Thank you.