Performance of Marine Vehicles at Sea

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Lecture No. # 39

Heel During Turn, IMO Requirements

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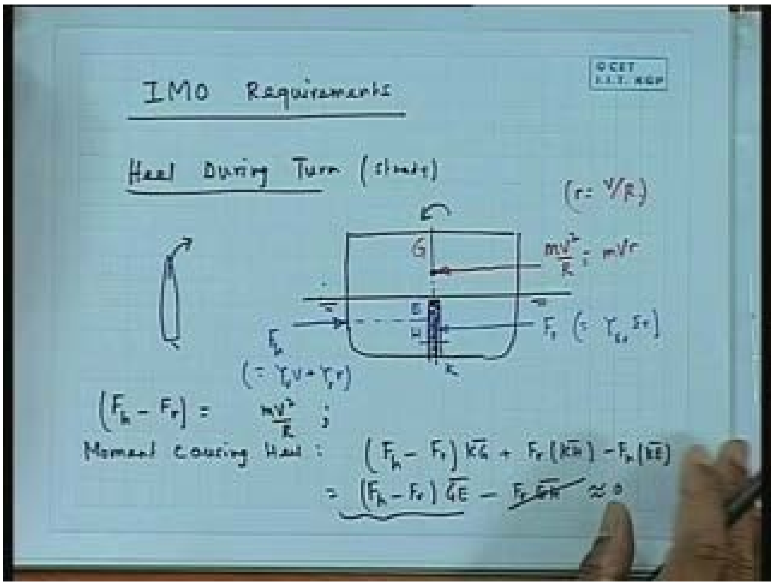

Good morning, today, I am going to talk, this lecture is termed as I M O requirements. You know international maritime organization, they have now some requirements regarding maneuvering standards. I will talk about that mainly, but before I go to this, I want to complete what we left yesterday, that is, heel during turn because, that part we could not complete. This is basically set of rules regarding the zing zap and turning maneuvers. But let us talk about the heel during turn before that.

So, we are looking at ship turning this side, you know, so I had a cross section yesterday drawn, let me use colored black pen. So, this is the g here and we had here this force because, it is turning this side, that is mass into v square by r m is the mass, this is everybody knows. In fact, v by r is omega. So, its m v omega whatever equal to, you can say, m v small r small is v by r you know. Now, we have also here, rudder force that comes here, this is my rudder, typically rudder will be of of this type. So, rudder force come here acting, if rudder which will turn out to be equal to y delta r into delta r. This is the by force that come essentially, that is what you say by definition.

And as the ship is turning, obviously, it is going to produce a reaction force which is F h, may be it is acting at a point, we call it e here, this is h here, this point, this is g here this is k here F h is equal to in a steady turn is y v v plus y r r. Basically, F h is the y force on the hull and the hull y force is actually, because of d y by d v v and d y by d r r, because it has got only v and r, it does not have v dot and r dot right now. In the case of initial phase, you will have v dot and r dot; I will come to that afterwards. This is on the, I am I am looking at heel during turn, which is steady turn. Now, we have to look at this, here now you see according to our mathematics F h minus F r, there is a net force on this side, should equal to force on this side, this should be equal to m v square by r. And the moment this is the force equation, the net force is zero and the and the moment equation will tell you, now, we want to find out what is the moment causing heel, the net moment causing heel. So, if we look it about, say, moment about g is F h minus F r into k g we actually, I am just following this, here h is this one minus F h to k e, this will turn out to be, I will simply write the final result G E.

See what we have done, it is very simple here, we are taking moment about this point. What is the moment of this point? It is F h into G E, this distance, the the heeling moment. See, we are talking of heeling moment in this direction F h into g minus F r into g h, this we are writing in in this form simply for some other reason, actually that one only you broke down because, that will turn out to be equal to F h minus F r into F h minus F r into G E minus F r into e h. The reason we are writing, want to write it this because, we wanted to write in terms of F h minus F r. This formula is extremely simple, I have got a force and acting at point one, another force acting at point two and taking moment about this point and we we find out that the moment is this absolutely straight forward. The main reason of writing this is that, it turns out form many ships e h is very small, why because, you see rudder will be typically over the entire draft, mostly you know, slightly less than the draft. So, it will come about middle of that, as you can see, the rudder is not really ending at this point, ending at this point normally you try to make a rudder which is because, you want to take more area. So, you increase that rudder up to more or less water line, design water line.

And this part will also come at more or less center of that. So, therefore, F h and F r are more or less collinear, you one can always try to find out where is the center of action, but, it turns out for all ships, this is very similar. So, that this is almost zero, this is why it is written this way e h e h because, they will act more or less in the same line so that my moments are to be like this; this is the reason of writing that. So, once we know the moment causing this heel, obviously, we can find out the amount of heel, we will, which we will just talk. So, this will be understood. So, this becomes the moment causing heel F h minus F r and you can actually find out what is F h minus F r as I said, F h is y v v plus y r r and F r is y delta and delta r. So, if you know the hydrodynamic derivatives, you can find out now, obviously, delta or we can see delta g n.

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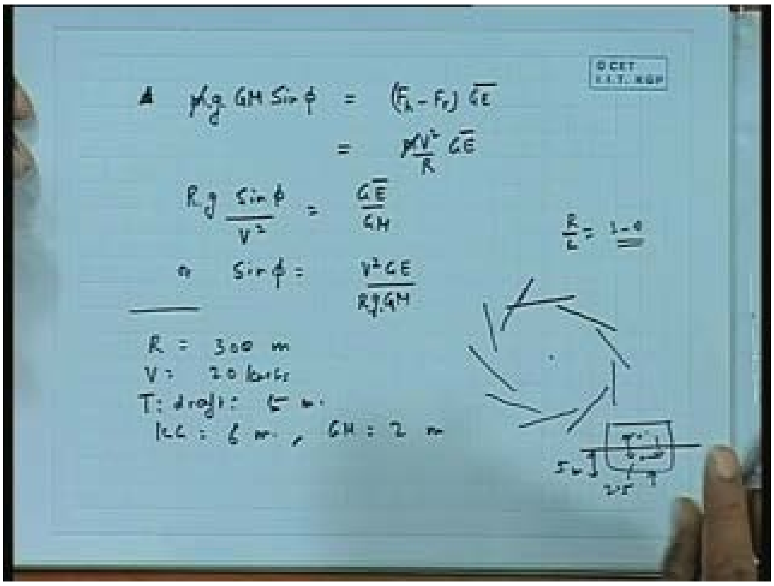

In fact, I should say, weight here mass into g, I want to rather write this way, the g m sin phi phi is a heeling angle, and this we have done it before, is equal to healing moment. This is F h minus F r into G E, which is equal to, now if you look back, that F h minus F r oh [fl], there is one more way of looking at that, F h minus F r, without going to, this is equal to m v square by r F h minus F r is m v square by r. So, if I put root, that is even more simpler; it is m v square by r into g ok. So, we can get this m out, then, it will turn out that, r into g r into g into sin phi by v square equal to G E by g m. So, form there, you can find out phi or rather in fact, we could have done done it from here, only v square G E v square g by r g m into g g g m, like that. So, you see, you can find out this more or less and G E and what is e, if you look at that, e can be taken more or less to be half way half the draft yeah.

If this is the draft here, you can take half of the draft t by 2, see we are looking at g, you know, sorry, k e to be, you know, t by 2, we will work out some, we can work out some problem later on. So, like that, we can easily find out. So, this now, of course, from there, you can easily find out phi, if we have written it sin phi, but if phi is small, we can always say that phi equal to so much; that is very simple. This is how we actually find out, let us say, that we will be, let us do a kind of problem, a typical numerical problem where, r is say, 300 meter, where I am just looking at a typical number that might come. See, some ship is turning at 300 meter because, it turns out that r by l lies between 3 to 4 for most ships for more. In fact, we will talk about I M O requirement, where it says that it should be less than 5. So, r by l is about 3 to 4. So, let us say, this is a small ship say, 100 meter long ship, so, 300 meter.

Sir it radius of turning the length of the ship

Radius of turning, normally for a large ship it should be, it normally lies between 3 to 4 or around 4 you can say, but for a navy ship, very tight turning, that double rudder ship can be as small as even 2. You know, it can turn radius is 2, that means, diameter is 4, remember, that you know. In fact, if you see this diagram of simulation, the ship scale is like that, the it will look something like that, you know that had some turn. I mean I am just showing in instantaneous diagram, it is a ship, is the scale diagram, if ship length is so much, there are cases where within this, Sir almost r Ah yeah within this almost r, almost 1.5 time you can you can have pictures of ship turning like this, just to give a feel. Anyhow, we have got this r equal to this thing v equal to say 20 knot, of course, you can make out. See interesting thing that, obviously if the ship is shallow and high, the g is above very much high of course, g is very much high, g m also it tends to be low.

Then g and this ship has a larger draft, then this becomes more in this, increases if this increases, then there is an increase in the angle, speed is increases, increase in the angle or r reduces increase in the angle. You know this angle, therefore the ship will more heel if it make a tight turn, this ship will turn more than if there is a larger one, obviously because the the centrifugal force is more.

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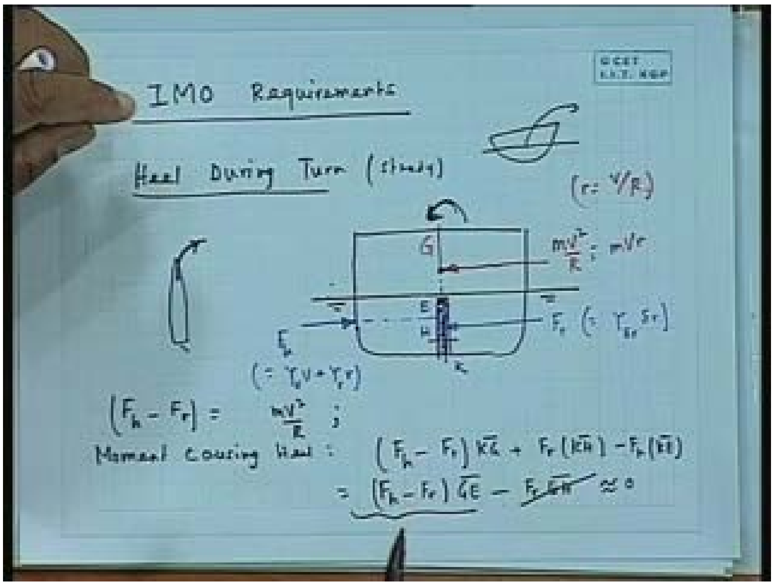

G m, again you can make out, it is inversely proportional to g m as g m is high, angle is low, etcetera etcetera g m is high, obviously the stiffness is more. So, you need more moment to heel. So, if you do that and the draft of the ship, this is draft, say 5 meter and kg is say 6 meter and g m equal to, here actually it is, see, draft is for this ship draft is 2 meter 5 meter. So, you can take the center of action to be half way through and kg is 6 meter, that is you know, k 2 g is 6 meter. So, I can take this to be 2.5 meter so that, this distance becomes 3.5 meter. So, you see what happened, G E becomes approximately 3.5 meter. Actually, I let me do it in a different paper piece of paper that is getting small. See, we have got this ship now here, which says, the draft is 5 meter, this is k, this is g, k g is 6 meter, v is 20 knots equal to say, well 10 into something, 10 into 0.5144, sorry, 20 meter by second.

Sir you may taking as six meter sir.

k g is 6 meter and g m is given as 2 meter. So, what what I mean is that, you can take e point e to be half way through this draft. So, you can take this to be 2.5 meter and therefore, this is 3.5. Therefore, if I go back to this formula, v square G E by r g m, see, sin phi v square g by r g g m, this will turn out to be, you can see the units, also, this is unit less v square is meter by second. So, this, let me write this to be approximately 10.28 or something 10.2 8 eight square into g is 63.5. this Let me see the, check the meter square by second square into meter, this is the unit r is 300, that this meter here g is 9.8 meter by second square g m is another meter 2. So, you see this all matching, this will turn out to be some number. So, here from there, it will turn out that phi is approximately 3.5 degree, you can work, it it is of this order, you can just work it out.

Sir G E comes to this thing g 10 distance minus 2, which g? Sir, taking that center sir e we are taking at center.

Yeah yeah yeah, center of the graph V, we are taking at half way to the draft, see I mean this engineering approximation where will it be, tell me where will the the when there is a flat, H h and F r is at that point.

Yeah, but he tell me logically, there is a pressure acting here, throughout this. Where is the expected center? Will it be somewhere very much in the top or will it be somewhere here? It will be somewhere in this region half way through rudder, is always more or less in the draft. Where will be the centre of pressure? It will be always, it is not center, I tell you, it will be in plus or minus 10 percent. So, you do not go too much wrong, you see, you do not like 2.5 meter, you make it 2.25 meter, you will get, probably you know, little more, may be, 3.8 degree, so it will be of that order.

You are making an engineering judgment. You know I mean, when nothing is there, you have to use your you kind of judgment on that, so you can get this. That is what I am trying to say. one interesting point that is to be said about this, you see, suppose the ship is turning, now now you see here, which side the ship is turning is, as it turns here as it turns here, it is heeling on this side outward. So, you know where you will see this picture of the ship heeling like that, as it turns, I have got a nice picture on my desk or aircraft carrier turning this side that is heeling, you can make out that at the heel is in fact, it almost 10 degree or so, you can make out. Next time you come, I show you I have got that matter, very nice picture. You cannot make a mistake of the turn because, the wake will tell you which side it turns, that a real picture.

Now, interesting point there that I want to mention two things, 1 is that, see supposing suddenly you decide to stop this rudder. So, the ship is turning, the initiator stop that rudder, what will happen? Tell me in this equation, what will happen? Now, you see this forces F h minus F r that is the force. If you if you look at that, I will just put in this way, then, it will be easier. See here, I have got F h minus F r into g is this formula because, this is F h minus F r. Now, suddenly I want to reduce F r, if I if i make F r 0, because, suddenly if I turn my rudder angle to 0, F r is, after all y d r delta, suddenly I make delta at 0. So, this will go to zero. So, this will go to 0, but, at the same time, the speed v n r will not come to 0, because, the ship is v n r is moving. So, this will still remain as much almost as much, but this will certainly go to 0. See, you are going to bring the rudder back to 0 in say, 5 seconds. Normally, 3 or 4 degree per seconds, is there say, like that, but velocity has not come down. As you know, ship you would know much more than me that, it will take long time. So, suddenly you are reducing this to zero, what happened earlier, it was F h minus F r g. Now, it is f x g. Which one is more? This is much more, so, suddenly it is going to find much more of turning moment. That is why if you suddenly stop, it will have a jolt and try to heel more, it may in fact, heel more and may capsize; this is why it is suggested that you should not bring the rudder down back to 0 when it is making a sharp turn during the turn very quickly. You should do it very slowly so that, you know that there is an adjustment time. In fact, interesting point is that, this I wanted to tell you also that, initial phase if if you remember the first phase of the turn, as as soon as you put the rudder up, this reaction force is actually small reaction force is small. So, you have given a rudder force, but no reaction force. So, at that time, the ship is turning inward. So, initial phase is the ship turns inward and then the reaction force becomes the acceleration force. If you recall, you will find out that the reaction forces y v dot v r because, we had first phase on the v dot and r dot now v and r.

So, initially, when you put the rudder, I immediately have this force, but no, not this force; what happened, the ship as actually turned inside. So, it initially, as soon as you put rudder ship turn this side, then it begins to turn this side and that is why if this all. And also, we can see form the magnitude, the typical turn will look something like this, this is what another diagram I had shown it to you that, as it turns, you know if this is the turn angle phi angle here. Let us say finally, it will turn here, first say no angle turn is there, this is say, you know, plus minus whatever.

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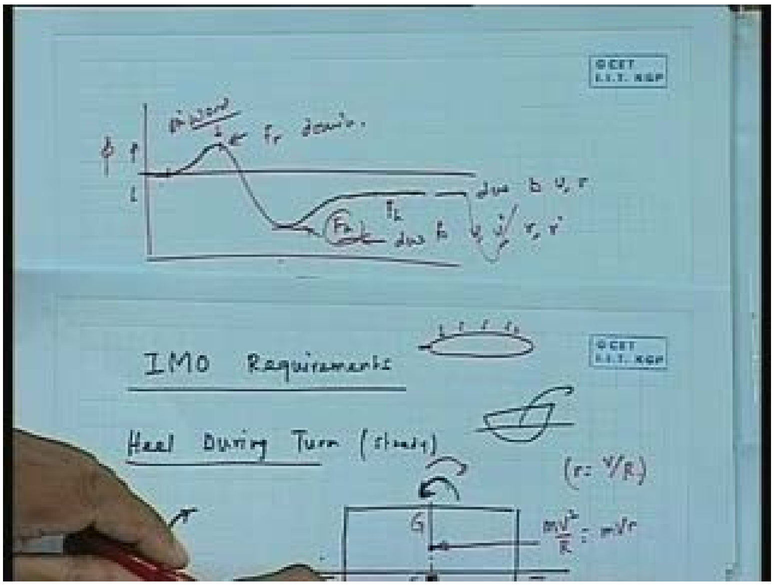

First phase, it would actually of 0, then it turns this side initially, then it has outside this side. Then, actually it it comes down and comes from, why, I will tell you why it is like this. Now, there is also interesting point. Initially at this phase, you have no angle, why, initially it has turned inward, this is inward and this is inward turn, this is inward angle that is turning on on this side angle. Because, I do not know F r, but I have f a sorry I have got F r, but no F h. So, therefore, it turns this side, So, initially turn this side. so, maximum turn. Then eventually, this side begins to come up. So, it is gone to reduce reduce and begin to turn on the other side and there is a point when this F h is very large, because, it has got both v dot and r dot as well as v and r. This is where it is more, that is my transient phase, my total force is y v dot v dot plus y r dot r dot plus y v v plus y r r. So, it is more, then, eventually the acceleration force reduces. So, it comes down and comes down like that. Sir F h will always dominated there. Ah. F h will be always be higher than f v Yeah yeah yeah yeah yeah F h will be always ultimately higher than that and it will always turn this way. yes you are right F h is Because of that, there is also reason for that, see, F h is a reaction acting on the entire. If you look at the hull, it is on this entire hull and this is only on this part.

So, you know this this entire force is acting on that. So, it is always so, but, this is interesting how that in here, no force in here F r dominates in here F h, but this F h is larger than the actual F h and here also, of course, F h here F h due to v v dot r r dot here, only due to v and r. So, you see this, now at this point suddenly if you reduce, that is going to actually snap roll, what they call snap roll, and actually, it can certainly have a large roll. So, it just an interesting part of rolling along with, you know, like during maneuver this is of course, obvious that as you turn.

Sir this could be also stern on the basis of that it initially you do not have been centripetal force Yeah yeah yeah actually the centrifugal actually you know when you say that you know it is a question of chicken an egg egg problem which comes first for actually this is a like an inertia force which is always existing when there is a v.

V will come because of this force. So, you know you can see that way, it is only equivalent, but it is like mass into acceleration force. But, you have to give force to get acceleration. So, this is the acceleration part. So, first you give F r, that is why there is a v setup, that is why this comes and this part actually is only in the steady turning time. So, we do not think of a steady time, then we do not know what force, when dot and all coming. You can think there is a force coming here, but take that point to be the point of action and take moment about that so that, that action force does not contribute.

That is only F h will be. Yeah F h and F r and of course,, the the relative you know like magnitude of that. So, when greater this brought to zero in the moment of turning. So, F h will try to delete other Yes because you are suddenly see initially you have no F h only F r. So, it is turning this side inward then eventually F h becomes more. So, you know like this diagram we we showed yeah it is turning on say it is turning. That means same rudder position Yeah yeah same same rudder position. Same rudder.

Rudder you already finish here. So, you have given a rudder, say you want to make a port turn turn starboard turn. So, you have given a rudder, accordingly you know on this side, the equation of convention you know, like you have a given a rudder on this side, so, the ship will turn. So, initially, the ship will first heel during in the starboard side, say little bit. may be three degree, then it will it'll now begin to go on the other side, may go to 5 degree and then eventually come little less and then stabilize. So, it will first start like that, so, it will go first of all, it shift this side, you know. So, it will shift this side, with this angle difficult to say, shift this side, this angle then, it is going to go like that like that and then slowly like this and turn and then if you suddenly, this thing, it will go go more. So, this an interesting point to see you know that. So, therefore, it is a same thing that, when you are turning, you should not suddenly change and I tell you one interesting thing. many of It is said that many of these small boats that applies in river, you know, like vessel, they capsize not only because of low g m, also for this reason, some time they turn very heavily and suddenly change and they do not know there is a snap roll there you see.

River ferries whichYeah river ferries and all. So, this also is a reason, it is not something to be neglected. You know that maneuvering is a reason because, it tends to, all you need is for one second g m to become negative, then capsize, you know, you do not need for a long time, just for an instant the g m should become negative or it should have a large angle so it will capsize. Anyhow, now we will come to this I M O requirement, I wanted to speak this today.

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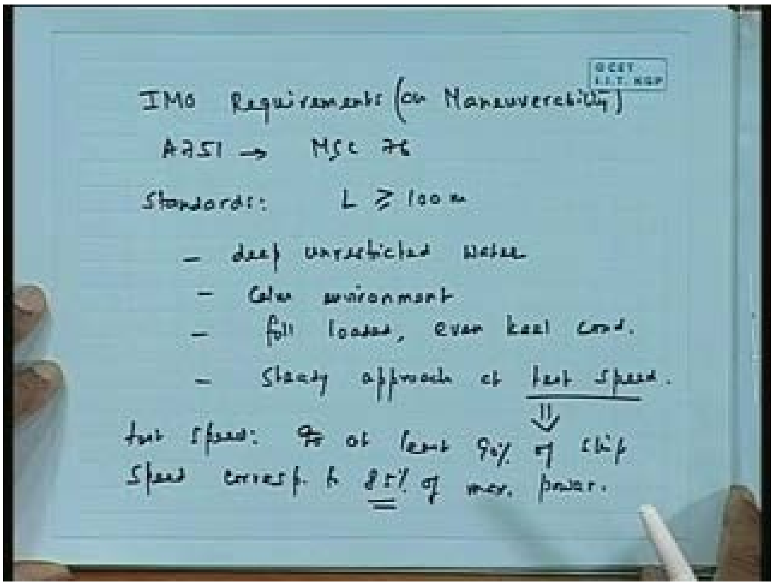

Obviously it is on maneuverability, see, I M O has given. In fact, this a some clause I think, a is 751 and it has now changed to, I do not remember m s c 76, these are all clauses, forget it, but they have got some, I mean, resolution; it reads long, thing I am not going to read write down the rules and regulation all step, does not make sense; that you can read and best would be the project on a screen. But, I wanted to tell about only some essential features of that, you see, that now a days what happened for all ships in order to asses that it has got some kind of directional stability and some kind of turning ability, I M O stipulate some requirement saying that it must maintain this, this this I will just basically, broadly mention those requirements.

First of all, the standards they tell apply to ships length over 100 meter small ships normally, you see there, we should understand this. They are interested sometime in the rules and regulation, the absolute dimension, you see, there is the port is 500 meter; now, if the ship is small, say 50 meter boat, it is going to, even if it has a 56 times, its turning radius, it will still be 300 meter, less than 500 meter. But, bigger ships will be small requiring more space, that is why, the rules are more for bigger ships 100 meter and all mostly ocean going ships. You can apply that and we have in fact, recently checked it for a sixty meter vessel, but it is not mandatory requirement. Then, there are some kind of specification, of specification of what I should say, kind of, standard for fits less above 100. Yeah yeah yeah this this I M O standard that we will mention here now are applicable for ships over 100 meter and there are some other kind of ships, etcetera and they should be done in what is called deep. The the the application applicable conditions are for deep unrestricted water and in calm environment for only fully loaded condition condition and steady approach at test speed. Now, I will tell, see these are standard; that means, in a very standard standardize environment, in a deep water ballast, water condition, etcetera, a ship must possess at least so and so maneuvering characteristics. What are those, so and so, and. So, and. So, this thing I will tell you and this is to be done and checked finally, by doing those maneuvering trials that we mentioned last class.

Sir at test speed

Test speed, yeah there is, that the now now this There is a test speed given here, which should be, that it is mentioned here, you know that test speed should be at least 90 percent of ship speed at corresponding to 85 percent, at least 85 percent of maximum power, I will tell you the reason for that. You see what happens, you have an ship with an full power, sometime you do not actually you know if you give the full power, you will have a, you know higher speed, say ship is designed for say, 16 knot speed. But this standard, somebody will say that I am going to go at 14 knot speed. Always, but basically it turns out that if you increase the speed, you normally have you know, like it has an effect on the turning abilities. So, they specify that you must do this test at least at 8 5 5 percent of the 95 percent of the, I mean, I mean the the speed should be at least 90 percent of the ship, corresponding to the 85 percent of power.

Sir hundred percent power what is the speed that ninety percent. Yeah yeah yeah yeah yeah. It is eighty five percent of the m c r m c r. Ah exactly. And what it say that Ninety five percent of the ship speed. Point nine of that

Yeah yeah Basically, it it specifies a upper, a lower limit of speed; it must be at least at that speed you know. So, you can calculate that, suppose a ship is designed for 18 knots, it the test should be done at least for say, 16 . 5 knots. Whatever I got in there, you cannot do it for 12 knots and say, because, 12 knot, I think basically equal. So, they have got this various rules and regulation. I do I am not mentioning that they have got standard definition of what is meant by length, whereas, l b p or not, what is draft, how to be taken, all that are there in the rules; that is less important for me for my this class so much. I want to turn turn more, consider more on the turning ability and the reason why it is say, that rather then you know, it is, he will tell me that you know whether you take this l00 meter, is it now, it should 95 meter, that is the question of just reading the rule correctly. In fact, all these rules, you know, in a book, all the definitions are given in the Yeah it. So, here also I have not, as I said I have not repeating the rules, I only want to just take, all rules will have, you know, 3 . 2 1 to 1 . 2 2. This is say, rules and regulation course, he will you know, place it on your screen and you will see read that.

We had on this

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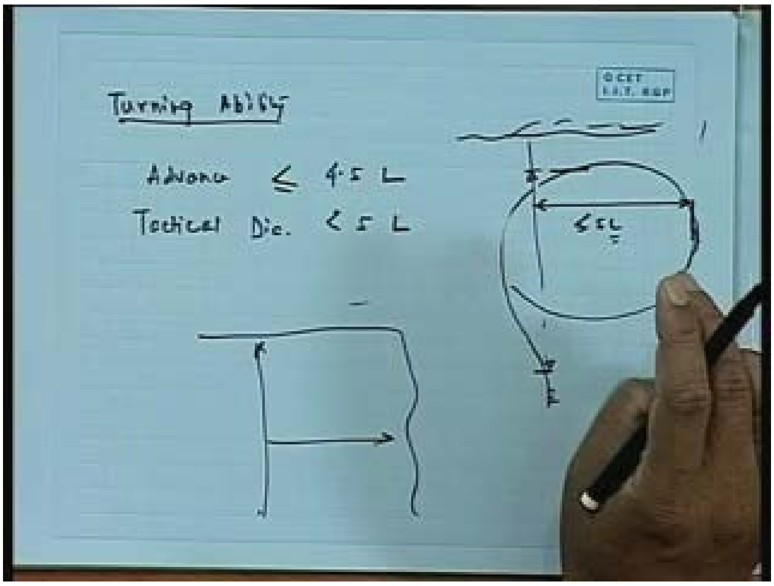

Yeah yeah You had this. So, I do not consider that you know that you can read it. I only want to stress here, some of these final points, that is all. So, here, that this condition are there, see what it involves is, turning ability. Three things it involves turning ability, initial turning ability, both of them you are testing through your turning circle maneuver and then zigzag maneuver, these two are main thing. This they it says now, here I will just write this advance should be less than or equal to 4 . 5 ship length and tactical diameter tactical diameter should be less than 5 l. Now, if you see, advance and tactical diameter yesterday, if you see that actually, you know, if you go this way, I then write this this diagram here where in fact, here the advance has been defined to be where it is changed 90 degree.

That is where you started turning, you know, advance is the x this distance, advance was the distance along the x axis where, the heading as just changed 90 degree and tactical diameter was this, where it is that that another 90 degree here and this, see it is. You may say, why not the maximum one? Normally, they are not the maximum 1 for, I do not know what reason because, may be, it is much easier to measure the heading angle, you know, locate this point more easily when the heading is just 90 degree, then to pin point the location of maximum width so that they seemed to be closed by. So, this should be less then equal to 5 l and this should be less than equal to 4 . 5 l. So, it again, it is very important why these two parameter because, you see there is a restricted water harbor, there you start to turn here, you know, see some restricted water there, etcetera, so, obviously, it will tell you how much of space you have got in front, how much we have got inside. See, the logic is very simple, it tells in this two, how much you can actually has space front, therefore, it must be less than that, that is why there is a specification with respect to the front distance, that is advance distance and also the tactical diameter distance. In fact, it does not say here anything that I found out; may be the there is a equation about the turning radius, actually it tells about this two.

But sir other way it is taking r by l only that means Which is That r by l what limit we have. No no we do not have the limit no see that is what I make r by l what I said it is not the limit. It is a normal thing happening. Normal ships have r by l or d by l of that much. Sir if it has specified

Yeah yeah I M O does see we have to understand this, I M O is more concerned about not making accidents, you do not turn or do not turn different, but you should not turn such larger, you hit the other side. So, there it is a safety regulation, the it is not trying to tell you your ship is very highly maneuver, it does not say that your ship is, you know, owner may not be happy, he will be happy it is not going to hit the side. So, these requirements are more of you know, like that end, that prevention end rather than you know, quality end of it and the problem now it is is that in the designs time, if he does not meet, then, they will not sign it, that is it, you see.

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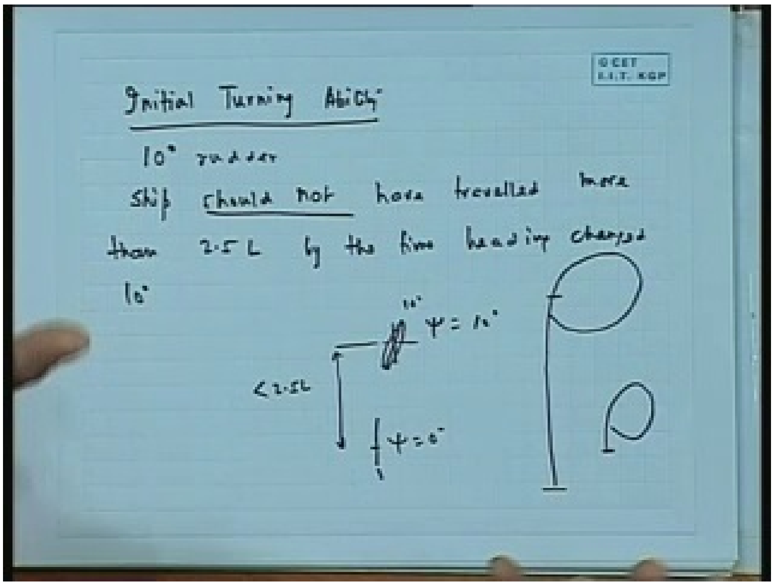

So, this is one of this thing and there are more details, the second thing is this initial turning ability. It says here, oh this also, I did not say, here you may ask the question what is the rudder angle given here? ok. Ah what is the Ah that rudder angle also, they are actually specified here, the rudder angle should be, let me tell, something like it should be the maximum rudder angle which is 35 degree, but not less than some number you know, it should be actually basically maximum rudder angle. But, there is some stipulation given on the rudder angle, let me try to just find out this thing. yeah It is basically 35 degree or the maximum rudder angle that is permissible normally, most ships is 35 degree. Again, 35 there is a reason which next lecture will tell you because, that is where the angle of stall occurs mostly. So, that is why you have that way but we cannot have the radius smaller than this.

Yeah yeah yeah.

We wll have more than this only normally. So, you have more than this only, but this is, anyhow this is a stipulation that it says that 45, it is measurable, the radius it will make. No no there is a point at which no force has started acting. See what happens is that, that that we will talk next class, hydrodynamics of rudder, that you keep on increasing more, you have plate here, you keep on making more and more and more then it will not produce lift this side Oh It will not, just it is like a plane. So, there is a limit, in fact, no use of giving, No no no it is like a plane, you know. If you want to go like that, it is going to go up anymore, because, it is going to be just a drag. So, for producing lift, you need to know angle of attack, an angle of attack should be some 38 degree yeah. Normally, they call angle of stall, after that, it actually comes down and 35 also is very high, most ships may be 30 degree. I do not know, you see, even you design it, you probably design up to 35 degree both sides. But we do not go away frequently No You do not go away, you do not need to go, you see, that is why, I am saying initial tuning ability because, most of the ship unless the emergency, you do not make a u turn to run away, see for a big ships, that is because, if you are a smuggler, you are being chased, you might try to run away, but that small ships, but here you do not, do you need to check that, but initial turning ability is more important actually.

See here it says that, when you keep 10 degree rudder, then this is interesting. It says the ship should, I will tell you, just write it now, not have traveled more than l by the time. See, it it means that, see the ship is here, initially you give a rudder 10 degree, now the ship heading will change at some point, the heading has changed to 10 degree, this distance must be less than Less than 2 . 5 l. In other words, as it turns, you know, this is a this is a ship here, I mean, if you draw like that here, the heading psi is just 10 degree here psi is 0 degree, rudder is being applied, you know, you are applying rudder. This is a starting point, whatever what it say is it is called, the initial timing ability, initially it it should not be that, you you want to turn it, should not be that it is very slow to respond and it takes a long time and then begins to turn, you see, it it can be, it should not be like this and then turn like that. That limit is given to 1 by 2, Yeah so, that limit is give it should be turn more like this, it should be full action by 2 . 5 Yes yes by two point 2 . 5 length. By the time you reach, the heading must have begin at least 10 degree, the same rudder angle that you can, it should turn 10 degree. In fact, these are all nice simulations are possible. As I told, I have got results of this full thing, we have done a simulation now for a design. You see, these things are all requirements, how do you check the requirement?

After you are build the ship, I M O much will be there, the ship trial will be held, then, you have to prove this. But, to check that, you know, that these are the requirements. So, at the initial stage of design, only you can actually kind of asses that by trying to estimate the hydrodynamic forces and try to do a simulation, because, if there you detect that the hull is really bad, it may not meet, you know, there are some chance. Of course, what you get there may not be exactly this, but you have a feel that is bad, then, you should make an improvement right at the at the design stage in vessel. So, now a days, it is becoming and many of the owners are insisting that when you do the design, along with the part of the design document should be the sea keeping behavior as well as the maneuvering behavior and the simulation showing the I M O satisfaction and criteria has been satisfied. I forgot to mention all these things will apply to both port and star boat rudder.

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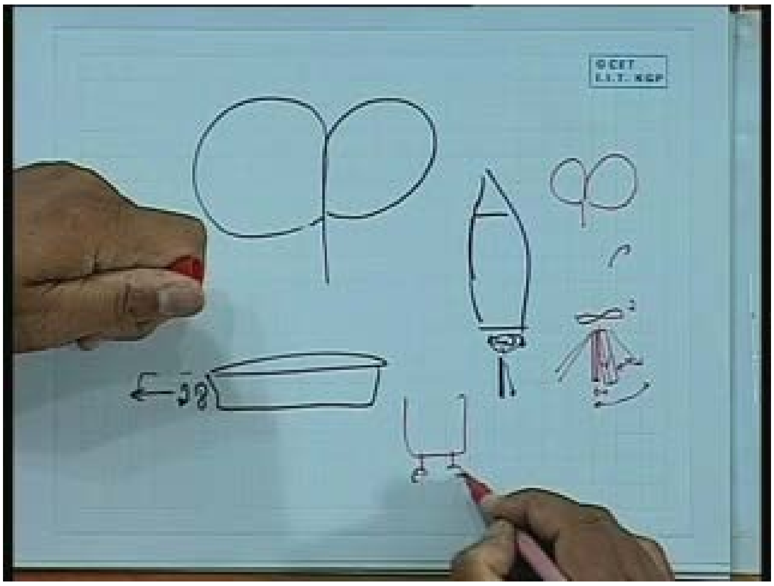

Now, you may ask why port and starboard rudder, that the thing is that, as far as rudder is concerned, port and starboard makes a slight difference for a single screw rudder, because, in a single screw rudder, the propeller moves in one direction. So, the flow that comes to rudder may not be exactly along the x axis, slightly angle. So, there is a bias one side and other. Many people will show you, this simulation, you know, this will look like that and the other side will look slightly different, not so much, but slightly different. They are not symmetric necessarily, so, this rule applied for both sides if it is at. Because, you know that the way it is that, it is the ship here, there is a there is a propeller here, rudder is here, this propeller is rotating in one direction. So, the flow is having slight bias, it is may be coming like that, see if propeller is rotating in one direction. So, the flow is not symmetric exactly along the x axis.

One side it should be symmetrical Now, how can it be symmetric see there is I this is very difficult to draw three dimensional picture,, but see Propeller is rotating here in in this direction, so, along this line, along with, if you take a center plane, if you take a center plane here see if you take a center plane I do not know how to show that propeller is rotating in one direction. So, here the flow is not exactly along this line, it will be slightly having this side you see, because propeller as we mean, two side propellers, there is, if they have got counter balanced. Counter balance. But is one side propeller you see, in fact, productivity is so important that that you have a counter rotating propeller, because, you know when you that is why actually, you some time you must be knowing that you have to give some 0 zero angle. Rudder angle may not be the 0 offset, you might have to give some small angle. Yes just two offset this. So, propeller clock o is turning propeller. Um. Which one will take a bigger circle and which one will take Ah that I cannot often tell because I cannot often tell that this answer ah. Let me know

Yeah let me think that if if you have clock wise turning circle, that is this way and the ship is this side, then the flow tends to be actually bias this side. So, angle of it depends, you can make out from angle of attack, most likely that the the turn on ah.Turn on the port side sir. On port side. I will tell you afterwards, but you I will tell you what you can do is that, you can actually imagine that this is my rudder. So, I am turning it this side, now the flow, if the flow, see if the propeller is right hand this side, there is a tendency of flow to move this way. So, there is a vector will coming this side, more if it this side, more comes here, then this angle will be the 0 setting angle, more or less. That means, you want to turn more this side; that means, for port side, you might have to turn more to get the same radius and star board side may be turn less, you can make it out from that.

See, what would happen is that it is many of thrust that is coming. Yeah no no what I am telling you, that Because of this propeller, let me put the thrust on that rudder. See the propeller is moving in one direction. So, what happened, the flow direction will be average this side, not straight line. Yeah. So, therefore, if the rudder is here, flow will be creating coming on this side and in other words, you can say that, if you keep the rudder at this small angle, Whole thrust this will be the neutral angle. No no turning force will come, therefore, if you want to now, if you want to turn this side, I have to give more rudder here. So, I end up giving say, same angle from this place, which means, more angle from the main line, see this may be 28 degree, means 30 degree from here. So, the 30 degree may be equivalent to this side 26 degree in in other words. Therefore, it means that, if I give 30 degree here, it will turn quick; that means, it will be smaller here, this will be larger here for the same angle, this is what I would think, I am only thinking about intuition, I have to check. But, I think that is how you can you can make out. No, not thumb rule, it is also proven actually. Rudder empirical formulas also tell you the rudder force is different in both side, port and starboard.

Right screw propellers and right screw left screw. Yeah. Sir this logics of vendors propeller is moving that water which comes out its not been the access always it'll decide why actually. Oh that is obvious because something is moving in this plane no see there is a flow here now think of a point here you are pushing at this side then naturally a flow is being pushed this side slightly. By circulating come outside sir. Yeah see it is it is a circulation. So, it has got an axial velocity at this side and a velocity this side see any point is being pushed this side and this side. So, it as effected this way. Resultant will be Yeah you see the fan here our ceiling fan or any fan you you see the flow is in front,, but if you take a vector it is not exactly along the straight line you know it will not be straight line and this is why for a ship if you have a twins screw if you have a this one this way this one always this way always have. So, that it balance. Yeah always. So, it is more stable does

Always always you cannot have in 1 one side, this way; that is always the case. See, the reason of one propeller, professor Mistral might have explained to you, is that, if you have one propeller, it it is more efficient, it contrary to propeller, believe less more more blade area, less r p m, one propeller is more efficient. So, you have this ship propeller, big blade area moving at not very high speed, you know you can even count 100 r p m 1 a second like that.

Back on that rudder part that angle is around hundred degree. Teach yeah. Actually its offset delay here Yeah it is offset that is why the reason is offset yeah that is offset its offset. Sir to resolve the process on one is Yeah. You do the left other is. Drag yeah. Ah drag

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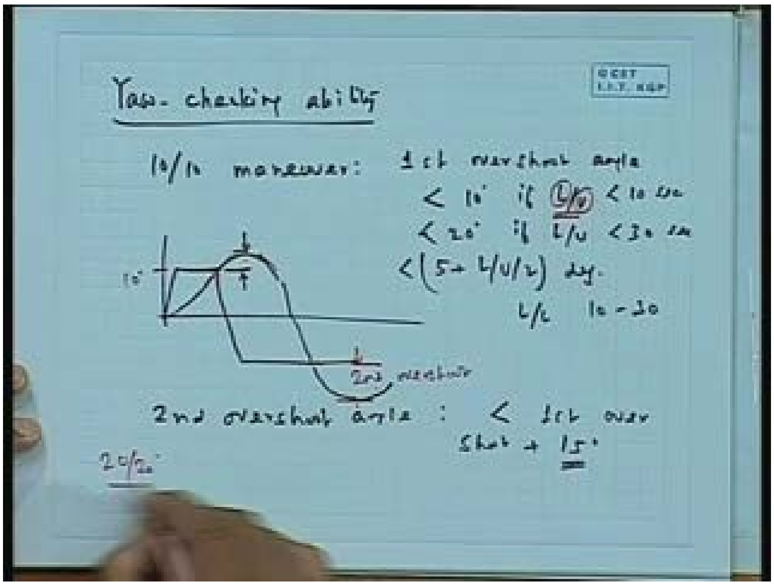

Now, we have got now that comes as zigzag actually, the for zigzag, it is called yaw checking ability. See this two that I mentioned, remember earlier turning ability is al,l both are output or results from turning circle maneuver. yaw Checking ability is basically coming from zigzag maneuver, it says here that, that for a 10 10 maneuver, I am again writing the zigzag maneuver, see this 10 10 maneuver, the first overshoot angle should not should be less than 10 degree, if l by v is, you know, less than 10 seconds. I will tell you about this 1 less than 20 degree, if l by v is less than 30 second and basically 5 plus some, some this is l by v by 2 degrees for l by v, between 10 to 30. Forget this part overshoot angle and also, it says the second overshoot angle. I will just explain to you this in again in a very brief way, the same thing will happen for this. See what happened, you see that there is an overshoot here. As you know, this is my overshoot; the overshoot angle is this angle, see, it is suppose to be 10 degree, at 10 degree heading your chance. So, that is an overshoot, this is the first overshoot, the 2nd one is more, normally 2nd 1 is more after only 2 or so. It stabilizes, that is why, beyond 2, they do not go; this one is a second overshoot angle.

Now, this is, given a stipulation with respect to 10 degree, if l by v is less than 10 second, now, you may say, why l by v. Now, this is actually because, it is found out that, this overshoot obviously is connected to speed also. So, if it is higher speed, you expect more overshoot angle, that is why, they have given this l by v criteria. You see, if you think of a ship fixed l v is increasing, then, l by v is decreasing. When l by v is decreases, then you must have smaller angle, lesser overshoot because, otherwise, it it tends to like heading is less, but the yaw will be more, because, it has less time to go up. So,. So, it kind of restricts the path width basically. So, this is how they have given, because, you you want this overshoot angle. First of all criteria with respect to first and second overshoot angle, second of all, you wanted this overshoot angle to be somewhat connected to length and velocity. Longer ships should have, you know, be allowed more overshoot angle or whatever this l, you know, l by v parameter is here you know and you can make out from their first overshoot, should be 10 degree, etcetera ah. And, my my saying is the the the my my emphasizing the point is that, overshoot angle is obviously a criteria, but as overshoot angle depends on length as well as speed, the the criteria has somewhat connected this with length and speed l by v. You can see l by v is a unit of time, so, l by v becomes actually like a time period. So, you know it is tied with the time period; this is how it is mentioned see.

Let me say about this 20 20 one then, I will, because, we will have more time for that, for the same thing, for 20 20 maneuver. It says, first overshoot should be less than equal to 25 degree, something like that, see again, I will, just because we do not have so much time, I will just try to tell you the logic behind this. What they are trying to say is that, 10 10 maneuver which is more logical, normally, you do not maneuver with a very high rudder angle for 10 10 maneuver. The 1st overshoot and 2nd overshoot angle are specified, your ship must maintain that criteria. So, first overshoot must be something and that criterion is related to length and velocity. You can always workout, you now y l by v etcetera, it is between 10 to 20 degree and in between, it is a it is a this formula is absolutely a straight line interpolation between the two, if it is less than 10, so much more than 30, so much and between 10 to 30, it is just linear interpolation this.

The first overshoot Um. It should not be exceeded; further the second overshoot should not exceed the first overshoot. Yeah see suppose first overshoot should not exceed, now by the say here the answer is say say the l by v is so and so, that the answer is 12 degree. Suppose the l by v are a ship is such that the first overshoot should not exceed 12 degree then, 2nd overshoot should not exceed 27 degree, no 27 degree, 2nd overshoot will always find as large and then actually all these ships, you know, you will find that it goes like then, like that, I mean the this larger here, then stabilizes. It starts quickly, Yeah and now just to quick, we say because, we have to very soon end the same zigzag maneuver. Another criteria is there for 20 20 maneuver where, the stipulation is only for 1st overshoot. 1st overshoot should not exceed 25 degree. Essentially, I want to tell you is that, this is limiting, the zigzag maneuvers ability for the ship to turn, so, it should turn. But here, they are concern about it should not turn, I mean that, the overshoot angles have to be less, which means whether the ship turns or not, it should be safe. See, here the I M O's requirement is not that it, you know, supposing my ship turns very slowly like that, it is a agreed to this thing, it is agreeable to I M O. So, I M O is not bothered if your ship is really sluggish and turns very slow. They only want to make sure it does not turn so fast. Your enthusiasm you have not given such a big rudder that it it well, turning it, heels the bank on the side, that is what they are interested and the last one is the stopping ability. I do not have so much time, but just to tell, there is a stipulation that the ship should stop with in 15 ship length, that is all.

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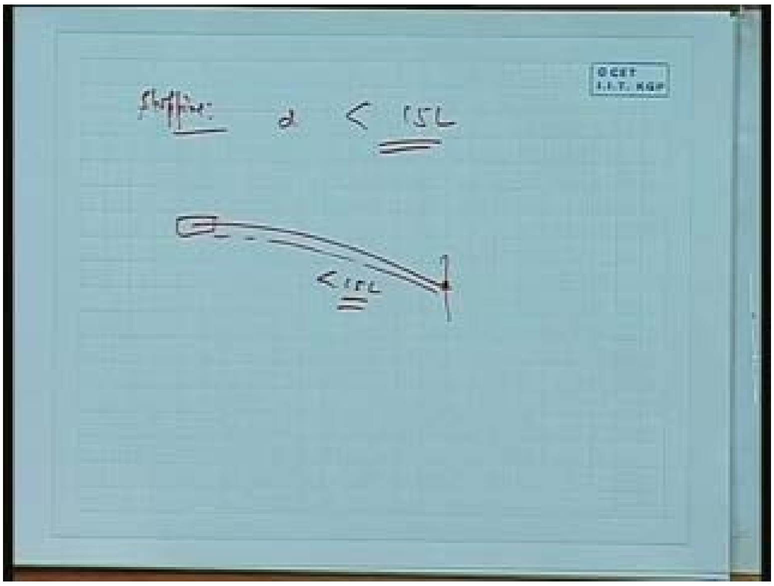

Stopping ability is the final thing, its distance should be less than 15 l actually, but this can be changed etcetera, But basically, if the ship starts, here it kind of stops here, actually it says that this distance, this actual distance should be less than 15 l. Where the v becomes 0, that is again a very you know important for tankers and all, but it says here, the administration can change this, because, for many, very large tanker, this may not work. So, it can be.

Sir it will very down there Yeah so Yeah I mean I will end it here, maybe we can pick up again little bit of that next class. So, I will just stop here for the time now, see next topic.

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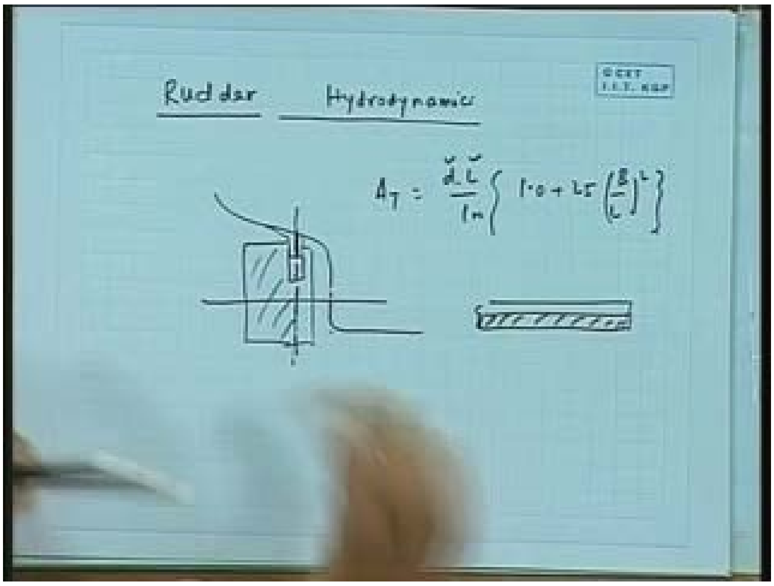

Preview of Next Lecture.

Lecture No. # 40

Rudder Hydrodynamics

This hour, we are going to speak about rudder. But, I call this lecture as rudder hydrodynamics, because, we will concentrate more on this performance part of it you know which is because of hydrodynamics.

See as you know there are various kinds of rudders, I do not want to go into the detail, there are rudders which is which are, you know, like balance, not balance having a post; number of types of rudders are there. Essentially, rudder is a device which you can rotate about some axis and by rotation it causes primarily force in the y direction. This is what you are interested, you want to generate turning moment and turning force, this is what exactly it is. So, if you if you take a rudder, here something like that, it has got a rudder stock, it might have earlier as a rudder post, but as I said I have i've not getting into the detail of the construction part of rudder. In fact, there used to be an empirical formula about the rudder area, also how much it should be. it'll it turns out approximately 2 percent of the central plane area of the rudder. or some other formulas are there, like some empirical type formulas, d into l by 100, something like that 1. I have just give you 1 formula here etcetera etcetera and this various kinds of formulas, it obviously, it is, d by d l by 100 gives you the percentage. you know the d l is the, for a ship, the center plane area, more or less this this area.

So, a t is some kind of percentage of that. As I said, if you work it out, this will turn out to be again around 1 or so, 2 percent or so. The purpose of today's now talk is that, how rudder produces force, how the cross section look like and some detail regarding his performance. So, if you take a cross section of the rudder here, typical see this is a simple rudder, actually rudder will have a many other shapes; it can be triangular, it can be whatever.

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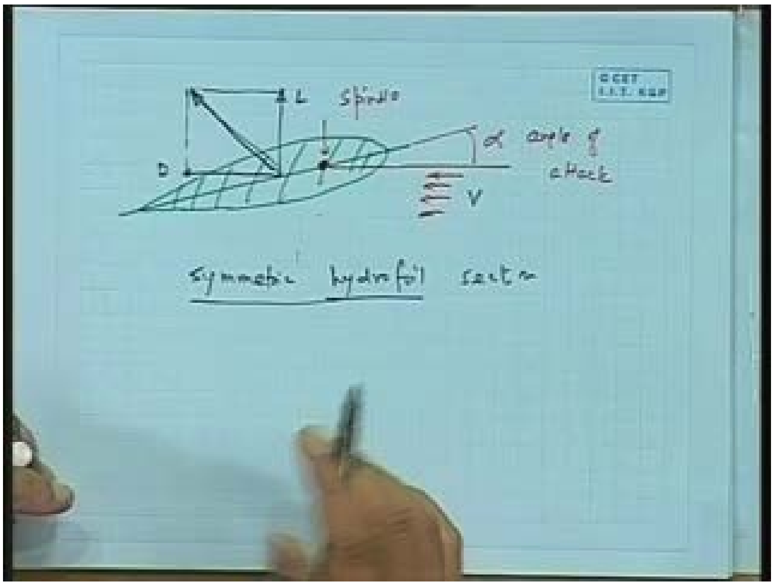

But if you take a cross section of the rudder, here, invariably this rudder will look like a aerofoil section, a symmetric aerofoil section. Let me draw form here, rudder will be looking like a, I will just draw in in this way, it turn rudder it it will have a symmetric aerofoil section. This is a typical cross section if you take and I have assumed that it has been turned little bit it, will be turning about some point here, this may be the rudder stock point or spindle, I can call an axis, about which it is turned.

Now, you have a force coming here, I mean the the axis, let us say, like this. So, velocity comes this side and I can call this to be angle of attack alpha. let me again say, if you take a cross section of the rudder, you see first of all why cross section? For hydrodynamics it is only obvious, because, you would expect the flow along the rudder to be along this line, not having a vertical motion much. So, any cross section you take, you can find out and you can take each cross section, add them up, you will get the total force, more or less. So, therefore, cross section is very logical approximation. I just want to show or tell what kind of forces etcetera, will be acting on that. You will have a rudder spindle here. Of course, this this is a symmetric aerofoil section, let us use the word hydrofoil, this really not much.

It is symmetric because, you know, mostly because, you want it to have same performance both sides, not like an not like a airplane where you have an unsymmetrical, you know, aerofoil. Because, you want the ship to only plane to only go up not down, similarly, propeller, you only want force in one direction mostly. Therefore, it is not symmetric, but in this case, it is always symmetric, because, either turn port or starboard, you want you know equal kind of forces. Now, if you have a velocity coming here v, what happens? As you all know, it is going to produce a force in some direction. Primarily, there'll be a component in this direction, which is known as lift force and there is a component in this direction, which is called as track force ok. There will be Therefore, if I combine the 2 here, this is my net force, sorry, this will be my net force that will come. See, by definition, in aerofoil, there is a force there, you can call it this way that, the net force is this force, say, f.