Performance of Marine Vehicles at Sea

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Lecture No. # 37

Ship Trials and Maneuvers - I

Earlier, we have talked about this fact that if there is a ship here, you have fixed the control, you have studied the mass behind various forces that act on it and try to find out or try to describe the properties or characteristics necessary for the ship to maintain a straight line; in other words, we had tried to find out what must be the hull characteristic - hull's hydrodynamic characteristic - that would ensure that the vessel has some kind of directional stability property.

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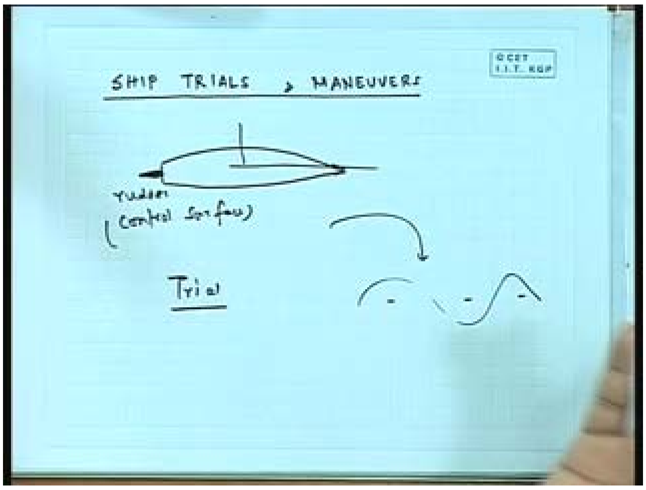

But, in reality what happens is that what you want is with the control surface, that is a rudder - we can call this to be the control surface - with this working you want to find out how the ship handles; there are two things of this handling - one thing is that, if you want to change the direction - if you want to go in a zigzag manner or whatever, you want to turn - you want to maneuver and you want to find out how effective the rudder is; moment you get the rudder - after how long it turns, what is the radius it takes to turn, if I want to change course, how fast it can change - all these characteristics will be so called handling characteristics with the rudder working; similarly, you also want to see that even with the rudder, the ship must have more or less directional stability - should try to follow a fixed path - if you do not want it to deviate.

These strings - that is, its ability to maintain directional stability and ability to actually turn fast - these are all what you can say broadly the handling characteristics; how to check them? Typically, what happens is, when the ship is almost ready or fully ready before delivery it goes on trials - everybody knows that; where you have many tests including a number of maneuvering tests or number of maneuvers; those maneuvers are what are known as definitive maneuvers - means, trying to take the ship in a certain course - this is very common in any vehicle, even car; you will see that in a car they have put some thumps and you have to take the car like that - you have to see how fast it will turn - all this stuff, ship also same thing happens.

In order to assess certain handling characteristics - which we will now discuss…because, there are definite tests and definite quantities to measure; and from there, you can draw definite conclusions regarding the handling characteristics.

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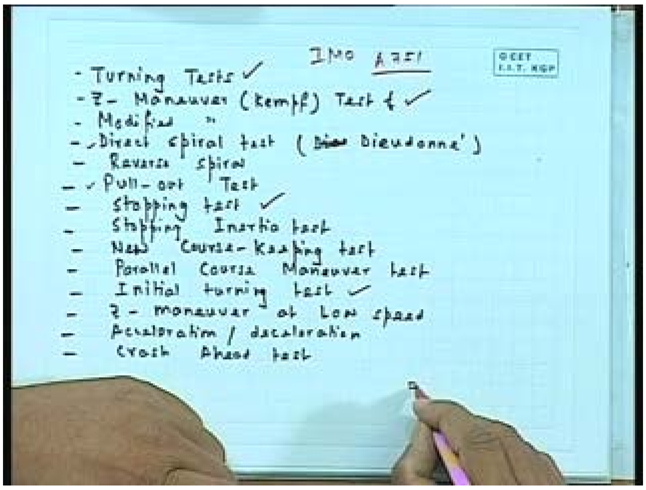

Before I talk about the test - which will be more of a description - I wanted to say that there are many tests possible; I will just write a list of tests that have been recommended; there is a turning test - what is called Z maneuver or Kempf test…I am just writing some of these; modified wave maneuver test - now this is also called… this is…this will be… then dio is a name to it dio sorry d i e u d o n n e; then, reverse spiral, then pull out test -

I am just writing to show you…stopping test (No audio from 5:10 to 5:48)…just a few more I will write (No audio from 5:49 to 6:31); there are some more.

Why I wrote this is - quite small - the reason for writing these is that there can be a number of tests; because, after all by doing tests you are trying to assess the handling characteristics; there can be turning test - called Z maneuver or this is known as zigzag maneuver or Kempf maneuver because see this is the person who suggested that test. There is a modified zigzag maneuver, direct spiral test, reverse spiral test, pull out test, stopping test, stopping inertia, new course keeping test, parallel course maneuver test, initial turning test, Z maneuver at low speed, acceleration deceleration crash ahead and more.

I M O today…various… actually… societies are I M O, ITTC, then Snambe, may be certain law exempted d and b societies; they give recommendations that you must have these tests done and the characteristics must be this, this and this. What is the most commonly accepted - for most ocean going ships more than 100 meters - is the one of I M O resolution; we call it A 751; I think this has been now a superseded by some m s c clause…whatever - it is almost the same. These tests - the important tests - that are required are the turning test, maneuver test and stopping test; in turning test we also have this initial turning part…list one. I am going to talk about this test mostly and also I will talk about pull out test and the spiral test

Now, I will tell you what the meaning of these tests is etcetera; without writing, turning test obviously tells us the ability for the vessel to turn - radius of turn, which is one of the most important maneuvering characteristics; because, you are going in direction one you have to go in, say, direction two; you turn - you have to see how much of area you need to turn - especially when you come to port area and restricted water. What is the radius you turn? We will discuss this test and various measures etcetera; it is for turning ability.

Z maneuver test is zigzag test - it is what I told; it is also done in a car also - you put some kind of like obstacle, take a car and try to see how you can go past it - how quickly he can turn; this is done for a car, there is a name - I forget the name of that for car; it should not topple - I remember this specifically because when this Mercedes small car came up it failed this test; while turning it actually overturned, if you remember and there was a big chaos.

Anyhow, the thing is that this zigzag maneuver test - direct one we will talk about; it tells us the ability for the ship to respond to the rudder - how quickly it responds; if it turns fast means it is responding fast, but sometimes when it turns fast you will see that it overshoots more; if it is turning fast, it will make it turn very quickly, but it overshoots more; turning slowly - overshoot maybe less; both have their limitation; you are going in canal and you want to turn fast, but it might reach the side; you do not want to have that kind of a fast response; on the other hand, you do not want to have too much slow response and all that; but, essentially this is the maneuvering or characteristic of the hull.

Turning test has one more part, which is this initial turning test; because, most ships do not actually turn full three sixty degree - there is no purpose; you are going from one direction and you want to turn slightly - like you are going in certain heading you want to turn - say, ten degree heading - changes the course; that characteristic is the first part of the turning test; turning test has some interesting part of healing during turn and all that; these things - I mean, turning test - and Z maneuver test and initial turning test are connected to vessels ability to turn or maneuver - how fast it responds to rudder.

On the other, hand spiral test and pull out test - these two tests are to find out whether the ship has an inherent instability, directional instability; whether, if you maintain a rudder fixed does the ship maintain a straight line or not; if the ship does not have an inherent straight line stability - what we discussed before - then if you do not move the rudder if you held the rudder fix the ship might go like that; it may not remain in a straight line course - that is tested; the control fix stability characteristic are tested by this pull out and direct spiral test.

Stopping test is nowadays becoming important as you know - those who are in large tankers; you have to stop I M O requirement; is it simply stop the engine, reverse it whatever - it must stop at a certain distance; problem of big ships is that the mass is so large - inertia for this is so large that it keeps going very slowly, but it keeps going it does not move. I will give a small interesting episode on that - icebergs you know I worked in Canada at one time - in east coast - massive size; it can be millions of tons weight; they move very slowly with the current - may be half a meter per second, one knot or so; but, if there is an offshore structure on the path of it - see, there is a big iceberg coming and you have an offshore structure - it will come very slowly, but it may actually just wipe it out and take it.

Very slowly, but it does not get stopped because the mass is so large that…cannot be half m v square - m is so large - it can just take it away; it becomes a problem; just to tell you that mass has lot to do with stopping - in order to stop that big mass you need a very huge force; anyhow, stopping test is done; we will talk about this test - I will first talk of this spiral and pull out test and then Z maneuver test etcetera; how it is conducted, what you measure and stuff like that.

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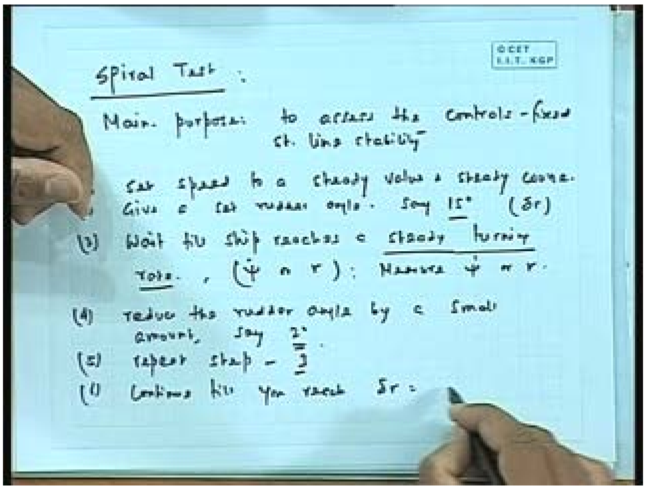

Spiral test - let me go from here, little bit (No audio from 12:39 to12:57); the main purpose of this, as I said, is to assess the control fixed straight line stability - as I said initially; how is it done? I am not going to write the details because it becomes too descriptive, but I will just tell step by step or maybe I have to write little bit, very sketchily I will write down; always, all tests will start with a steady forward speed; you first steady the ship to a certain speed, the trial should be in a position where minimum wind, calm water and all that; as much as possible you should chose a date for trial in a very calm pool of water; no wind, minimum environmental disturbance and at the beginning you set speed to a steady value and a steady course - this is obvious; the ship is steadied with rudder angles same - this thing, zero.

Then, what you do is you order a rudder angle by some amount; then, you order say…let me give an example, say, let me see what an example here - say, fifteen degrees - some rudder angle you give; what will happen moment you give the rudder angle? The ship will begin to turn - you keep on letting it turn; ultimately it will reach a steady state. You are giving a rudder angle - I am calling the rudder angle as d r; you give a certain value d d r, then it is going to reach a steady turning rate because is going to turn steadily; when it has reached a steady turning rate, then you measure the turning rate r or psi dot - let me write here - wait till ship reaches a steady turning rate; that means, steady value of psi dot or r

D psi by d t is steady now or r - the rotational velocity - is steady; that is, d psi by… if the rate of change of heading is now steady; because, that means, it has now reached (( )) is just turning steadily; I will discuss that after wards - the velocity, the rotational velocity has become steady it is not accelerating anymore; then you measure, obviously, psi dot or r; rudder angle by a small amount, say, two degree - that means, the d r is now… actually, what happened? You are setting in the fifteen degree, what you did is that you at fifteen degree you found out what would be the steady rate of turn - that is, you measured that; it will be some rate of turn.

Again, you steady the ship or in fact, at that time after your measurements, now you give an order that the rudder angle is to be reduced; again, you wait and repeat…here actually, say repeat step three; now, this we continue till you reach d r equal to minus d r; that means, you are start at fifteen degrees port, you found r thirteen degrees find r - like that you keep reducing go to zero go to other side go all the way down there; that means, you are basically finding out for every fix rudder angle what is my steady rate of turn. So, you go all the way - I will give the drawing then you will understand; having gone to other, side reverse it; start from 15 degree port go to 15 degree starboard or some degree from there you come back.

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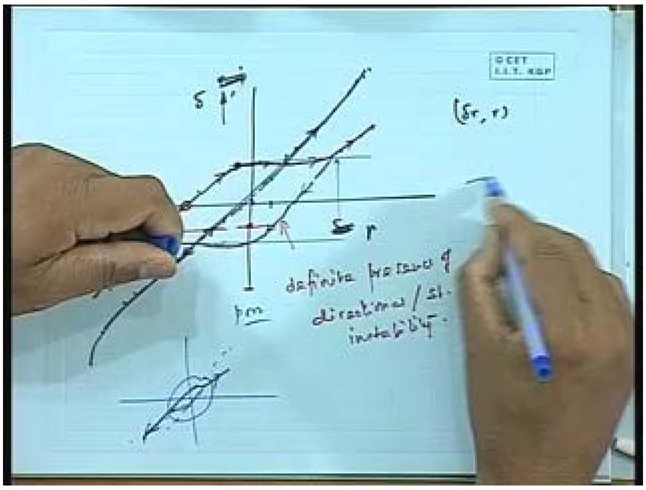

What do you expect now? Here is a plot that you do - here you have got rudder angle d r and here you have got, let us say, r or psi dot - I am just not going to… this thing say ten twenty or whatever you have got. Now, what is happening is that initially the ship was coming in a steady force - some course steady; now, you are measuring… for a given d r what is r? You are measuring d r, r - this set; you are giving a rudder angle and measuring what is my steady rate of turn for that rudder angle - you measure here.

You have got a plot; the plot may look like it is going - like you have got these various measurements - it may look like this; that means, the ship has gone like that and and again you are reversing this way; but, it may also look like…this is r versus this thing, this is star...no, I think this is d r versus this thing we have done; let me find out this starboard side; now, let me change this the other way round - maybe, I do it delta and I do it r here - which is the same thing.

The reason I am doing that is because now other way round we can do; supposing I will give a delta….it turned out that the graph actually might look at some times that it… instead of like this - when you have plotted - the plot looks something like this; I will draw that with a different color; the plot may look something like…I am returning; this is a very interesting part - we must understand this; what have we done? Remember, we have basically given a rudder angle - this side is rudder angle; say, I started from here I give a rudder angle here.

This rudder angle is, say, fifteen degree; so, I found out what is my rate of turn - I found it out; made it small - I found out; I have got these points - now these points when I plot them, one ship shows that the plot goes like that sometimes it is found out, because you are not doing anything you are just measuring it - you find that the plot looks like that; if the plot looks like that, obviously it means that…this is what is called a hysteresis loop - there is a loop there which means that for a given rudder angle - for any given rudder angle here - you do not have a fixed rate of r dot.

Whenever you are going this side when I give my rudder angle so much I had my heading - rate of change of heading was like this; but, when I was coming back I found there is more thing; what happens is that it turns out that when I was going I found this value, this value etcetera; I found out that at zero degree rudder, even that the rudder angle is zero degree the ship is still turning at this point; and at some point - this is found out for many ships - suddenly at this rudder angle I was turning this side, suddenly if you give the slight change it just jumps to the other side.

If you find a plot like that it is a definite that this plot means the definite presence of instability - directional or I can say straight line; because, you do not have a unique one to one correspondence between rudder angle and the rate of turn.

We would have been on the same lines if the….

It should be like, it should be…. see, it should be this one - this stable ship should go like that; if you give a rudder angle - no matter whether you are increasing or decreasing - if rudder angle is fifteen degrees - if I fix my rudder angle… this will happen, for many ships it happens at a small angle; supposing, the rudder angle is kept at two degrees; now, earlier it was fifteen degrees I brought it down to two degrees; then, at two degrees - whether I brought it down from fifteen port to two degree port or fifteen starboard to two degree port - at two degree port I must have the same value of r, if the ship is stable, but it turned out that for many ships it is not.

That is shown by this; when I am turning… this is actually… let us say, this side is - I can say a port rudder - so, I started from port rudder then from port rudder I came down and made rudder to zero degrees, still it is turning; when I got that side now - from starboard when I come back to zero degree - now it is turning on the other side.

That means, my ship… I turn the rudder from this side to zero it is still turning on this side and when I bring it from other side this it is still turning on the other side; if that happens for a ship, that means the ship is inherently unstable; in fact, this loop will tell you that within this range of delta r - a plus minus of so much, the ship is not stable; if you keep in… what it means is that within this rudder angle you keep the rudder somewhere - fix - you do not know which side the ship will turn; it is not zero - you give a zero rudder, but it is still turning in some direction; this is a… it happens to many ships, in fact, it is very classically proven that if you have that stability index to be not satisfied, this will happen.

This is a very a big curve; in many ships the actual curve will not look so big; it will look something like this - the plot will look like that, it is a small thing - it will look like… this is not… I mean it will look…a small hysteresis loop - it will look like that; there will be a small loop….in most ships it is found out that for a small rudder angle - may be plus minus t degree or so - the ship may have no fixed…. like a delta r and r correspondence.

So, bigger the loop or why does the loop… more unstable, obviously; if the loop is ten degrees plus minus - within ten degree rudder you cannot control it

Coming in a straight line…

Yes, obviously you would want the ship to be straight line of course, but the question is that whether these ships can also be corrected; what happens…there is something like this - rudders effectiveness normally with small angle - say, plus minus three degree or four degrees, whatever - may not be much almost as if the force coming on the rudder is very small; so, even though you give you give three degrees rudder force may not act as a correction force

Let us say that the ship is inherently unstable; it means, that it has a tendency to keep shifting from one side or another; is it… you are not… a smallest way which keeps turning - by giving rudder you are supposed to correct it; but, now what happens is that within plus minus three degree or four degrees the rudder force that you can give is so small that it cannot correct it, which is why there is a hysteresis loop. It cannot happen that the hysteresis loop is very big; that means, that the ship is simply unstable you would not accept it, but…

Suppose it should actually the when you give rudder it should actually does

That is what I am trying to say - many ships you do not have that; it is….this is…what you are saying is true, because almost all ships that you design would be always having directional stability, but there can be cases where it is not directionally stable and in a small angle - small loop - it may not be there; in fact, that is the proof - you must have a ship… by this test showing this - it should not show like that.

So, what are the factors that cause loops?

The standard instability of the ship - that straight line…we…you are asking this question and I will answer this question; you think of a simple case in an analogy - you have a… an arrow… you are throwing just an arrow - no weight is given no feather is given just throw; it is not going to keep a straight line it may actually go like this and like this -

fine; why? Because, it turns out that as it turns here there is no corrective force; now, you give a rudder… if you actually give here a tail fin it tends to correct it - rudder does the same thing.

Supposing, I had a body which is inherently unstable and if I give the rudder, then it will try to correct it; rudder correction is how? By giving a rudder force - that force is more and more as the angle is more and more; so within a small angle it may not be able to correct it; inherently, if the vessel was actually stable - like if I put a weight in front - then the error would be stable I do not have to put that behind; what I mean is that it is actually difficult to explain more way, but you can also see that normally if you want to push it there, there is a tendency vector turning; you may not be able to maintain a straight line because know many forces are coming, because you are pushing from behind.

Sir the movement of the ship influences the rudder again

No, it is not…let me explain this in…

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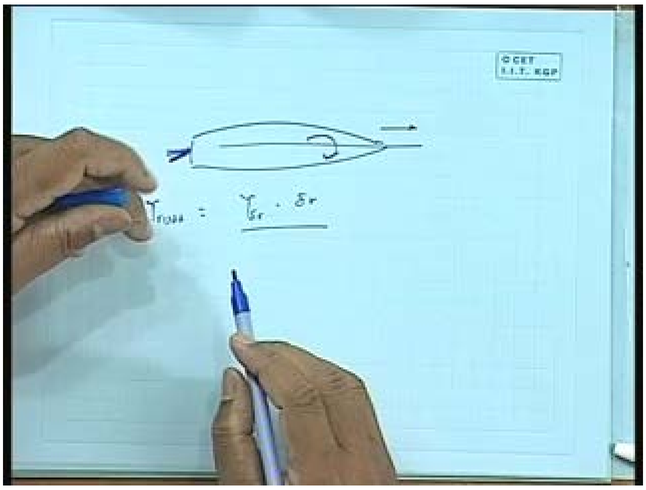

No, I will tell you a little more…the explanation…here, you have a ship without the rudder - you have this ship here - I am not putting the rudder I just have the fixed rudder; what I said is that if this ship moves here - fine, but suppose it has got slightly turned by one degree; as it gets turned by one degree there will be forces coming on the main hull - various kinds of forces - that we discussed earlier; those forces may want to bring that one degree to zero or might want to bring the one degree more.

It might actually induce some kind of a motion rather than bringing it back; suppose it does bring it - increased motion - now I have to correct it; I correct it by applying rudder - I give a rudder and then apply; let us say, that instable force is so large that by giving one degree rudder it cannot be corrected; then, within one degree…. or let us see it cannot be corrected by giving say up to plus minus four degree; I can say that… because, rudder force - y rudder - is after all y delta r into delta r; that means, the force will be more as the rudder angle is more.

When you give a very small angle of rudder, the rudder force which is supposed to correct it is not sufficient to correct or make it stable; if the ship has inherently… supposing the ship is trying to go…the forces …when I say very highly unstable means that with slight disturbances it will just turn; it means, that with slight disturbance the ship tries to turn and then destabilizing moment is very high; it is the same as saying that the g m is very large negative instead of large positive.

If the g m is - you think of it - if the g m is positive, it is stable and if g m is negative it is unstable; when you say negative unstable what happen? As you turn it, it gives a turning moment - how much is the turning moment? It is mass weight into g m sine theta, let us say; if g m is negative, the turning moment is in the same direction, but the magnitude is to be decided by the amount of g m; if g m is much larger, then the magnitude of instability is much more; supposing the ship… therefore, you see…tends to turn that if I have to put it back I must have equally large correction force

This is what happens - if the ship is very unstable then it simply tries to turn too much for a smallest disturbance and the rudder correction force you need has to be that large, which can only come if the rudder angle is at least up to some angle; this is what we are coming back to that here - this shows that within this rudder angle the rudder correction force is not sufficient to correct and make sure that a rudder angle gives a unique a rate of turn; the smaller it is, the…you can say it is still unstable, but the range of instability is small.

Yes.

Therefore, this exists; first of all - exist - if no loop existed by this test you know that the ship has directional stability with control fixed; if it has a loop then it tells you what is the extent of instability; in fact, I will tell you this interesting example that I recently did myself - calculation for maneuvering characteristic of a passenger vessel and it has got instability - slight; and we proved by spiral test that it is within plus minus some rudder angel - the instability is there

It is not unacceptable, because if it is within very small angle you can corrected by rudder - so, it is not unacceptable by practice; I M O does not specify that specifically, but they tell you that you must establish the extent of instability; this is one of the tests which will tell the extent of instability and we will talk about the pull out test now, which is another test which will tell you the extent of instability

This test… if you look carefully - description wise - is simply to find out the relation between rudder angle and rate of turn; rudder angle delta r against the rate of change of heading - you can say the rotational velocity; is it one to one correspondence or not? Stable ship should have one to one corresponding - if you give a rudder angle ten degree no matter whether you got 10 degree from 20 down to ten or from 0 up to 10, whichever way you moved if you give ten degree rudder angle the ship should turn and keep turning in one side.

But, here it turned out that some ships when you have given twenty it was turning in one direction then you bring it down to ten it is suppose to reduce the turning from that side to lower down to…let me give an example - if you are giving a twenty degree rudder angle, let us say the ship is turning in one direction at the rate of some radian per second - say, 5 degree per second, this turning.

Now, when you bring it down to 10 degrees it should reduce down from five degree to two degree per second; think of the fact that the ship was not having a turn - it was zero in the first place; now, if you are giving from zero to the other side ten degree, then from zero it should have gone to that that two degree per second - it does not go; it goes in some other angle - that means, it is not stable. Depending on from which side you have turned…you take of a car or any other vehicle you turn from this side and it takes this line, but if I…. actually that angle from other side to bring it back it does not - it shows an instability.

Do you get my point? See, it… the initial condition from which you start it…

Balancing property.

That may not - yeah - it should be perfectly balancing, but it is not; as we have shown in this diagram - if you started from ten degree port and got down to zero, you are having a turn; if you started from ten degree starboard and got down to zero you are having another angle, because initially it was moving in that side it is supposed to come to zero, but it did not yet come to zero.

It should be in centre, whatever…

It should be zero.

Yes.

Stable ship should be zero - it should be unique delta r and r relation.

So, but with the end lenient and then come through the statement.

That is what I am saying, that for some of the ships when you do that it does not; you wait for any time - it does not; this is what you are saying it should be…yes, a ship should be like this and most of the ships you have traveled in would be like that; but, it is possible for a ship to have also this.

Even after making all the designs…

Oh, yes, it can happen in… there are ships in which it does happen; in fact, there are unique cases of certain design characteristics by (( ))… when it happens you put a keg - standard thing is that you put a keg behind then that will correct it for many vessels and if you do not put a keg it may not correct; it also experienced in small boats some time - where you want to turn it fast and if you want to turn it fast it has not - lack of stability.

I will just tell you about this other test - pull out which has a relation to that; pull out test is the same thing - pull out test has got… I will simply tell about the way it is done… time versus…(No audio from 35:20 to 35:34).

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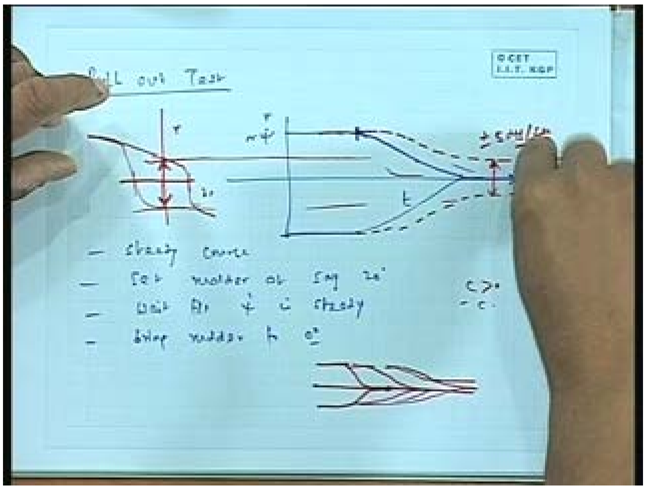


Pull out test is very simple, you know how? First of all - same thing - initially, you have the ship going in a straight line then you give a rudder angle - twenty degrees; so, you give steady course; then set rudder at say, 20 degree or whatever some angle; then wait till psi dot is steady; it means that, you have given a rudder angle twenty degree and the psi dot is steady; so, psi dot has become like that - a straight line; you are measuring with time, then when it is steady for some time bring rudder to zero degree.

Do you understand? This is a very interesting or the other kind of test… you are turning you are turning and you have got a rudder angle of say, twenty degree; the ship is turning steadily as it has reached steady turning rate that is transient have gone it is turning steadily; bring the rudder angle to zero - what should happen?

The vessel is supposed to come back to zero degree; now, you see the two or three things that can happen - the plot may show… here you brought it to zero degree say, rudder so the ship will begin to - heading rate will begin to come down; eventually, it should not change, but it turns out that for some…. it can be like that; but, there are some ships you may find out that the graph goes something like… my numerical summation also shows very nicely this; you do the same thing now for the other side; that is, take the ship again change the - start the rudder from the - this was say port side twenty degrees you start it from starboard side twenty degree again steady it; it can… becomes like that or it can become….

This some of to under steer

No, you not under steering at all; because, you are bringing back to zero degree - this is what is happening; it is something like this - you are turning your car then you bring it back to zero degree as you bring it back to zero it should go straight line, but it is not going in a straight line.

You will give more… other side little.

Yeah.

Right, what is happening is - if you see that even though you have given rudder zero degree you are still having a rate of change; the ship is still keeping on turning in one direction and in that direction I was turning; it was turning in one direction one, so, you want to bring it back; initially, it was turning like that, like that and like that - you bring it back to zero, but it still turns at a lower rate; so force is not quite enough to make it - in zero degree it does not turn; if this happens, this is actually…what happens is that there is a definite that… the spiral test that we talked about - this turns out to be related to that that loop .

If you see - I mean the other way round - because this r here delta r here; this width of the spiral test is exactly same as this width, because it means that within this width the ship is not stable; within this width means what? The rate of turn plus minus so and so. This is a rate of turn - let us say, this is plus minus, say, point five degrees per second; within that rate of turn you do not know what the rudder is or where the rudder is and how it will behave.

In other words, the ship's rate of turn up to five degree - in here, the rate of turn - the ship is unstable in the other case you can say that it is this…within this rudder angle the ship is unstable; in fact, this happens and I can probably show you later some simulation results that I have carried out myself and is very interesting, because you can carry out this simulation by solving this say maneuvering equation in time, etcetera.

If you have this c - that stability index - negative you find out it has got this, if you have this as positive it just comes like to this; only thing is that if it is like…. just that, if it is very strongly positive it will come much faster here, if it is just positive it will come like that and if it is negative then it will try to have a spread.

It goes like this - if the ship is very stable it comes like that and very fast means that it will come to zero; if it is less - but, still just zero…suppose that c - our criteria - should be zero; that is, if c is just point zero zero one, then it will become like this; it will come to zero, but after a long time and if it becomes negative you will find that it becomes like that; what I mean is that, this is a very interesting…you can in fact establish from a simulation; the only problem in simulation is that in simulation you have to feed or estimate those hydrodynamic derivatives - those forces; and there is no direct way to so confidently measure; whichever way you measure, people do not trust it.

We do not have time in this course to discuss how we can establish those, but if you can establish those you can actually simulate them; it is becoming more and more popular now a days in marine field to have a simulator - to find out simulated behavior of the ship under various conditions; some ports also are exist in port area because they want to see by your simulation that if you give a rudder it is going to have this much turning; I M O also requires that - what we are talking about here is that the test, by definitive measurement - that means, the ship has been built already - you go to the trial, you do this test and therefore, assess the characteristic of that.

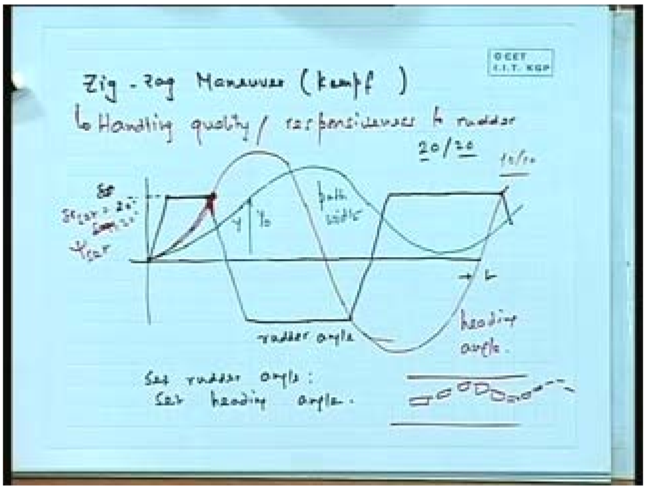
If you find the ship, what I showed here - in the trial it is like this and it has got instability; you come back, the owner's representative will tell that I am not going to take your ship - you change the design; you will have to increase the rudder or you have to put a keg, you have to probably shift some weight or you have to do some design modification, perhaps.

Because, they may not accept so much of large they might have want to reduce it; of course, this is not connect to I M O - I will talk about the I M O requirements, which is of course mandatory requirements - the rule requirement; so far they have not said this, what they have said in I M O is that in case the ship is unstable you must assess the extent of instability by pull out or spiral test; that means, tell how wide this is - more wide means more unstable.

More unstable.

Bigger means more this thing; this is a basic idea I am going to shift to the zigzag maneuver now, because we will be going out of time otherwise; zigzag maneuver is a more mandatory requirements so I want to talk about that.

(Refer Slide Time: 42:54)



This is also called Kempf maneuver; again, this is an interesting maneuver because this maneuver is essentially to prove whether the ship is going to be…how it handles the rudder - one can call it responsiveness to rudder; one can call this - to characterize handling qualities; I am writing it fast, but without writing too much detail; this is to establish the zigzag maneuver - how the ship handles, when you change - give - rudder angle or how fast it changes direction, etcetera; how responsive it is to rudder action.

For example, if you have a small ship with a large rudder you give a rudder to immediately turn; if you give a small rudder in a big tanker it may not turn at all; basically, it is to establish that characteristic - how it will handles; in fact, how its maneuvering qualities are; as you can tell, if the ship is too much directionally stable then obviously, you need large force to turn it; even if you give a small rudder angle, the ship just does not turn; directional stability and a zigzag maneuver has some kind of a reverse interest; I will simply tell you, instead of…the steps, that probably you can write down.

How do we do that - how is this test done? This zigzag maneuver is done with two angles; normally, the you call them to be twenty, twenty, twenty and thirty - I will tell you; these numbers - say, or twenty ten or something - there is a what is called set rudder angle and set heading angle; what you do…when you say twenty twenty it is set rudder angle twenty set heading angle twenty, etcetera - I will explain that; when you see the diagram it will be very easy; you always start the ship - that you can write it down - at steady speed; everything is fixed and you bring the ship in a course- straight line course

- speed is set, engine is set and that is it; now, the test has started - t equal to zero; you do not change engine setting and anything anymore, just set the engine like that.

t is zero - this is my t axis; you give rudder angle now to this set angle; this is my rudder angle - let us say, d r is rudder angle; rudder angle goes to zero they say, set angle is say twenty degree; obviously, it takes some time that is why this crop is there; you cannot give a rudder angle instantly - there is a rate of turn - three to four degree per second or something like that; it takes…you cannot turn it instantly; that is why it took so much time to turn it - keep it fixed.

What would happen to the heading angle? The heading angle is now going to…. the ship was having a zero degree heading; it is going keep turning and now it keeps turning; the moment the heading angle has reached this set heading angle - in this case this is twenty twenty - so, this is my set heading angle also; delta psi I say is also twenty degree; delta psi say, set heading or…. no let me call psi set; psi set is twenty degree, similarly I can say this delta r set.

Just understand for the sake understanding - there are two set angles; when you do twenty twenty, you are basically giving the rudder to the set angle and fix the rudder at that angle - twenty twenty is very common; twenty twenty and ten ten are the recommended… that is why I mention it can be also ten ten - whatever way it is, first one is the set rudder angel you set it to that angle, wait hold the rudder; ship will begin to turn - as it turns here it will you measure the heading angle it reaches now set heading angle; at this point what you do is swing the rudder back to minus twenty degree and then hold it fixed.

Opposite twenty

Opposite twenty - minus twenty; this diagram should be here - in a same point I…anyhow, this is the same point - this point; what would happen? The ship is… what would happen is that the ship was turning this side so, obviously, it is going turn back; so, it is going to basically go like that and then it begins to turn; in fact, at this point you can also measure the path width; path width means, it is going to the… it was going on a line - why it is going to go like this? This is may, y; y direction means the distance - the pathway - it goes like that then, of course, it also begins to come down

Then what you do is, again as it reaches - as psi dot reaches minus twenty here - just do the opposite; just reverse it again back to plus twenty and hold it fixed; this is going to go up again and down again; eventually it is going to begin to turn again on this side this is going to be like this - again, at this point you turn it back; we do not have time for this now, but…. and then this also your are measuring; this path width - this will also… actually it may go like something like that; this is my say, y zero or path width… I will tell you…

This is my - black is rudder angle - this is my heading angle; I will very soon stop and pick up from that; we unfortunately did not have time; therefore, it is like a zigzag - you actually steer on one side as it goes to that much heading you turn it back - swing it back - as it goes back to that heading you swing it back again; you keep on turning like that.

You can do that for long time, but normally two or three swings are good enough; because, eventually it is supposed to reach a steady state and you keep measuring the rudder angle, you are giving and the heading angle and of course, the path angle; because, what happens is that the ship is going and if you see a canal the ship was going this side, then it would come to this side then it come back again it will come back it will keep on going like that - the ship would.

I will discuss that - this is the zigzag maneuver; we will stop here; in the next lecture, I will pick from this diagram, because the time is up for this one and see what we measure and what these measurements mean.

I will stop this part of the lecture, but we will pick from this diagram in the next hour .

Preview of Next Lecture

Lecture No. # 38

Ship Trials and Maneuvers - II

We will start; this part of the lecture also is continuing on ship trials and maneuvers; I will start again from where we ended in last class - zigzag maneuver; now, we understand the maneuver - what we do - we turn the rudder keep on swinging and you measure that; what do you measure? Here at these quantities - this is what I should write down; let me see these terms here or…

This point will be called, first execute; because, that is the time first time that you are executing the rudder - first time that you are actually… at the this time - this is t here, right? This is the point of time where you have made the first execute of rudder - you have given the rudder angle to be plus; this point - this time - is the time for second execute, similarly here - third execute, etcetera; the one two three executes are the time when you have…

Changed the rudder.

Changed the rudder angle.

Important thing that you find out is this - what is called overshoot your angle; how much it overshot - it may overshoot…. there can be a ship which can overshoot for this thing; these measures…this is my first overshoot, this is my second over shoot and like that third over shoot - you understand? Obviously, I had given rudder angle twenty degree I would expect that the ship would reach twenty degree or you know… sorry, rudder twenty and my set angle is twenty degrees.

As soon as I set my… heading has reached twenty degree or that set angle at that time I have actually swung it back; it should have come back immediately - started to change - but it did not change, it started changing in the same direction for some more time and then came back; how much more time it has same… how much more angle it turned is my overshoot yaw angle; for the first execute - first one, second one - second one, like that.

Then, comes a question of time - this is called… I can also call this yaw overshoot; yaw - same thing - my yaw was at this point when I have my execute; say, at this point I change the rudder, my yaw - my ship - would have started to come back on the other side, but it did not; it started going in the same direction for some more time; so, this becomes my overshoot path width; how much it over shoots - think of a canal, if there this is a canal size it has come here and at that point I have given a rudder back; it should have come down, but instead of that it kept on going some more time - distance wise.

Always, overshoot is the maximum that it has reached from the time when the rudder has been reversed; because, we expect that… you know car and all rudder is reverse back they may instantly the ship would turn on the other side it does not happen for a ship; it keeps on going in the same direction for some more time - that is what is called over shoot; this is my first path with the over shoot; then also the question of time is coming; this is the time - this time is known as reach; then there are the time of period it is actually time from this to this - one swing to other; it has become complicated, but I will just show it to you by description - this can be called period.

Let me explain - not go into so much detail, because ultimately the over shoot angle is… what actually is the I M O requirement I will tell; understand that basically what you are measuring is…you keep on changing - turning - the rudder this way and that way; you find out that the moment I change the rudder, after how long - number one, the ships heading turns back and comes to zero; and how much more it kind of keeps over shooting in the same direction.

This over shoot tells me how much it will keep over shooting - heading angle as well as path width and what is the time taken; you will you will find out that if you… it is something like if you want to reduce this time - that means, it should very first turn you will see that the over shoot is more; it is like somebody squeezed this graph from this - like you have a body and you are pushing it.

So, it is either… normally you will find that it turns very fast or it goes like that - you can imagine that; if it responds very fast with rudder - I mean, the moment you give a rudder there is a force there, it would actually go down here and it will want to turn, but it is already gone so much it will go like that and then turn; typically, you will find that if rudder is very effective then overshoot goes up and the time comes down because it is turning very fast, but then you do not want see in reality - you may not want both together, because if overshoot is too much it might reach and the reach the bank.

You always want a kind of balance; that is why to say overshoot is… to say, rudder - huge rudder - I will keep, it immediately turns, but it may turn just hits and turn like that - you do not want it; I M O requirement will actually come up with various kinds of measures; I will tell you again from this diagram - you probably should write this down; reach will improve with rudder effectiveness, means this time - how fast it will come back, how fast it turns and the quickness of turn - obviously will be more if rudder is more effective; will be less if the ship is very stable directionally, because if it is stable directionally as in some book I read - it is like a dogmatic mule - it does not want to change it just wants to go along a straight line.

Therefore, it will take a long time to turn it back; this reach will be… this will come down and it will get stretched this side - the full thing will get stretched this side; yes, like… as if you are holding and stretching this graph; if the ship is directionally stable and rudder effectiveness is less; on the other hand if the ship is directionally less stable and rudder effectiveness is very high - then this gets squeezed back.