Performance of Marine Vehicles At Sea

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Lecture No. # 12

Introduction to High Speed Crafts Part - I

Good morning, gentlemen. Today, we will be talking on high speed craft. Basically, this will be an introduction to various types of high speed craft. Sometimes these crafts are referred as advanced marine craft, why is it called advanced? Because the technologies used in this crafts are more advanced than the conventional technologies used in ships also, the hydrodynamic behavior of this crafts is quite different from the hydrodynamic behavior of conventional floating vessels- this has lead to advances in equipment and materials with regard to their applications to such force.

In this lecture, which will be primarily be an introduction to high speed marine craft, we will very broadly review the hydrodynamic behavior of various types of hybrid, high speed crafts. And I will make this presentation through power point projections.

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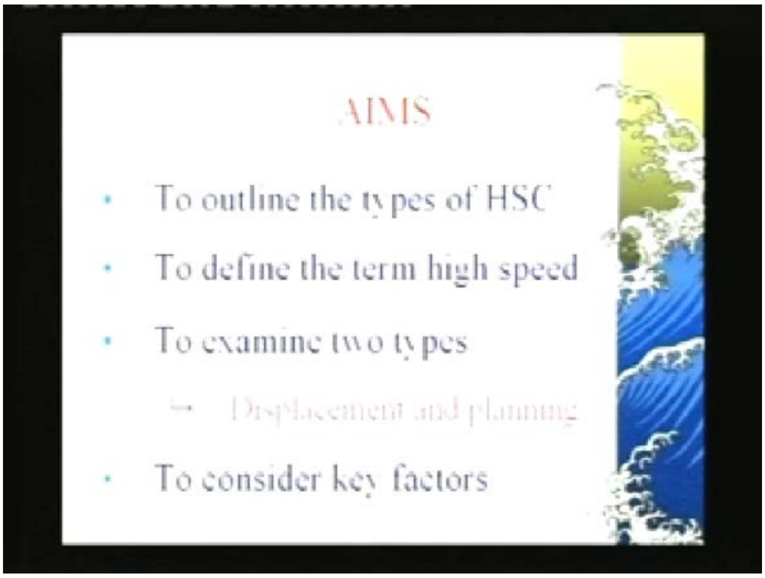

So, as I said this is an introduction only and I will be covering the following topics: we will outline the various types of hybrid craft high speed craft that are in existence in the world; we will also try to define what is understood by high speed craft; we will examine two types of craft, that is, displacement craft and planning craft; and we will also examine the key factors.

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Coming to types of high speed craft, let me first show you what are the all high speed aft and I will explain one by one.

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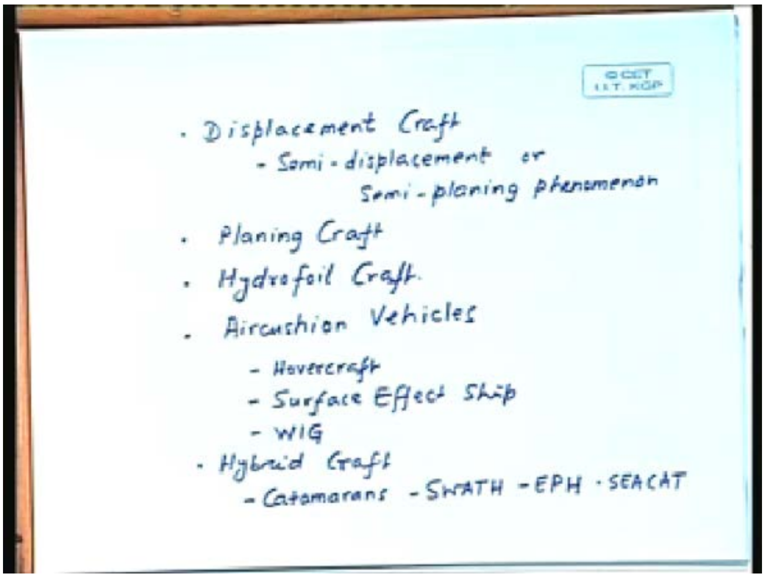

The various types of high speed craft that are there would start from the conventional vessels which are termed as displacement crafts. Can you see this? What does a displacement craft mean? It means that the vessel is supported entirely by its own displacement. What does it have to be support, what does it have to support? The weight; the weight is supported entirely by the volume of the displacement, which is the buoyant force that is, the volume of displacement into rho into g that will give you the total buoyant force that should be equal to weight- that is what is called as a displacement craft. As the speed increases a displacement craft cannot move beyond a certain speed, we will later see why it is so.

And if a craft has to move at a speed higher than this sort of limiting speed for displacement craft, then it must necessarily be supported by a upward force due to flow of water underneath the body, or a lift force. So, if there is a upward lift force, then the weight is supported by this lift force plus remaining part due to buoyancy- so, how will this happen? The vessel will lift itself from the still water condition, or the volume of displacement, the volume of water displaced will reduce, so the buoyancy you will get will be volume of water displaced into rho into g plus the lift force generated due to hydrodynamic action, which will be equal to weight.

So, the balance of vertical forces will be attained due to generation of lift force which will reduce the buoyancy force, or lift up vessel from its still water condition, so, in this, this phenomenon is called planing phenomenon- the vessel will start planing. So, this does not happen at one stroke, it is a slow process- when the displacement, volume of displacement slowly reduce vessel will slowly rise and then ultimately a stage will come when most of the weight is being supported by lift.

Generally, when about half the lift, half the weight supported by lift is called a fully planing boat; half the weight, or slightly less than half the boat way- sorry- slightly more than half the weight is supported by dynamic lift, this condition is called fully planing condition. So, between this completely displacement mode and fully planing condition we have a range of speed in which the vessels plains somewhat and it is supported somewhat by buoyancy, that is called the semi displacement or semi planing phenomena.

You can design a vessel for the semi planing condition and also for fully planing condition; if we design for fully planing condition, then this is called a planing craft. And the lift generated is so high that it would more or less equal weight then, the vessel would literally come out of water- you might have seen very fast boats going skimming the water, just skimming the water then, the buoyancy component is very small. But then a stage may come when the lift will be so high that there will be no need for buoyancy and the vessel will come out of water- so, you might have seen vessels going like this, hopping on waters; as soon as it lifts out of water there is no lift because there is no hydrodynamic boat, so it must come down again and then, again, lift takes over and it hops when we increase the speed very high- so, those are planing craft.

Then, you have hydrofoil craft that is, instead of the vessel bottom itself generating the lift force due to flow past it you can have an appendage coming down from bottom of the ship, which houses hydrofoils that is, foils having cross section of those of hydrofoils, and if the angle of attack is small, then these hydrofoils will generate a vertical force, which will be lift; the hydrofoil is moving like this, if there is a foil like this and is moving straight, then there will be a lift force generated perpendicular to it, which will be vertically upwards.

So, if the vessel is there and I have some sort of a strut appendage coming down from the vessel and I have a foil here, then the lift generated by the foil will be upward force, will lift the vessel out of water, the lift can be to an extent that it can entirely lift the vessel out of water; in this case, there is no question of hopping because the foil is in water- do you understand? So, in this, what happens? The vessel comes completely out of water with the foils being in water, this is the, this is what is called a hydrofoil craft. Then, you have...

Resistance will reduced there?

Drastically reduced; we will see the resistance in a short while. Let us first... Aircushion vehicles. That is, if I can generate this upward force by giving a force downwards, then by reaction the vessel will lift itself. So, what we do is we provide slightly higher pressure air into a chamber which is below the boat, if I provide slightly higher pressure air, the vessel will lift, that air will support a part of the weight, so, the vessel will lift; and it can lift to an extent, by controlling the amount of air, we can control the lift, how much it has to lift; and this lift can occur at zero speed, with no speed if I press something down, then the vessel will lift, if I press air down the vessel, vessel will lift by simply air pressure acting upwards.

And I can also put down an amount of air to an extent that vessel will completely clear the ground, clear the water, if I can do that, then the vessel is no more in water, but it is above water, if that is possible, then the vessel can also move over land- so, this is the principle of aircushion vehicle where I can have a cushion of air below so that the vessel can get the upward thrust due to air pressure and it can lift itself from the water surface and it can completely lift itself out of water surface also and it can move on land. So, these are basically, this can be designed to be amphibious in nature that is, move on land as well as air, how can we do this? The air has to be contained in a chamber so that it can give the pressure; if I just press air and let it go everywhere, then maybe I cannot utilize this air pressure if it is open.

So, there are two types of aircushion vehicles: one is the hovercraft where you have a skirt around in the bottom of the vehicle, which is enclosed, which is inflatable, which is made of inflatable material, and it can be, it can be injected with air when inflation takes place and the vessel can rise itself due to the inflation of the this thing, it just provides a lift, static lift, it has not lifted from the ground if it was in water this will provide the so called buoyancy chamber- and in normal condition the buoyancy given by this will be equal to weight of the vessel. Now, I enclose this chamber, this skirt that I have is all around in a rectangular fashion, inside there is an empty chamber, I push pressurized air in this chamber, if I pressure, push pressurized in this chamber, then the vehicle will now lift- do you understand?- and of course, the air will ultimately escape from the sides, as I keep pressing air, air will keep on escaping, but all the same since, escape route is limited, it will have exert a pressure upwards and the vehicle will rise.

So, in this is hovercraft. Hovercraft is basically amphibious vehicle where a continuous pressurization of pressurized air has to be injected into the plenum chamber as it is called, and it would continuously escape, so there will be a steady state of providing pressurized air into the chamber.

Then, there is another type of vehicle where I do not have this buoyancy chambers, but I have skirts, just rubber skirts on all sides, at the bottom, and if I now press air, then the skirt will prevent free movement of air, the skirt cannot, the vehicle cannot lift out of water because that buoyancy is not available anymore and the air will escape from the bottom of the skirt through water. So, this is called a surface effect ship and this is not like a hovercraft, this cannot go on land, this is a water vehicle, but since its body is lifted out of water more or less with only the skirts below it, skirts in water, its drag is very less, so you can really achieve high speed.

Then, added to this you can have wings called WIG- Wing In Ground effect. That is, if I have wings on this SES or hovercraft, mainly on hovercraft, if I have wings coming out of the craft body about 2-3 meters above the ground and if this vessel is moving very fast, which is the case in this without the wings, then the wings will generate further lift. Now, particularly the, since the wings are not very high above the ground the air in between the ground and wing produces a dynamic effect which generates large amount of lift, this is called wing in ground effect.

Can you have the few sketch of this ?

We will show you, I will show you, I am just defining the types of high speed craft.

So, then it is possible for us to go at really high speed and this can go at high speed even on the ground, it is like a low flying, very low flying aircraft.

Then, you have vessels which combined some or all of this concepts and what we call is hybrid craft. Some of this hybrid crafts can be catamarans- you know what are catamarans- that is, two hulls join together, two hulls separated by a distance, but joined on top so that they provide one vessel- the primary advantage being that it gives high stability. But more than that if this vessel is, this catamaran moving in displacement mode as the speed increases understand that waves are generated and there will be interference of waves between the two hulls, it is possible for us to design the distance in such a manner the interference will aid wave making resistance, will reduce wave making resistance- we have seen how interference can be done, can be turned to advantage where one wave cancels the other and so, that depends on the distance between the two hulls- so, by properly designing through a system of experiments it is possible to design catamaran vessels, which will have less resistance than a single mono hull multiplied by two.

So, that is in displacement mode, but you can also have catamarans in all these other modes- in planing mode, in hydrofoil mode and in aircushions. If you have two hulls instead of one the distinct advantage you get is in term of stability in other words, you are having, if you are having large dead load coming up above a certain water height like carrying large number of passenger or military vehicles, landing crafts, where you will have mostly passengers and vehicles, heavy vehicles on top, it is possible to go for catamaran vessels depending on your speed requirement; as we have now seen if the speed requirement is low, you can go for a displacement mode, but if the speed requirement is very high, you can go for catamaran planing craft, catamaran hydrofoils or even catamaran aircushion vehicles.

Then, you have the other vessels- swath vessels. So, what is a swath vessel? It is a small water plain area (( )) in hull ships that is, where we reduce the water plain to bare minimum the hull is submerged in water like a submarine, the hull is in water, which is connected by a strut on to the deck structure, two of this; so, the water plain is drastically reduced it is only the water plain of the struts rather than full weight vessels, the water plain is drastically reduced; we get the advantage of separating the water plains therefore, the moment of inertia and hence, good stability; and we get the advantage of the bad aspects of motion of ships related to water plain that is, heave and pitch motion are drastically reduced, so you can have more or less stable platform in the form of a swath ship. The hull is submerged underneath like a semi-submergible, you can understand that it will give a large amount of weighted surface therefore, large viscous drag, it will not give large wave making resistance because the hulls are, the struts are thin and long, but it will have a large viscous drag, which will also be complicated due to the interference of the underwater body and the strut.

So, these swath vessels are not necessarily high speed vessels, but they are advanced vessels all the same because they have problems of strength and other material problem- materials have to be selected properly, this structural designing is advanced and so on and so forth.

Then, you have extended performance vehicles, extended performance hydrofoils- will show you some diagrams. And surface effect catamaran is called sea cat- we will show you some of these photographs. So, we will go to the next slide.

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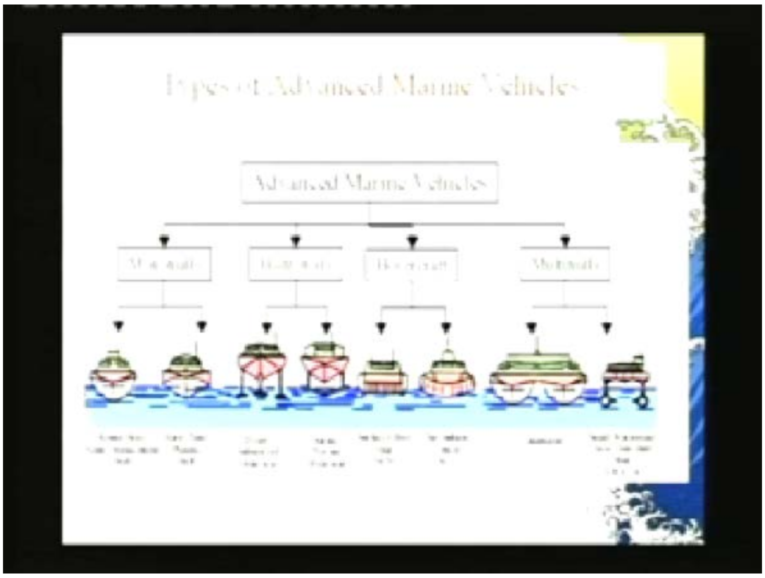

Diagrammatically, if you look at this we have mono hulls, hydrofoils, hovercrafts and multi hull vessels; mono hulls, you have the displacement craft- the first one; and the next one is planing hull, which is hard chine, hard chine means the hull is not, the hull section is not smooth like this, but it is in straight form with very distinct discontinuity- can you see this, can you note that? Next, you see the hydrofoils; there are two types of crafts shown here: the first one is having three foils- can you see that? - and all the foils has submerged in water, this is called submerged hydrofoils, this has one disadvantage that a stability of such craft will be a little a problematic particularly, the longitudinal stability, the vessel may tend to pitch quite a lot and you may require to control the foils automatically, as the vessel is in progress you may have to control the foils- you look at how the foils can be controlled later; the second type of hydrofoil craft you will see is what is called surface piercing hydrofoils that is, hydrofoils which come right up to the surface and pierce it- can you see that the foil below can we see the foil?

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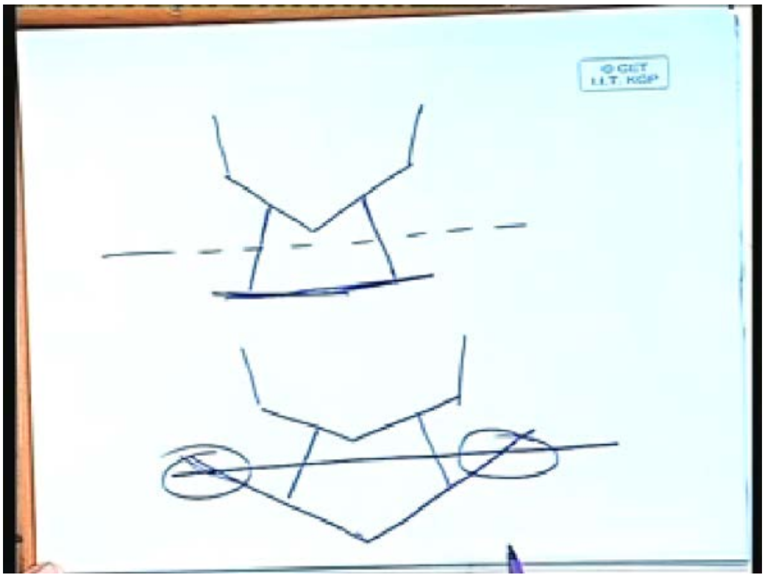

This is a hydrofoil craft. Now, this thing, one is when you have foils here, or you can have foils completely, one foil here and your water plane is somewhere here, this is the submerged foil; the other one you see, the disadvantage with this is this foils are, as we discussed yesterday, the foil should not be very long, so this strut will not be very long, there may be a stability problem because the length is not there though, they are separated you may not get adequate stability.

So, what we do is, the next alternative is, can my foils come out of water? So, the foils actually come out of the water then, what happens? I also take this area, which is still further apart for my stability, so, this vessel becomes very stable. But I have the disadvantage of the drag coming due to piercing of the water surface and particularly, high speed you do not get wave resistance, but what you get is large spray, so spray drag will be there.

The (( )) is, throughout the length of the ship?

It need not be throughout the length of the ship, no, it is in fact, not throughout the length of the ship- we will see some photographs. And next, I have shown you is the surface effect ships; on the left hand side where you can see the skirt in water and the air in between- can you see that?; and the other one is the hovercraft where as I mentioned there is a chamber all around, this is a three dimensional drawing actually, it has come out of water; and the last one is the multi hull vessel where the first one is the catamarans and the second one is the swath vessel. Let us go for the next slide.

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I will show you another photographs of various types of craft. This is a completely displacement vessel where the weight is supported by the displacement due to displacement of water only. You can see the large amount of waves being created- waves and the disturbances in water as would occur in high speed because of the breaking of waves on the sides and may be some separation.

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See, the planing boat, what can you see here? You can see the forward part of the boat is more or less out of water, it is the aft part which is providing the lift- can you see that? What is the drag part of it? You will see there is hardly any wave making in this vessel; please note that there is no wave visible all around the boat except large amount of water coming out of the boat sight, which you see as a white mass particularly, in the aft region- we will discuss this later on, but this is how a planing craft would, well designed planing craft would behave.

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This is a surface piercing hydrofoil- can you see the surface piercing part? The foil piercing the surface, the vessel has completely come out of water; the aft portions you cannot see due to the large amount of spray generated by the forward foil as well as aft foils, which is moving in a disturbed water anyway, because it is in the disturbed water, flow due to forward foil.

If the main body is above the water, how does it get its (( ))? That is a problem in hydrofoil boats; you have to have propulsion either coming through the foils the propeller shaft through a z drive or you have to have a product propulsion drive from top- hydrofoils boat have that problem.

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This is a hovercraft. You can see the aircushion, the inflatable portion of the cushion around, you can also see this vessel has not lifted fully out of water it is still somewhat in water that is why you see the spray coming, the flow being disturbed; and this is normally propelled by air propellers, we can see the two air propellers. So, the engine provides thrust to the air propellers, or torque to air propellers, which provides the forward thrust, and also the exhaust of the engine is used for providing pressurized air into the chamber, or you can have fans to get air from atmosphere, pressurize it and push down to chamber- the pressure is just little above the atmospheric pressure.

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These are surface effect ships, which, both of them; you can see the amount of spray, they create is much more than what you saw in hovercraft, because there you have control, the lift is quite high, here the skirts are in water, as I have told you earlier since, the skirts are in water they generate large amount of spray when moving in high speed.

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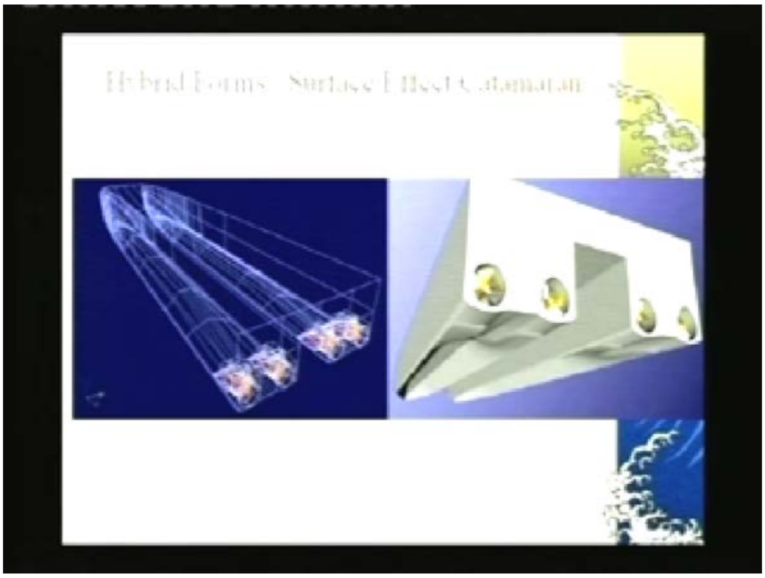

This is a hybrid concept surface effect catamarans or sea cat; you can see there are two boats there, each boat having a plenum chamber inside and here we have rigid skirts, the skirts are not flexible like rubber skirts, these are the rigid skirts, each boat has its own skirt; you can see the plenum chamber from bottom, two plenum chambers and each boat is provided, is properly propelled by two propellers, so there are totally four driving engines and four propellers; and separation gives a lot of advantages, the plenum chamber becomes long and thin, each plenum chamber is long and thin and you get adequate stability because these chambers are separated.

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Look at this; this is a hovercraft with Wing In Air effect. You can clearly see that the craft has taken off from water.

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Same thing, Wing In Air effect with a hovercraft propulsion initially then, the wing takes off and provides large amount of lift. If you go to the step compound in IIT Kharagpur then you will find there is a entrepreneur who is making a wing in air hovercraft in the step building, which should be nearing completion now.

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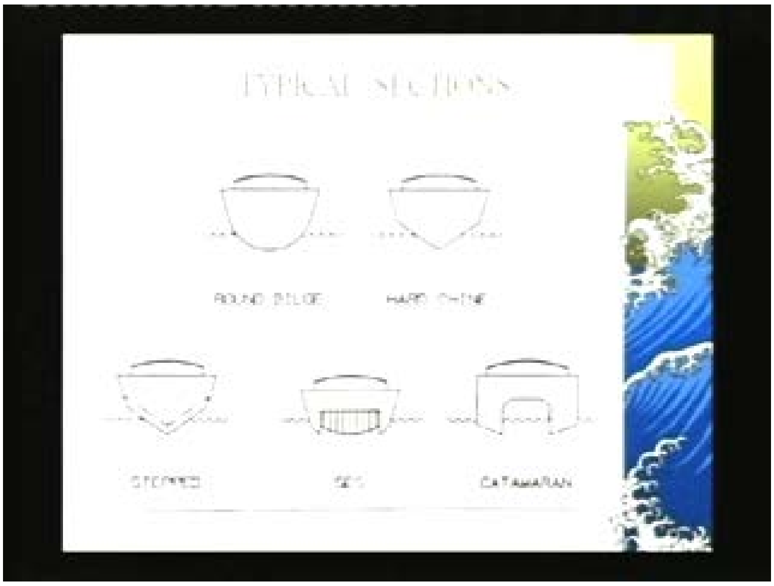

These are the typical sections, which we have talked about- can you see- all of them have been shown; where are they applied?

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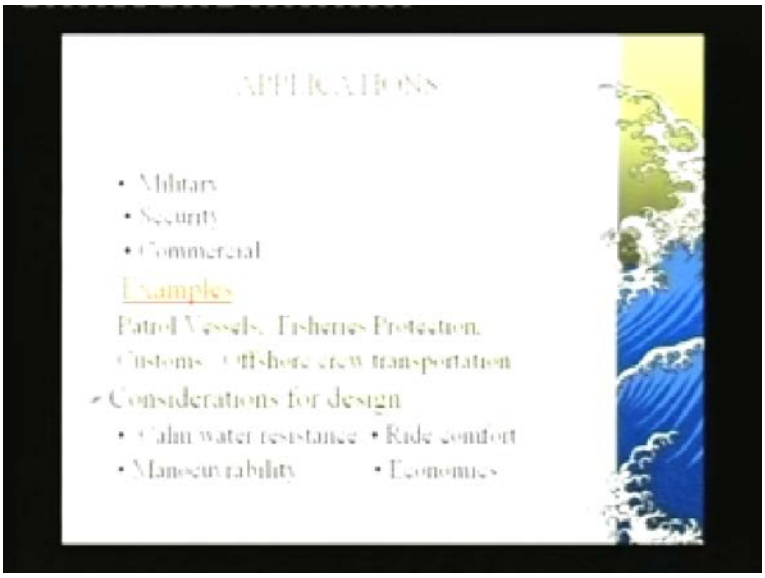

Large application of all these crafts is of course in military use where high speed is required, large amount of passengers and military hardware required to be moved across the seas quickly; and another area is security that is, BSF, customs and such parties which guard the coast line, they require high speed movement to safeguard the source- military also includes coast guard mind you; commercial, commercial applications- we will see. What are the commercials applications you can have in these vessels? Passenger movement for one, large passenger movement on a commercial basis and the other one is of course, pleasure- the other two main commercial applications: passenger movement and pleasure.

Sometimes we use research vessels which may require some of this. Typical example would be a station keeping or watch keeping of some kind at sea, an example would be- a satellite is being launched and that has to be monitored during the launch process and till it is in orbit, the signals that the satellite sends may not be possible to obtain in a particular land based station and we may require a sea station to obtain these things then, we require a stable platform and such platforms normally provided by swath vessels, which are fairly stable. Customs, offshore crew transportation.

Considerations for design, you have to have, what is this, what are the design considerations in this, in deciding what sort of, based on the use what sort of high speed craft you will use. Calm water resistance of course, is one of the main features; as we have discuss this we know now that hydrodynamic behavior with regard to calm water should be one of the main considerations on the based on which you will decide the type of high speed craft. And the other one which is very important is the ride comfort, whenever you increase speed it will become so much more difficult to move at sea because of the waves, and waves generally provide motion which generate large accelerations on deck where people are sitting and therefore, ride comfort becomes a crucial item in selecting the type of a craft you want.

Maneuverability; I think you can understand this how easily the vessel can be maneuvered, let me give an example. Suppose, I have a planing boat which is having a flat bottom at the stern, we have seen that the forward portion comes out and aft portion is the main one that generals lift and it is from common sense we can say that if the bottom is flat I would get better lift. But if I have a flat bottom boat in that condition, you can imagine that the vessel, it will be very difficult for the vessel to maintain course, it will have very poor course stability. So, therefore, I have to do something so that the course stability is somewhat manageable, for this reason I would like the bottom not to be flat, but like this, V.

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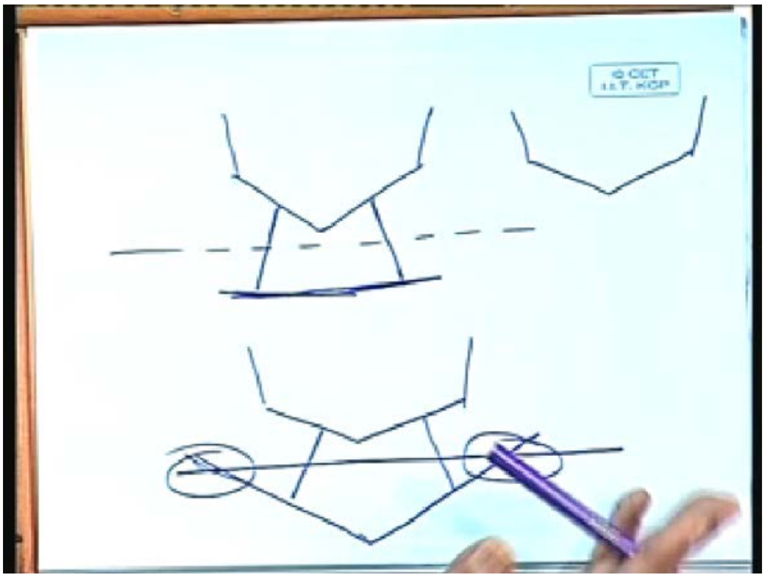

We have seen the planing boat sections which are V sections so that I have area underneath to restrict the vessel from showing uncontrollably. So, maneuverability is quite an important aspect in high speed vessels because control at high speed is also much more difficult.

And finally of course, ergonomics. You can imagine even the drag reduces when you are talking about vessels moving at 40, 50, 60 knots; just the drag into speed will give us the EHP and EHP is some 10,15,20 times more than what it would have been otherwise. And if you are thinking of a vessel moving at 50-60 knots, you will be thinking of 5000 600 kilo watts of power and that too in a small boat, so you cannot think in terms of a diesel engine generating that power and getting inside the boat, you will have to think in terms of gas turbines and such low weight engines which will give large RPM- remember that you cannot have a large diameter propeller, the propeller diameters will come down- so, the only way you can generate the required thrust is by providing a high RPM.

And you have already mentioned some other problems like how do you house the propeller, you may not be able to immerse the propeller completely. Please understand that as soon as you have high torque coming from the propeller and you are expecting large thrust to be generated, and the propeller is just below water, it is also prone to cavitation, the propeller will be cavitate; not only propeller all this planing surfaces, the hydrofoil, everything is likely to cavitate; so, your design considerations will change, you may have to go for a type of section in the propeller blade which will not cavitate such as, a ventilated propeller or a super cavitating propeller; and if immersion is really a problem you may be also thinking of a surface piercing propeller that is only half immerged in water.

So, all this will relate to ride comfort and propulsion- there is calm water resistance, and propulsion is not mentioned here, but propulsion becomes an important characteristic in high speed craft and therefore, it is closely related to ergonomics.

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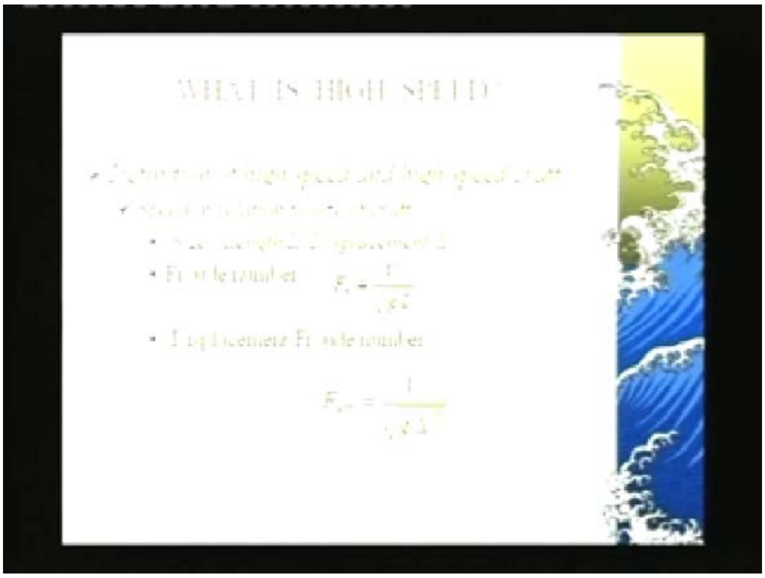

What is high speed? Now, we can talk of high speed. We have seen earlier that speed on its own is not a criterion for defining the speed characteristics of a vessel, that is why the word Froude number has been spelt out that is, speed related to the length of the vessel in other words, speed related to size of a vessel. We have seen when we did the tutorials and resistance that a small model can move at 2 meters per second, but that translates to something like 10 meters per second on a bigger model – is it not?- so, that means, the hydrodynamic behavior of a small model will be nearly similar to that of a geometrically similar larger model- I say nearly similar because there will be viscous, Reynolds number dependent differences- is it not. So, what we see is that these two small model and large geometrically similar model have the same speed characteristics, but the actual speed is different.

So, when we say high speed craft we must necessarily relate the speed to the size of the vessel otherwise we cannot define high speed. For example, a 6 feet boat, a small boat, a 6 feet boat moving at 10 knots will be high speed whereas, as you know in a merchant vessel moving at 10 knots we generally consider as low speed. So, high speed will be dependent on the size of the vessel.

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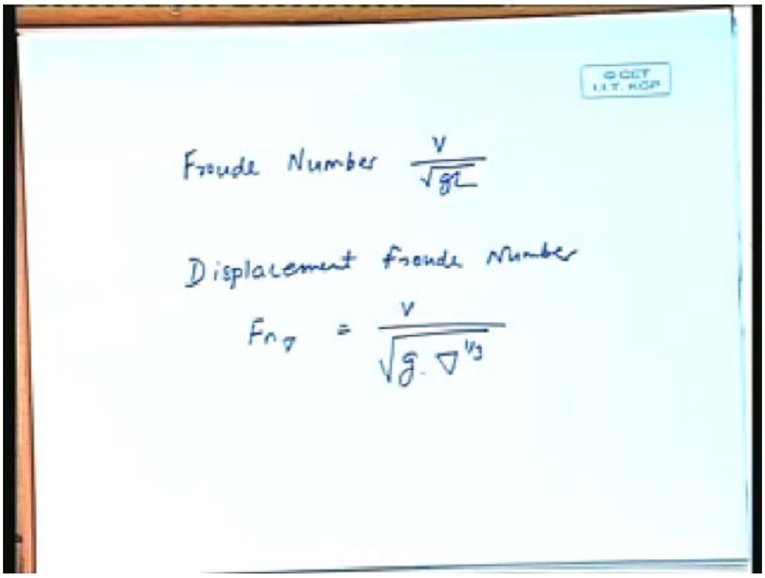

And we generally define the size in terms of length that is, Froude number- v over root g l. But this is not always a very convenient number to define the speed performance of a vessel, let me give, explain to you. When a planing craft is moving as we have seen, half the length of the vessel that we consider for Froude number has come out of water, so the length has actually reduced- we do not know what is the length, we do not know for fact, unless we do some measurements or something we cannot find out- so, then, Froude number is much higher actually then what we calculated in still water condition; so, we cannot really compare because the vessel size has remained constant.

So, what is that parameter of the vessel which does not change? We cannot even say volume of displacement because that also changes as we see the lift has. So, primarily, the thing that remains constant is weight, weight does not change and therefore, since weight is equal to the still water displacement- instead of weight we can say still water displacement- we define a Froude number based on displacement, that is called displacement Froude number. Generally, denoted by Fn with an inverse triangle is equal to v over root g displacement one third, which is in the same unit as length- so, this still remains unit less. The advantage of this is I can now not only define the speed characteristics of this vessel, but I can compare it with other vessels which may have a different lift performance- do you understand?- which may have different lift performance, the lift generated may not be in the same propulsion as weight as my one vessel. So, different vessels I can compare with this displacement Froude number because length is now not known very well. So, these are the criteria with which I will try to like to define resistance.

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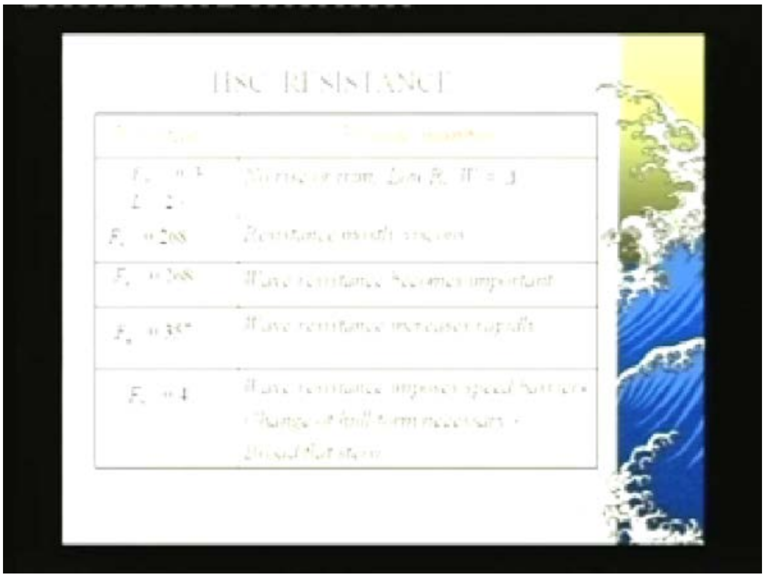

We have seen that when Froude number is very low say, of the order of 0.1, the main resistance component is mainly viscous- wave making resistance is 0. As the Froude number increases wave making resistance starts appearing and speed goes on increasing, Froude number goes to 0.2,0.3, etcetera. How does my resistance curve look?

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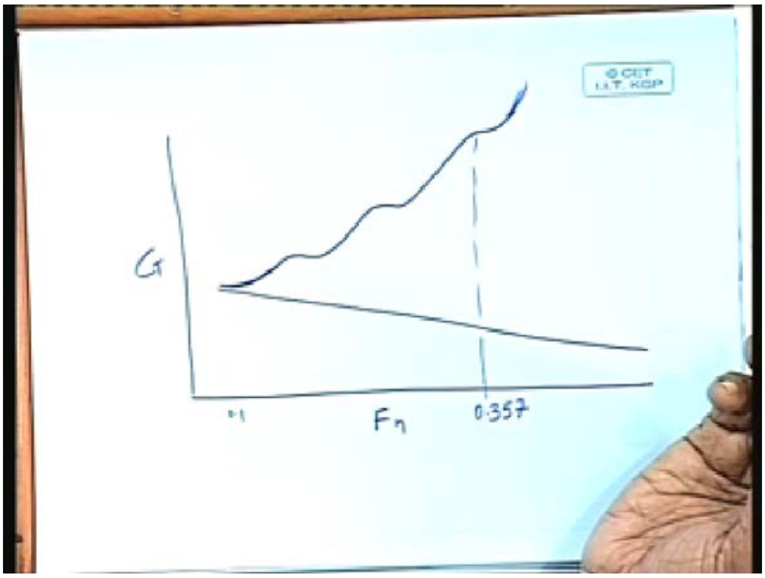

We have seen the resistance curve. If I plot CT here and Fn here, I have the CF curve coming down like this and my wave making resistance Fn; we will start operating at this, may be something like 0.1 or something to start rising above this and then I will have, do you remember the interference we talked about that the ship, the bow will generate a number of waves, a set of divergent and transverse waves? Divergent waves are the waves that go like this and transverse waves go like this.

So, along the length of the ship is the transverse waves that will be visible, we have seen that, and if the speed is low then there will be a number of transverse waves on the ship side, and the length of transverse waves will increase as the speed increase- we have seen this we have studied this- we have also said that the forward shoulder, aft shoulder and stern will also generate similar wave patterns and there may be interference between them; then, we have said that at particular speeds this interference will add up to give humps in the wave resistance curve.

So, this is what will happen, hump will appear here then, this is the addition of resistance then, again it will go up like that- is it not- this is the, as the Froude number increases the wave resistance will become more and more prominent, and somewhere around 0.357, this should be something like 0.357, it can be shown by a simple calculation that this is the third hump in the wave resistance curve, which will be very high, you can see the magnitude here, the frictional resistance is only so much, wave making resistance is nearly 70-80 percent of the total drag, can you see that? This should occur somewhere around 357; and I will say, it says that below 2, 0.268, which may be somewhere here, the frictional resistance is predominant and wave resistance is less; and between 268 to 357 the wave making resistance becomes more dominant; and then beyond 357 the wave making resistance rises at such a speed that it becomes virtually a barrier for the ships to cross the wave resistance phenomenon, and the displacement ships cannot move any more at a speed higher than Froude number of about 0.4.

So, what we do, or why is there a barrier on wave resistance? This has to be understood, this we will see in the next hour, we will stop here.

Preview of Next Lecture

Lecture No. # 13

Introduction to High Speed Crafts Part - II

We will start with resistance of high speed crafts, how it changes with, as the speed increases? We have seen that at about a speed of 0.357 you get third hump by a simple calculation, it may not be exactly 357, but linear about that, and we have seen that as the speed increases further as we go to 0.4 or so, the speed or the wave resistance forms a barrier, resistance becomes so much that it cannot overcome it in displacement mode and go further. What happens?

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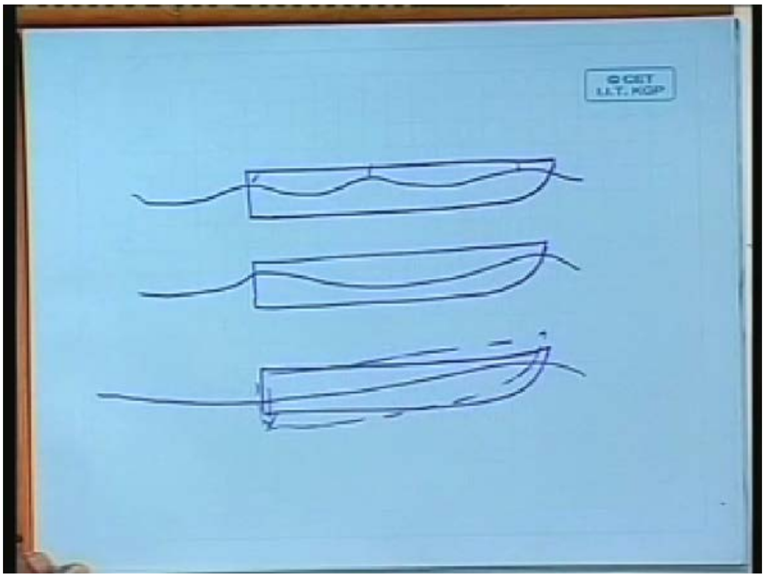

Let us look at the wave making of a ship. We have seen that at low speed there may be a number of waves, transverse waves- these are the transverse waves humps- as the speed increases the wave length increases and you may get a speed at which wave length is equal to ship length, you should normally work about this 0.357 Froude number or there about. And then, if you still increase the speed, then the wave will become bigger, wave length, transverse wavelength will become bigger than the ship length and it will become like this that means, there is only one bow here. What is the effect, what is happening here? You see, there is high pressure here and low pressure here because of the trough, buoyancy is very little in the aft side; if you remember, the conventional stern of a ship, the buoyancy as this draft reduces at the stern, the buoyancy reduces drastically, but the weight is there, so the vessel would sink the stern would like to squat.

So, what will happen to the vessel is, vessel will go like this- do you understand what I am saying?- the vessel will trim by stern, the stern will keep going down so that the drag will increase tremendously because the vessel is not designed with a half trim- do you understand that?- the vessel will sink and trim heavily by aft. So, physically this is what will happen, you might have noticed that even in normal merchant ships of high speed type such as LPGs and passengers vessels if you have moved, if they go at high speed, a Froude number of about 0.35 or so, you will find there is a squat on the stern side; so, the vessels starts sinking at the stern and it is unable to climb up anymore, so, as if the vessel is facing a barrier and it cannot come out of it. We can calculate what will the buoyancy generated and its centroid.

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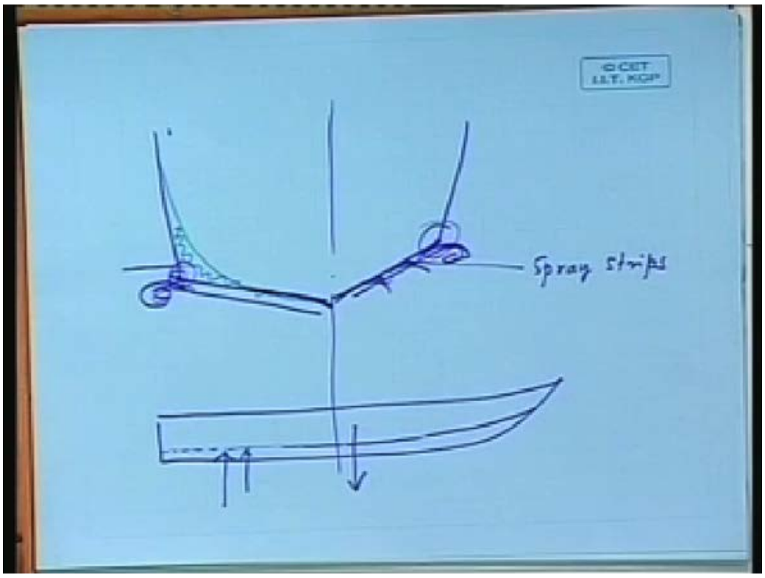

So, these three forces typically, the weight may act somewhere here, lift may act somewhere here and buoyancy also may act somewhere here; so, this is trying to lift and trim the vessel this way and this is trying to trim the vessel this way, so there will a balance between, the trim will be a balance between the moments of the three forces- lift, buoyancy and weight. Lift and buoyancy will depend on the geometry, design of the boat, but weight on the other hand will depend on weight distribution. If these are not controlled, then your vessel's planing characteristics will be totally bad therefore, these boats are very weight sensitive boats with regard to their distribution.

Even if you copy a design from somewhere else if you cannot control weight, the same boat will not give you planing, which has happened in many of the planing boat manufacturers- when they do not understand this very important factor, they get a design from somewhere else, the hull form, they manufacture it, put all the weights, but they have not taken control of it and it just does not ((play)), this happened.

Propulsion of these boats, how do you propel these boats?

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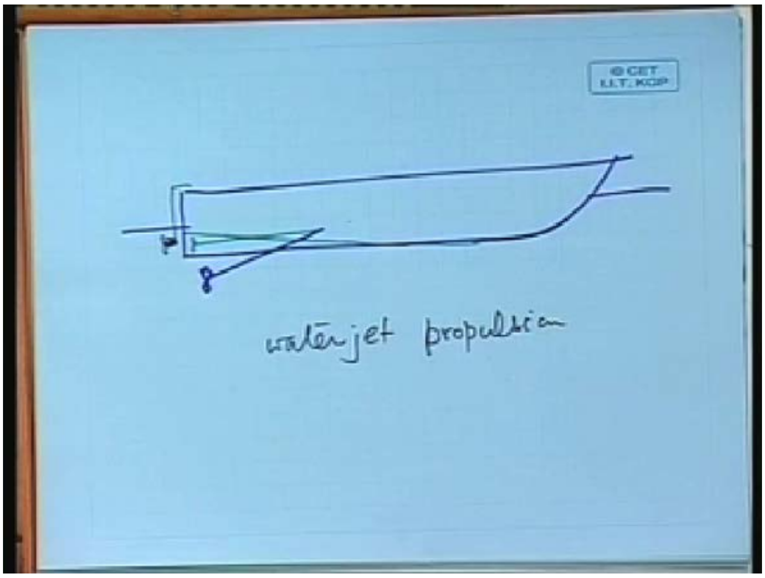

Invariably, if this is a boat, then I will have a engine which will be bring down the propeller here, this is one way of propelling the vessel; the other way is if this is my water line, the other way is if I can bring a stern up by somewhat designing it in such a manner that my stern can come up, then I can give a propeller here-alternative.

So, fitment of propeller will depend on how much of water depth is available with you. Of course, you can always have a third alternative, a product propeller, here completely behind; but here one has to be careful that, you see this is the position where all the separated flow is taking place at the stern, so if a propeller is not separated from this kind of flow by a small distance, then it is likely to not only not generate thrust, but may cause a large vibration- we have to be careful about this.

So, these are the conventional propulsion methods. The new ones are what is called water jet propulsion; that is, if I push water, take water from front and push it behind...

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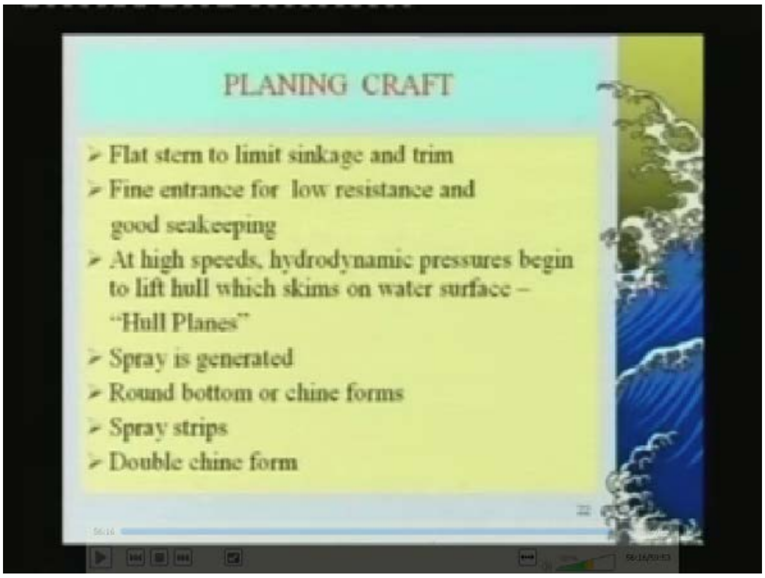

Flat stern to limit sinkage and trim- we have discussed this; fine entrance for low resistance and good seakeeping- V shaped sections, we have mentioned; at high speeds, hydrodynamic pressures begin to lift hull which skims on water surface- hull planes; spray is generated, there is a large amount of spray in this because of the separation at the sides and at the end; round bottom or chine form; spray strips double chine forms. All these I have discussed.

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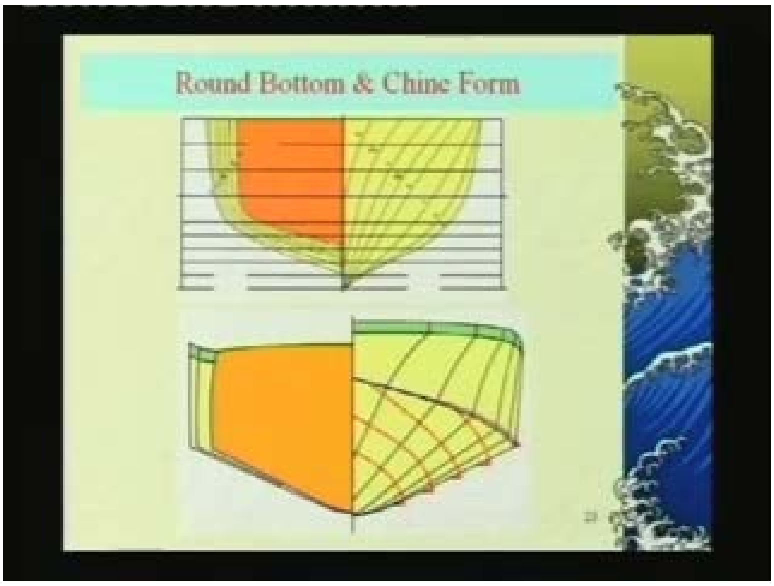

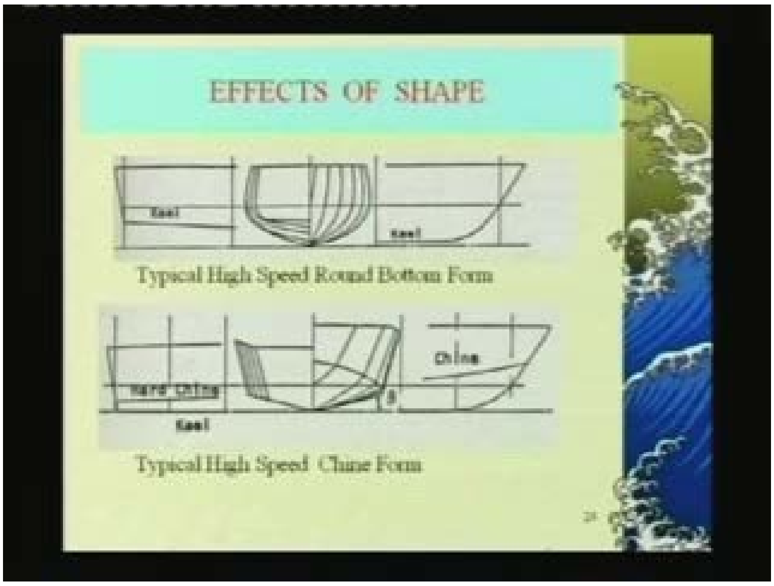

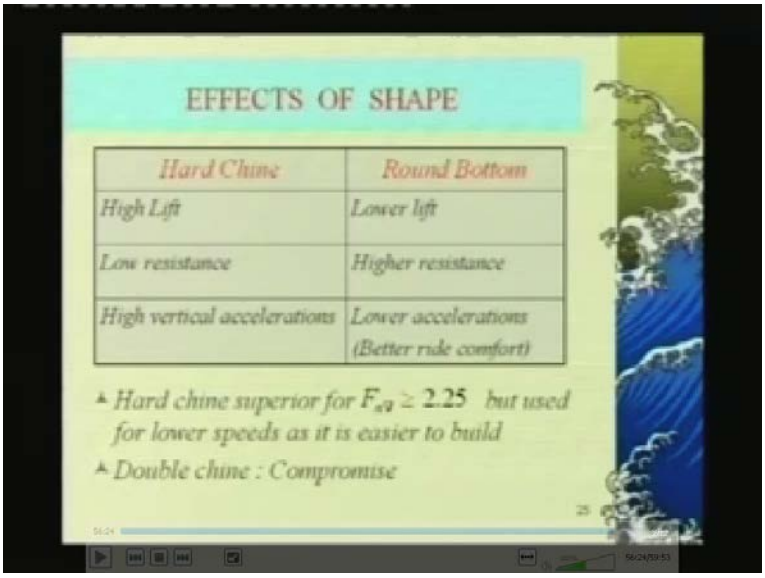

I think we have gone through all the slides.

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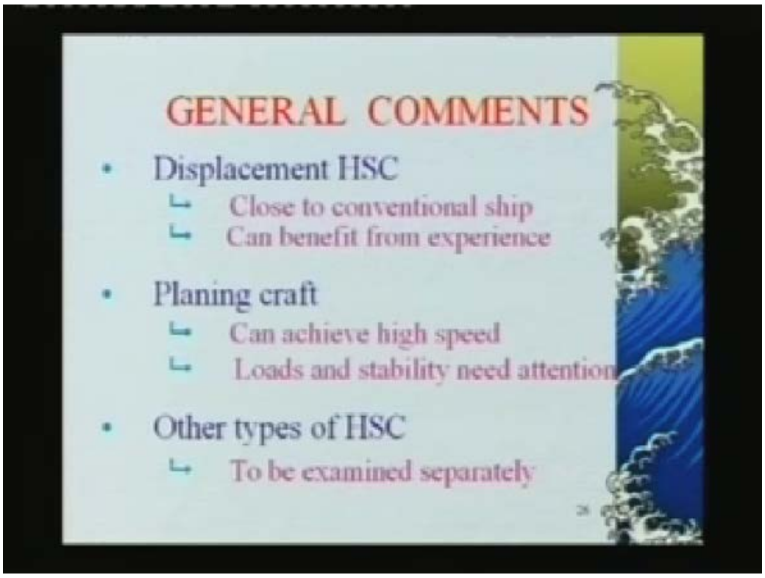

And general commence we have seen, we can now go to the concluding slides.

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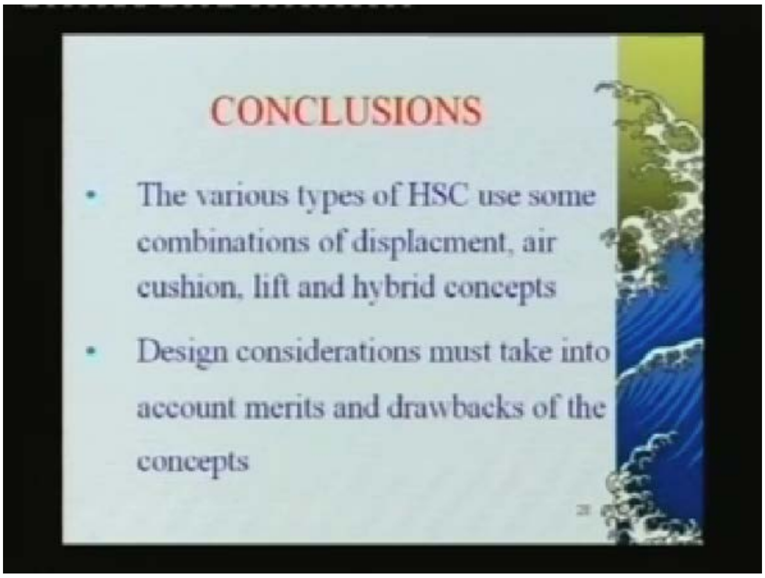

This also we have seen. What we conclude from this two hours, there are various types of high speed craft; use some combinations of displacement, aircushion, lift and also hybrid cushions, hybrid concepts combining 2 or 3 hydrodynamic phenomena or lift phenomena, but basically all high speed craft use vertical lift and reduce the hydrostatic lift. Design considerations must take into account merits and drawbacks of the concepts- this is very important, you cannot blindly use that I want 50 knots, so let me use any one of these. You have other considerations which are necessary for you to consider which one will be the more suitable.

Those are the two main conclusions we get from this chapter that how you generate the lift to lift the vessel out of water and the other one is for designing you have to consider the other types of behavior apart from drag, drag alone is not considered sufficient you have to look at propulsion, how you fit a propeller, the power plant, the materials used, the loads coming on the vessel and its ride comfort.

These are the things which you must consider for designing a, deciding on a high speed craft and later on perhaps designing and manufacturing, any questions? Then, thank you gentlemen.