Performance of Marine Vehicles at Sea

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Lecture Number # 36

Hydrodynamic Derivatives and Stability Criterion - II

We will continue our talk on the same topic - derivatives stability criterion; this is the directional stability; again, I will just bring back my last class…last lecture's slide.

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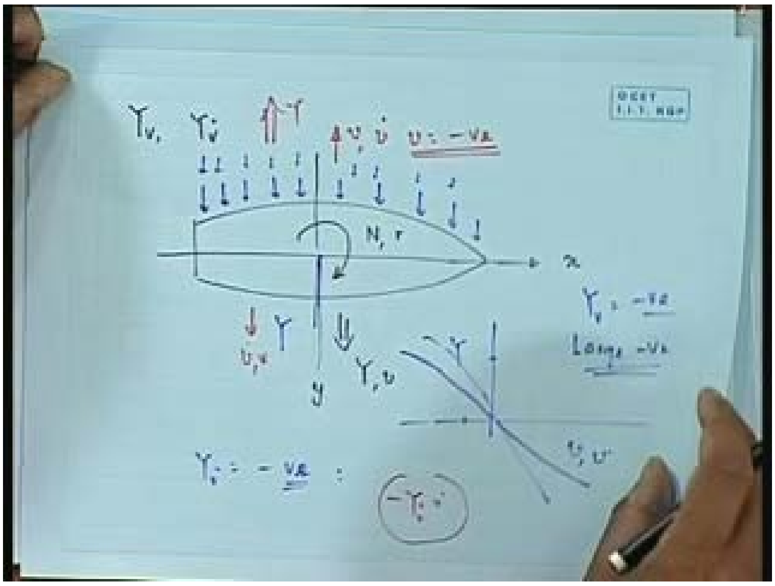

The reason I want to bring it back is to tell you about what we were talking - that, whichever direction you give v and v dot…see, normally what happens is if you give a velocity in direction one then the y is going to be in opposite direction. Give you motion in v v dash direction would be opposite direction; therefore, number one is that both y v and y v dot are (( )); see, this and this both are negative - that we know.

Sir, why do we have two negatives?

Oh, why? Now I understand your question - why am I taking negative? You see, if you give plus y it gives - no, rather I will tell you this on the other section; plus v gives minus y minus v gives plus y.

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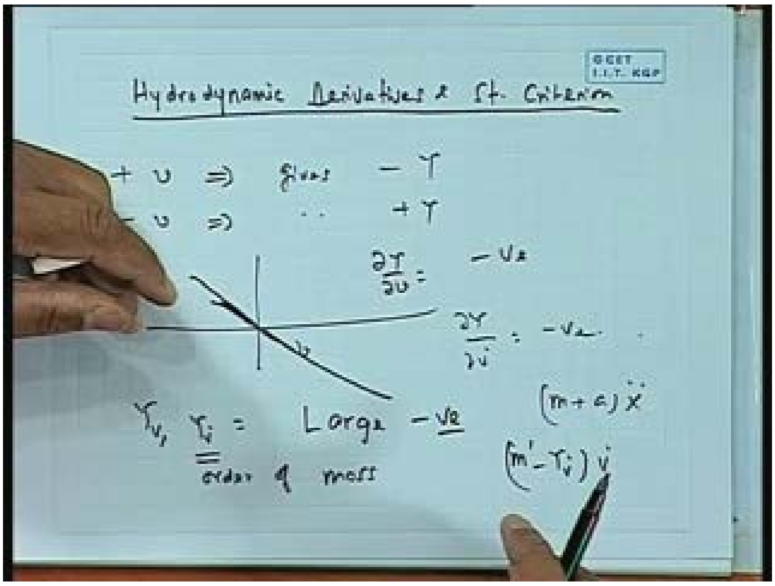

If you do a plot here - v and y - the plot will look like this and like this; this slope d y by d v is always negative - minus by plus or plus by minus is always negative; that is why… similarly d y by d v dot is always negative - this is why it is always negative; not only that, we know it is always negative it is also a large negative.

Large negative.

It is… I can say that y v y v dot is large negative; in fact, this is of the order of mass, because it is added - it is sway moment of linear; in fact, that equation is written as m dash minus y v dot v dot; you would have actually…it is interesting because you would see now it is… our other equation was mass plus added mass into acceleration - that was the equation; this has become the added mass - minus y v dot is added mass - not y v dot; y v dot is negative so minus y v dot becomes added mass; analogically, if you compare with heave and sway and all…if you look at their equation of motion… if you actually look… I will just give more examples.

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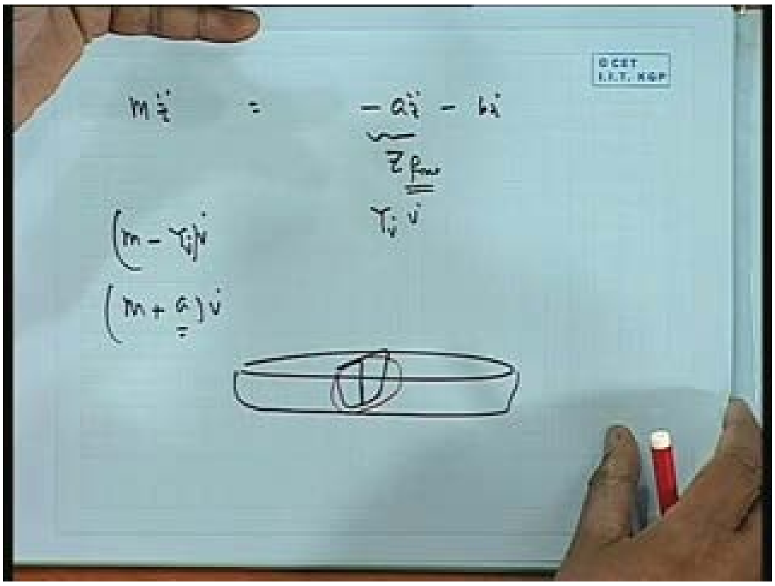

Here, we had got m z dot dot equal to minus a z dot dot minus v z dot etcetera - these were my radiation force; radiation force was minus - minus a z dot was the radiation force - this was my so called z force; when I brought it back this side it becomes plus; here, my z force is actually y v dot v dot; that a is minus y v dot, that is why when I bring it back this side I end of getting this minus y v dot v dot v dot; or, same as….you can say a of eta; the analogy is like this - if you see that y v dot is minus or negative added mass in that direction particular and added mass in sway and heave are very large so this is a very large number, but it is negative now.

Order the mass? Order of this mass? The theory is like this - if there is a ship here, the added mass is equal to almost…like, water of this circle and if you take this cylinder you it will be…you can imagine that that volume is almost like a mass of the hull - if you take a cylinder; it becomes…obviously, it is what exactly mass may be - point nine nine point eight time even one point one; in a heave it can actually be twice the mass in this direction, but because the ship is not…again, a dipper ship - like a frigate - we will have a much larger y v dot than a very shallow river boat, which is…

Dive surface is more.

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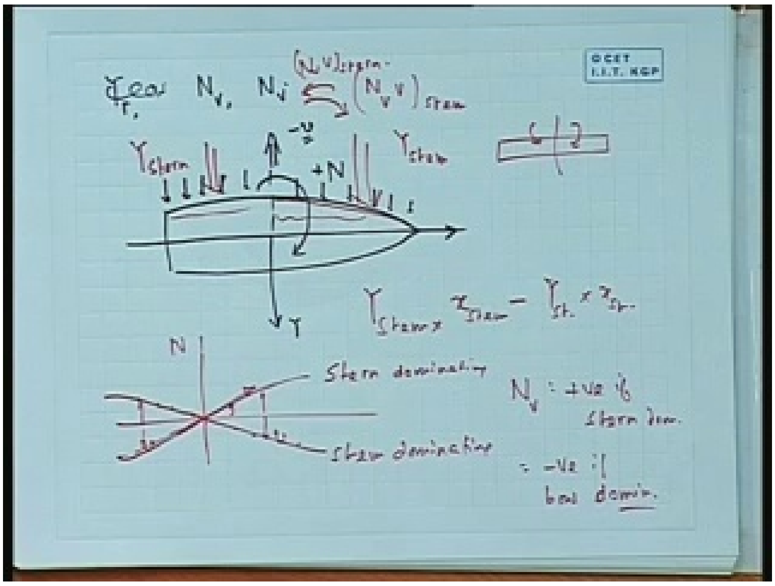

Yes, exactly, that surface…the depth is much more so it is going to push much more; we have got this y v y v dot, now let us see y r y r dot or…let us now look at y r….let me see … we have got two directions v r v and r and two values y and n; we have got y and v, we can do n and v now; let us say n - n v and n v dot - let us let us do this one; again we have to go through this equation, but here we will just write - this is my n - plus n .

Now, I give a v - let me assume that I am giving a v - in any direction I can give - it is easier to think that I have given a v here - negative v I am giving - again it is going to give pressures; you can…here I…we can make…this part - this stern part - I can say…we will have something like y stern; I can assume that this is something like y stem.

All these added up together you can assume… when you add all the pressures on this space there will be some pressure and let me call that to be the net y force is y stem and this pressure is y stern; what is happening is that this n is going to be y stem into this distance, say, x stem minus - because, this is a plus one this is going to be giving a negative - y stern into x stern.

This part is going to give me a moment on this side and this part is going to give a moment on this side; they are opposing in nature; in fact, if this was in exact cylinder, then this and this will have just balance and there will be zero value; here you have got stern and stem coming, if the stem dominates then you have a plus number; stern dominates, then they have got a minus number, but, it is basically, first of all small; so you what are you going to get here?.

It is that v here, in our case it is negative v that I have given; the negative v would give me a positive n provided the forward dominates; it going to be something like this or it can be something like this depending on what is dominant.

Supposing my…this dominates; my negative v would give me - this more than this so negative - this will be my stern.

But this y intersection will taking at the exact center sir

No no no no no I will just explain that here.

Sir, then automatically this length will change.

No, I will tell you; what is happening here is that this….I am getting n v v; here they have given actually v - I have given a negative v, remember; this I am going to get here - n v into v stem, because this gives me this way and this I am going to get here - n v into v stern; if this one is more than that then I have got net negative value and if this is more than that I have got a net positive value; what is happening ultimately?

Just think, that suppose the stem nominates then I have got what? A net positive value for a negative v; I have got a net positive value - this n value, net positive value - for a negative v; the graph…or net negative value for a positive, so the graph will look…the points will look like that.

On the other hand, if my stern has dominated then I have got net value of this side, which is negative; I would have got the entire thing turning on this side for a negative v; so, would have got a negative v giving a net negative this thing; that is, I would have got this value which means positive is positive - I would have got this line; I would have got this line as a slope - that means, I would have got n v positive if my stern dominated and negative if bow dominates or stem; this is what we are getting and both the cases the number is small, because obviously there this is a counter play of stem and stern.In case it is in exact symmetry, say, cylinder…you take mid ship this basically is going to be zero.

Sir what you find outs that this intersection of y axis y.

This line.

Should be always it should be always near the this line.

Yes.

This shows the center of gravity.

No sir what I have think. So, this part is heavier half part. So, the water acting this portion will be always tend to between more than the…

No no no no no that is no.

Next of the stem, next of the stern.

Ok.

Next of the stem should be always shorter No no.

No no that what you are saying is that the that no that is not always true; what you are saying is that this is always smaller than this, that is what you are saying; may be many for many ships, but it is not always true because sometime there is a rudder plate that acts - then, this depends on the center of gravity; mostly, if you take a ship c g may be around mid-ship, approximately mid-ship; so, the length part is the same; how do you say bigger? Because, it is a frontal area it is not the width of the hull; it is not the width of the hull - let me try to explain this; there is a ship here, it may be thinner and this thing, but it is not this with that matters; it is its length - this part and this part matters.

Yes, if this is more or less similar then you will have more or less the same number, because this is almost…you get plane; the fact that it is bigger here and this becomes thinner here does not really - necessarily - contribute; in fact, there is an interplay because what happened mostly is that you might have a bulb here, so it is goes up like that, but on the other hand you have a rudder here.

Sir then how is then we can take that this will dominate this.

No, you do not know - no; you are not…no, that is what I am saying; this can…good question - this case...therefore, you cannot tell - this is an ambiguous thing, it will be a small number - either positive or negative - you cannot tell off hand, no; this is what we are to determine experimentally or as a characteristic.

If you could tell all of them, then you could have told without any calculation that the ship is stable; so regardless of what the ship, you can say conventional ship is stable, but we cannot say that, there should be some ambiguity and this is one of this; you cannot tell like that - this is only to tell you in a qualitative sense - just in a qualitative sense, that this kind of term... but you cannot tell if it is positive or negative, unless we actually did a calculation for a given ship or you did some experiments for a given ship; many timea what happens is… you know - you can find out later on that everybody knows that you put a scale here - that is, you try to increase the area in the stern in order to make the stern dominating so as to make this n v positive.

Sir this is all happen due to the area

Yes, mostly with area, shape is there somewhat, but mostly with area.

You can say yes mostly.

Now, what did we….sorry, what did we get here? It is n v and y v - let us see what n v dot and y v dot…actually n v dot and y v dot will have the same nature - sorry, I am sorry. Here we have got n v, I say that n v is positive when stern dominates and negative when bow dominates - it is fine; n v dot is the same thing, actually n v dot we do not discuss so much more, because normally what happens is that this part is added mass acceleration; this becomes what is known as cross couple added mass, this is your… n is yaw - yaw sway added mass.

In fact, this term becomes… people know that this is a very small number; although, it can be positive or negative, but this actually becomes a much smaller number - as far as number is concerned, so people can neglect that or normally it is neglected. This v dot part - the added mass part - this is equal to a cross couple (( )) added moment of inertia, which means that if I am accelerating the body in direction n…let us say in yawing it - what is my sway force? That is normally very small.

This can also be positive or negative, but what I am trying to say is that in reality the added mass force says that this is reasonably small so we normally neglect that; this is the cross couple term - bow and stern like going again - positive and negative becomes very small; but, on the… if you do not want to take that you can also take that to be either positive or negative depending on bow or stern dominating, but a small number. It turns out, this is smaller number than n v; n v dot is much smaller than n v, usually for a ship.

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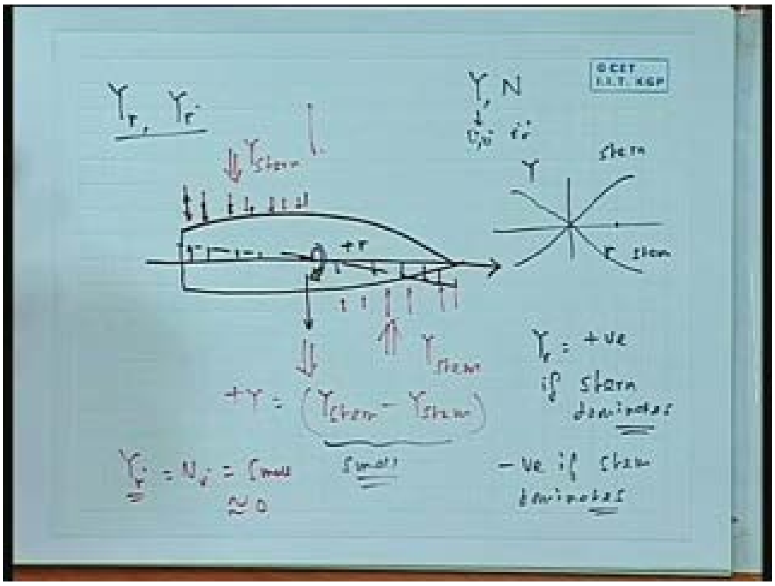

Let us look at y r and y r dot; whenever…see y and n and this is v v dot r r dot; if you take this and this - this is cross couple - this with this and this with this cross couple this with this this with this is…y with v y with v dot N r N r dot is the diagonal, whereas y r y r dot n v n v dot are all cross couple; we have seen that the first diagonal terms are all large negative - that is y v y v dot; now, we find that n v n v dot at cross couple terms can be positive or negative depending on bow stern dominating.

Now, we will find y r y r dot - another cross coupled terms; we will see that the same theory will actually apply; because, cross coupled terms always mean that there is an interplay of positive or negative; here, - this is a little more difficult to see - here what happened? You are now rotating it - positive; that means, if you rotate that basically you are giving a velocity here - the velocity wise…see we are rotating positively here - this positive part, this is right.

You rotate that and you are pushing it here; therefore, you are actually giving a velocity - velocities go like that; in other words, this is the kind of velocity you are giving; you are giving a velocity this side and therefore, there is a reaction force which obviously is going to be…and here.

Yes, that is okay; this velocity will be increasing out line and therefore, there each point is increasing; but, the force is this side and force is this side; there is a net force here this way, again you can say y stern - there is a net force here y stem; what is my y force total? The net force y - this is my positive side, positive y - positive y force - is equal to y stern minus y stem; once again, I have given positive r, remember; therefore, what happened that once more you can find out that…this is y so let me see this y part - y r have.

y r will be positive, if stern is dominating; therefore, what is happening is that if you now put a graph here - this is…I have got y here and I have got r here; remember, my r is positive - for a positive power my y is going to positive if this is positive; that means, if my stern is dominating I will get a get a graph like that; that is, y r is positive if stern dominates; exactly same way it will be negative if stem dominates; what happens is that this will be the case of stem dominating - this is stern dominating and this is stem.

Again, you will find that…second thing is that this a small number, because there is one minus other; I again find out that this cross coupled term of y r is a small number; of course, if you take y r dot it will be exactly, equally valid; in fact, y r dot and n v dot theoretically are actually almost the same, because this is actually the so called…one can show from the added mass theory that they will be same for a fluid - for a general body; from the added mass theory both are equally very small; added mass…but, you can also say that if I accelerate the same thing y y stern y stem etcetera, but normally we do not talk of added mass part because it is known that y r is equal to n v dot y r dot n v dot equal to small number.

It can actually be almost neglected, whether you take positive or negative it does not matter; it is…this is also small, but this is a much smaller than that and therefore, it does not it…it makes less difference and you will find out later on….later on we will find out that this term is always combined in our equation of motion with another big term as a result it will really not make into…something like there is a large term minus y r dot.

Whether it is positive or negative this is going to still remain a large number; what happened is that if you have a term - that we will show from the previous…probably... not e naught…. let me…. I just what to give an a example.

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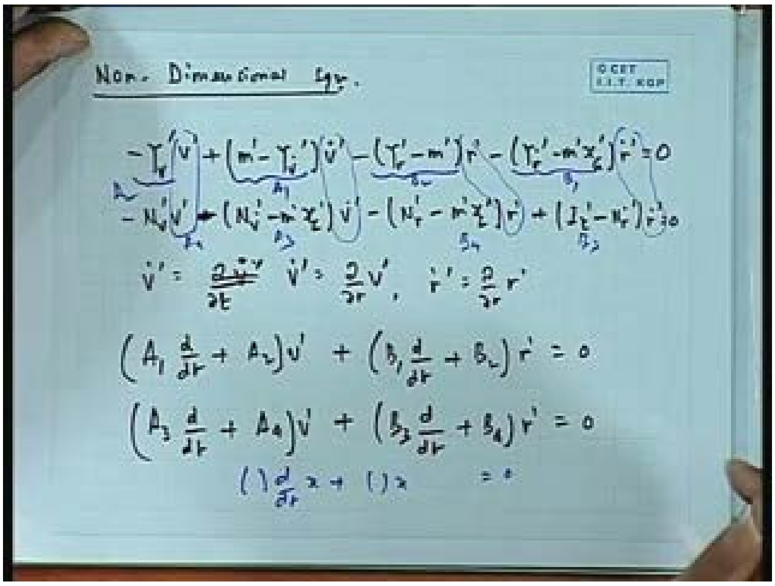

Suppose, we look at this sort of equation - what I am trying to say is that Y… here I have got Y r dash minus m dash; m dash is a large number, whereas y r dash is a small number - can be positive or negative…is a minus off set big number plus minus is small number is going to be minus the large number; therefore, it does not make any difference you will see that y r dash and n v dot they are connected to a large number already - see this m dash x g dot - this is actually large number.

This is actually a small number, therefore it does not matter; that is why we do not talk normally of n v dot - this cross couple n v dot and y r dot - because they are combining along with a mass term; thing we have to realize is that the added mass terms always are added with the mass - mass plus added mass; if that added mass is very small number - mass is always large number, it does not matter with plus or minus - that is why there is no discussion and we do not normally discuss that; on the other hand, Y r and r is small becomes…no not Y r - the other part becomes more important, that is what it normally gets talked.

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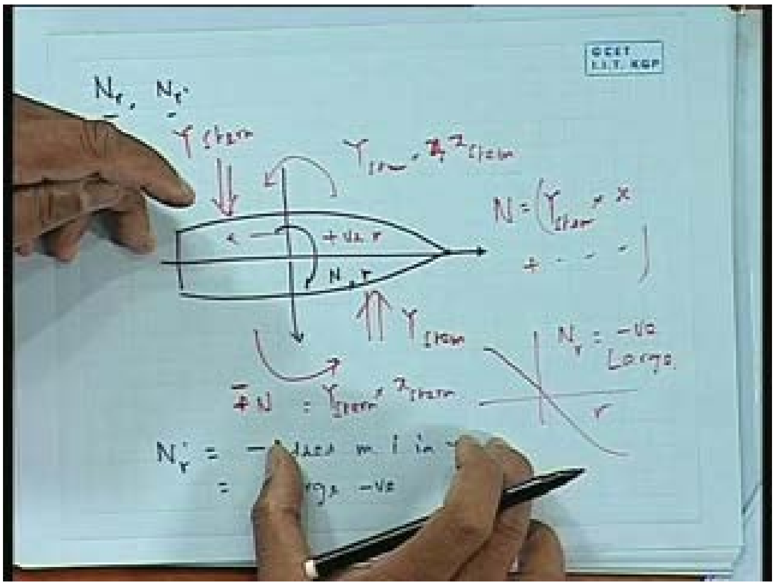

This we understand; now, let us go to the final part - the final part is to find out N r and N r dot; again, we are drawing that and this we will find is going to be…here, according to our previous diagram I have given an r; if I have given an r here - this way - there is a net force y stern; a net force y stem for a positive…we have done that, we have tilted that; as I tilt it this way fluid is pushing this side and pushing this side

Lets in a moment - what does this give? This gives me a moment; This part gives me a movement like this - y stern into a distance whatever distance say x star I am calling - this gives me a distance; what is this? This is a positive bend - no sorry, negative bend - it gives a negative bend. What does this give? Another negative bend - y stem into x stem; here, the interesting part is that both this part and that part give me negative and added up; so, they…though I end up getting N to be y stem into x plus rather two - they get added together and in the opposite side.

Therefore, you end up getting for a given r, a large N; N r is negative and large; exactly the same way you can show that N r dot becomes also large negative - N r dot…actually this is equal to….basically, my added minus of added moment of inertia in yaw - just like added mass; this also becomes a large negative, because added moment of inertia is always positive and in fact, this is equal to I z - almost; moment of inertia, added moment of inertia - see, if you look at that, that also is very interesting, because what is happening is as if you are you are shifting this; there is a water that is getting accelerated

- this water that is getting accelerated has the added - a sectional added mass - of almost the section of volume.

That into distance square - you add them all up; you see, this sectional area into distance square if you add them up you end up getting a moment of inertia, which is almost the same as the moment of inertia - rigid body moment of inertia - of the hull; because, hull also is like…in a hull you take a mass of the section into distance square, here you take mass of that sectional area's water into distance square - almost.

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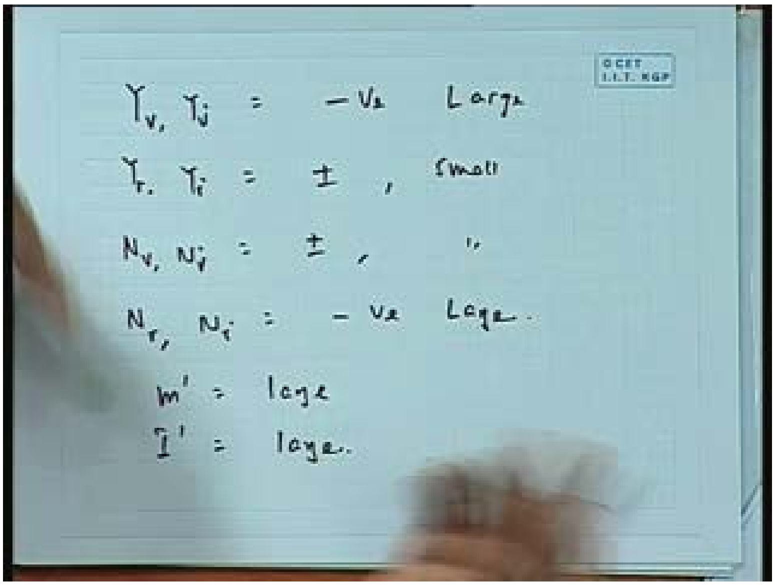

You end up getting a very large negative number; what we end up getting…. if I summarize it….we have got ultimately…y v y v dot is plus minus small; also m dash is large and I dash is large - because, these are moment of inertia of mass term; what we will now do is that we are going to put this back - we are of course, probably not going to work it - but, we will put it back and we can work one term - that will be interesting to work - one term out to see how it works a b c; to to say… that what happens to this a b and c?

Let me see - we have to look back at those slides; this is all a continuous thing - just one second - I will try to…that criteria part is…now we have this criteria b by a greater than zero c by a greater than zero.

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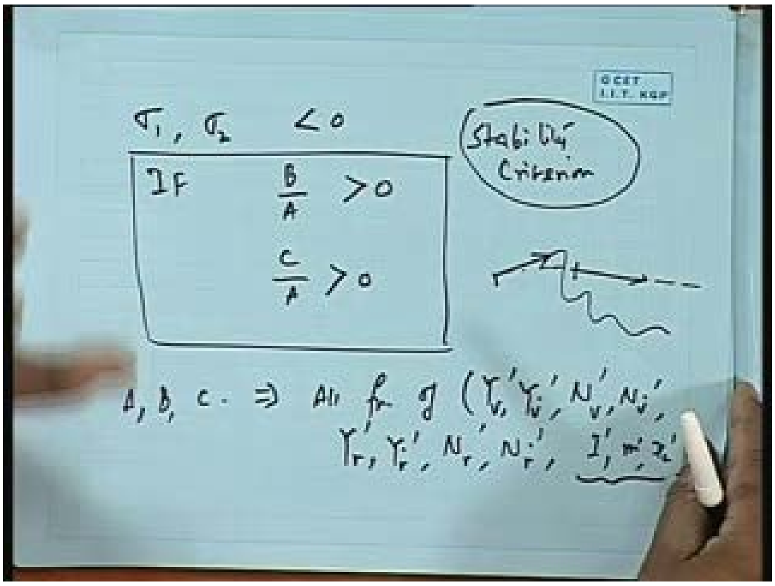

I will act… what happened is that now we have understood this part - I will not go through the detail - it is not possible, because it is a large approximation and we have to go through it systematically; what we will do is that we will just take a one term - say, a and I will tell you from those analysis whether a is positive or negative; like that, we can do for b and then we can do c

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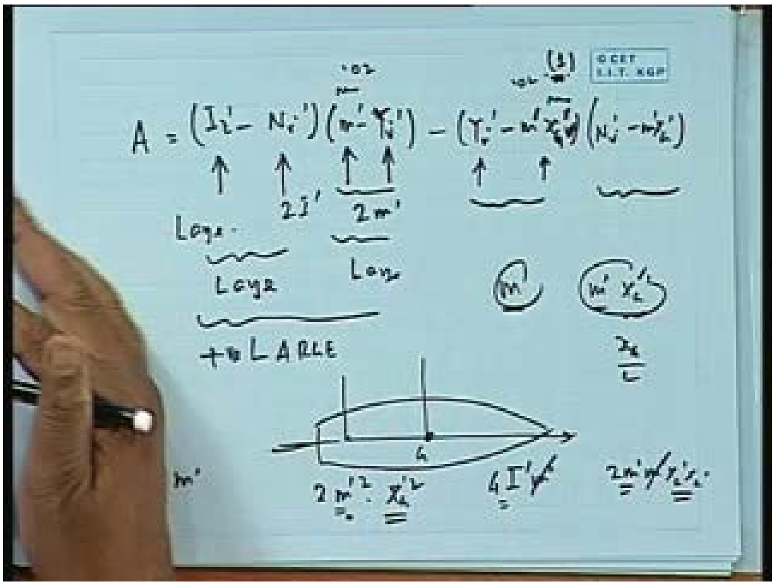

A we had earlier…A was given as I z dash minus N r dot dash into m minus y y v dot dash - it was like this; minus y r dot dash minus m dash x g dash into n v dot dash minus m x g dash something like that; this is large - this is large negative; minus of large negative of minus large this full thing becomes large; this is large, this is large negative this is large; this thing is - this is small, this is also small or this may be small or large, but this is…this x g dash… actually, you know is not very large closed by.

M dash is large, but x g dash is basically…x g dash is your center of gravity which is normally mid-ship; in fact, if you take it from mid-ship…actually this will not… this term will not be there; if you took the origin at mid-ship, this term would not be there; this is actually…x g dash is a small number closed by in m x g dash is actually moment because of the fact that origin is not coinciding.

You remember, one thing - it is that if I took an axis here then my stern stem definition differs and then I have got large x g dash; normally, if I took the x g dash here then… x g dash is such a point from where the stem and stern are almost at the same distance; therefore, the origin that we take from that x g dash is very small; therefore, this can be small and I can neglect that if I took the origin at x g dash - sometimes people do that; I mean, if I took the origin at g - g is not two far; g is not say twenty meters ahead of mid-ship - may be two meters or three meters ahead of mid-ship - that is also a true.

Regardless, this becomes a small number and this also becomes a small number, because this n v dot - does not matter even if it is a little larger; but, this is small - this is much large this is much large - this will be much smaller compared to these terms.

So, whatever happens to this and this term…

M dash into x g dash m dash is large, but x g dash is very small.

It can be zero also in a… see….

Zero then we get

No, this is large by…let me put it this way - let us not take that dash term; let us take that… suppose not done… now m is actually say mass

Mass

Twenty thousand ton - this is twenty thousand ton multiplied by two meters or so; of course, this is non dimensional, so there is a v term that l term comes in effect; if you take that…

No, the units are not taken - this dash - there is some kind of unit there; there was a u here that we did not take; if you take it properly this will be small number; it is not… see this is twenty thousand ton in a mass, but this has got…because I have taken a (( )) if you did not take a dash there will be another term that will come in so that the dimensional equivalence is there; regardless of the fact, this remains a small number and if you take a non-dimensional value, say, this is a large, but it will be, let us say, point zero two; this is supposed to be large because you are multiplying with half rho l q.

This is point zero two, but this is going to be point zero zero because it is x g by l - two meters by hundred meters or two meters by two hundred meters; it is point zero zero one something like that; sot this becomes much smaller; regardless of that, unless it is of the order of one this will not cancel with that; m dash and m dash x g… you compare this term - this and this; this and this are same, but this is of course, x g by l which is of course, much smaller than one; therefore, this term is much smaller than this term - relatively speaking, whichever way you look at that

Yes, I am taking non- dimensional - non - dimensional x g dash is x g by l; x g by l is always much lower than one - it cannot be actually one because it cannot be l; therefore, this will be much lower than that; similarly, here this will be so; what happens is that when you compare this term it is much lower than this terms; these terms are equivalent to twice of m dash and this is equal to twice of I dash, because it is in a minus is called.

This is almost like four times I dash m dash and this is actually m dash…m dash into another factor which is…rather first term is four times of I dash m dash; next term is actually twice of m dash square into x g dash square, but this is very small; this is actually you see smaller than… because, I dash is anyhow more than m dash; if you compare this with that, this is much smaller than this; whichever way we see we have got here I dash four times and m dash; here, you have got two times m dash m dash x g dash x g dash.

One of them goes away - this is much smaller than this because you see I is mass into distance square - this is much smaller because of by l coming twice; you end up getting this to be much smaller than this - no matter what ship you take; there is no question of ambiguity on this because x g cannot be more than length.

In fact, x g dash yeah.

X g dash has to be this one.

It has to decimal otherwise there center of gravity is half side the ship.

Yes

So.

No, you cannot design it.

But, if we are not if you are not considering dash then this it will be…

No, if you do not have a dash there is an additional term coming - that u term was coming here; if you did not take a dash, there is a u term that will come - x g u and x g u will again… u will be some kind of value, because all of them has a…if do not take a dash there is the other term of velocity square etcetera that comes in.

There is going to dimension (( ))

No, even otherwise this is not a calculation right now this is what we are trying to guess by looking at the equation - should a be positive or negative or should… or is it possible for it to either be positive or negative? What… you are trying to investigate the nature of it; right now, the analysis is all qualitative, when you look at this also it is qualitative; we are only saying that if B by A is…these two are greater than zero then the motion will diminish - at what rate? We do not know, from which magnitude? We do not know; because, we do not know the constant there we only know it is going to diminish - that is all we know.

Therefore, I am trying to find out here also - what must be the A, B, C? We know that… we do not know how much this number is going to be, but all that we are saying is that we are sure no matter what ship you are designing unless the ship is carrying mass outside it - which is not possible - you are going to get a to be a large positive number

Because that is the constant of dimension.

Yes, you can say that; you are going to get A to be a large positive number - that is what we are trying to say; A is going to be a large positive number and exactly the same way… I do not want go through that because B is much more complicated, because much more terms for…

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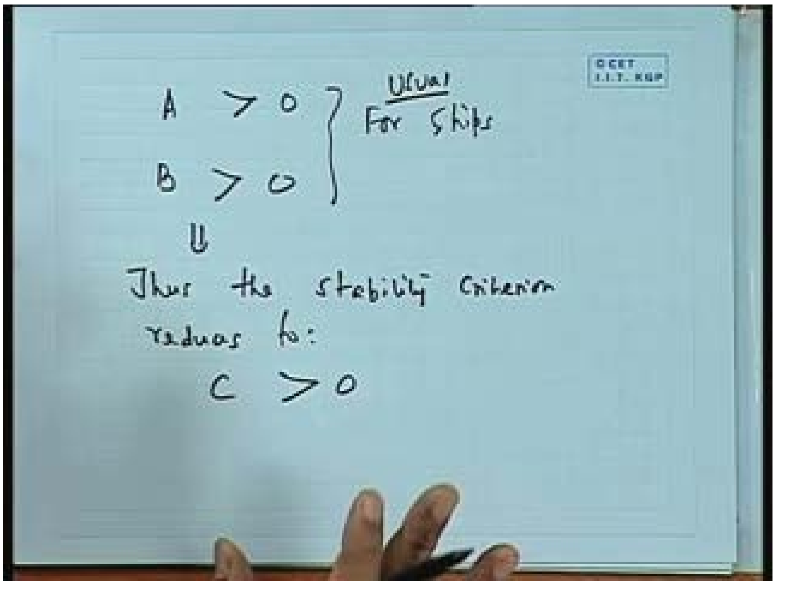

You can find out that b also becomes - for a ship - always more than zero; again, this is for - I will say usual ships - but, if you want to make them negative you have to be really unusual - not just unusual, which probably you cannot do it; look back at that - this is always positive and this is always positive; what does my criteria boil down to? Obviously, if this is positive (( )) means this is satisfied - this always positive means…it boils down for a ship that C must be positive.

My criteria for a usual ship reduces to the fact that C must be positive, ultimately; this is what we are trying to - I was trying to - sort of look eventually; let me see this part of …what is C? We will just write down… therefore, we can actually make that much simpler; c is now equal to… I am not… I mean I did not do that, but if you wrote it down C would be equal to N r dash Y v dash minus N v dash Y r dash minus m dash - this must be equal to 0.

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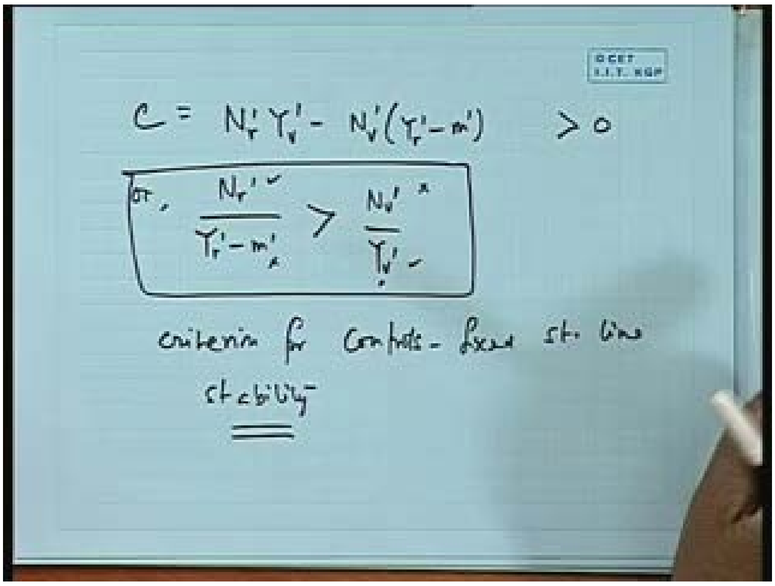

This is what the criteria becomes or that is equivalent to same - N r dash by Y r dash minus m dash must be more than N v dash by Y v dash; this is the criteria for a ship to be stable, therefore…now if this make sense because this norm…if you look at that N r dash and Y r dash minus m dash - N r dash of course, is large number of one direction, but because of this m dash here you do not know this.

This can be… this is some number, but it can be… remember there is a sign convention - let us say, this is always positive, but you remember that this can be positive or negative; because, this is N v dot and Y v dot; this is…no, sorry, this is actually large number - Y v dash - always negative, but this can be positive or negative; this criteria comes down to… because, I am sure about this sign and I am sure about this sign, but I am not sure about this and I am not sure about this and in fact, it turns out that the criteria reduces to this part and you may ask why Y r dash becomes equal to m dash.

That is because r dash is a Y force for r dash and although it is stem-stern dominating it turns out that it is…it is a small number, but a moment and mass if you see - small moment is equal to a mass, because whenever you take a moment it is mass into a distance - some kind of distance is involved there.

This is actually small all right, but small compare to the corresponding moment of inertia term; here, this becomes somewhat like…it could be like this - if you numerically calculate this dash terms what happens is that non-dimensionalization about this and this are different; here, I think N r dash we had half rho l five probably or l four - this is got l cube; there is an l factor there and that is why this comes like this; anyhow, the point remains that the criteria releases to this - this is the criteria of hydrodynamic; this is my so called criteria for controls - fixed ; obviously, now the question comes for a ship… therefore, if you want - if you are designing a ship, you will need to estimate this number - that is the first thing.

One thing that I want to say - and we will be just discussing that in a minute - is that the there are many ships which do not necessarily have straight line stability - it is not a mandatory requirement for a ship, because you can always make it stable with the rudder; I will talk about the rudder part and try to say how this rudder part - term - comes in to the picture; you can always make a ship stable by application of rudder - that means, by applying a control surface force; all right this was a control…

Fixed

Fixed force.

Obviously, this must be more than this - nobody says how much more; it turns out that if this is too much more than that it will be very stable; which means that you will have to produce much larger force to turn it; on the other hand is less than that - of course, it will continuously tend to turn and you have to continuously apply rudder; so the difference between the two actually tells me the extent of stability or instability - if this is less than that and is very much less than you know that for a wide range it becomes unstable, etcetera.

What I mean is that, although in this criteria we find out…again, there are…we will discuss this later on - there are number of definitive maneuvers from which you can tell the extent of straight line instability - the extent of that; let us look at one small thing here about this equation of motion when I am adding rudder; let me go back to this equation of motion part - this was control fixed; what happens when you add rudder and what is meant by control derivatives - that is what another thing I want to - I have to discuss; we have to go back to the first notes where we have this… I am going to write down this.

(( )) as if there are no rudder.

No rudder or rudder is actually frozen fixed - what we have got is frozen fixed; we have got an equation that is something like this - m minus y; I am just going to write down this equation again; so far what we had discussed is what is called controls fixed motion - means, I have no rudder or rudder is there and I have frozen it - I am not operating the rudder at all; all that I am trying to say is that if the ship is slightly disturbed and then the disturbance is removed, will it maintain a straight line or will it keep on oscillating?

Obviously, you would like to make the - correct the course with the rudder; supposing the ship has inherent tendency to deviate, then you have to continuously keep on applying the rudder - correct the course; your rudder force - the requirement on force - autopilot becomes much larger - you have to continuously do it; it is something like you are trying to drive a scoter which is very unstable or a cycle - you might have seen - you can still drive a bad…

But it automatically pulls.

Yes, but you have to give the other force; exactly, that is right - in car also it happens sometimes - there is a pull so you have to always keep the steering… but, you know it is like same thing; if I have a car and I leave my steering, my car it should try to go in a straight line; some car it lost steering will type on this thing; in that case also you can drive, it is just that you have to keep on applying… and your steering you have to probably go to the mechanic faster - similar thing here; on the other hand, remember that if a car is very stable then you have put like a truck much larger force to turn it.

Only power steering.

You need power steering - full power steering - something like that; this is what we talk, but what I mean is that now let us look back this equation of motion; again, I will write and I will see what happens if you add rudder.

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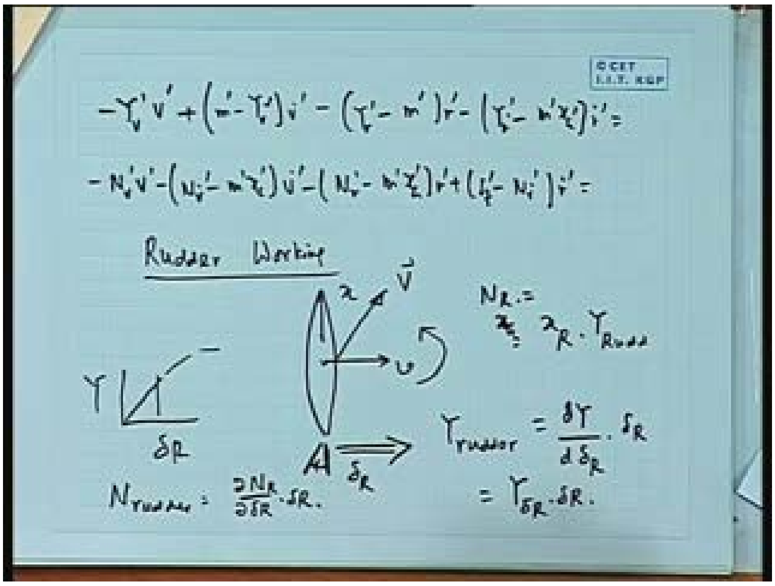

We had this equation of motion maybe I should write it this way - minus Y v dot v dash plus - this was zero - and I have got this, all this; this sometimes gets confusing - no, actually the… even I make mistakes in writing; many a times there can be typographical mistakes of writing, but that is not very important; I always say this way, in reality when you sit down and do you will have all the time - you will not have to just reproduce something quickly - like an examination or in a short time; if you think logically… suppose I made a mistake you then think that is must be dimensionally same etcetera then you can easily work back, that oh this should have been dot not dash by; that is a trivial thing.

I had this thing to be zero, initially; what I am trying to say now here is that… when you have a rudder - this part may be is… show this little bit …see from that little bit; rudder working…we have got a ship here and there is a rudder here - this rudder is in turn like that, for example; this is my, say, v this is my x etcetera; this is my may be the v vector etcetera; now, when you turn the rudder here - delta r - rudder end; when you turn this side rudder what happens? What will happen is that here you are going to get a rudder force - some kind of Y rudder; now, this force will typically depend on the angle delta r - more the delta r more the rudder force, something like that.

You can write this to be as d y by d rudder angle into rudder angle or you can write that as y delta r into delta r; again, you can say the rudder force is equal to the rate of change of rudder force with respect to rudder angle into rudder angle; in other words, d y by d delta r basically tells me what is my rudder force per unit delta; you are measuring y versus delta r; obviously, this will… for sometime it will be straight line and it might go further off.

But, for some time it will be a linear straight line; any control surface propeller, whatever; forget that part - the question is that you are going to get a rudder force here; the rudder force will be equal to or you can write them as y delta r into delta r - slope of the rudder; it is also of course going to give you moment - this moment is going to be… if there is rudder force action here and the point is here is going to be actually x g - whatever that.. x r you can say into y rudder - this is going to be my N rudder

Once more, I can write N rudder to be d n by d r into r; in other words, N rudder d n by d N rudder by d delta r into delta r - I mean… let me go to the next page and try to do that; what I mean is that Y rudder can be written as Y delta r into delta r; N rudder you can always write like that, because after all what is Y delta r? This is nothing but Y delta r, d y rudder by d rudder angle, similarly n delta r d n by d.

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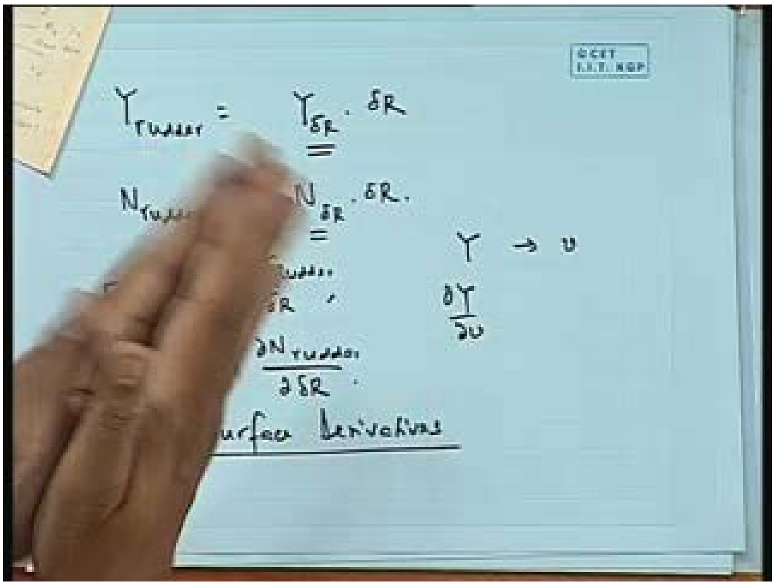

Actually, I not need not write partial - this is just by definition, just like earlier; what did I do earlier? Think of it - in earlier cases, whenever there is a y force arising for v I said it is d y by d v, because v is causing y; I want to know per unit is how much y; here, delta r is causing y so I want to know what is causing this; because, if I know this term then I know tomorrow if the rudder is at five degrees - so much force, ten degrees - so much force, eight point nine degrees - so much force, etcetera.

I have got this extra force coming; why I am mentioning that is because now if you go back to that I am going to have this extra force coming here y delta r delta r and of course, I will have to have these dashes here, because these are non-dimensional.

I am not proving - showing that, but because everything is non-dimensionalized this also becomes non-dimensionalize; delta r actually is already non-dimensionalized so we need not actually do this delta r, because it is an angle having…if you will use radium this becomes N r dot delta r; you end up getting this… the equation of motion with rudder working will have this, because this is an extra force coming here; just like a minus Y v there will be a you know minus Y d l delta which you can bring on that side; you end up getting a force like that.

All right, what I want to say here is that, this part - this and this - these are called control or rudder derivative; just like my other parts were called hull derivatives this is known as control or rudder derivatives or you can say control surface derivative; I can call these two as…for submarine and all you have got large number of controls of derivates; I will very quickly try to summarize this because we have got not much time; now think of a ship which is making a steady turn - a turning, which is a rudder action; when it is turning steadily I do not have any v dot because there is no acceleration; I do not have any r dot because there is no acceleration; I only have v, I have only this, I have only this and I have only this I have only this I have only this and I have only this.

What I mean is that, when the ship is making a steady turn I can easily find out an equation of motion during the steady turn - when it is making a turn, because it is at a steady state it is not accelerating any more under rudder action, then this equation - this will go to zero, this will go to zero, this will go to zero, this will go to zero and I have something v, something r equal to something something v something r equal to something no d y d t it is much simple algebraic equation.

And I can very easily find out what is my v and r and from there what is my r and delta; we will do this afterwards, because we do not have sort of time for today's lecture - we will discuss this when we discuss about the turning circle maneuver, but, what I want to say is that, this is a concept where we are trying to put by showing that if the rudder is working equation of motion gets modified, because you have now got extra forces coming; these extra forces are actually such device - such that - we will find out later on that this will cause - if I give a Y r… if I give a delta to be a negative the ship is going to turn on the other side; it is actually devised in such a way that if you turn it this side the ship on turns on the other side.

That analysis we will do afterwards for a steady turn; if you want to show the transient you have to solve this full equation, which cannot be solved easily; you can solve in a time domain - like step by stay stimulate - give a force, see how the trajectories are. This is about the rudder part and I wanted to say that if… here you will find out an interesting part that what remains here - this part this part and this term this term - we will find out that actually these two and these two have a relation with respect to my stability criteria; the stability criteria - if you look back, I have just show you little bit - it comprises of N r y v n v y r minus n; that is - where is it? N r y…y v here oh this v dot. N r… what I mean is that, we can actually show that there will be a… this r dash.. N r and y v - this multiplication and this will come; one can show that basically this criteria has a relation with this rudder angle; in other words, only for a stable ship… I will do that afterwards - only for a stable ship you will find out that if you give a rudder this side the ship turns that side - in other words you are actually assuming that there is a stability involved somewhere.

Anyhow, that we will discuss in the subsequent class with respect to our definitive maneuvers, but this is where I will stop; what I want to sum up is that we should understand that there is something called stability criteria, which is an intrinsic property of the hull - these are intrinsic properties of the hull; if you have a bad hull design, which has in intrinsically unstable hull, obviously you will need much more rudder control to make it stable; it is good to have a design from the beginning where this is just met and with a small positive - this is just little more than this. Thank you.

Preview of Next Lecture

Lecture No. # 37

Ship Trials and Maneuvers - I

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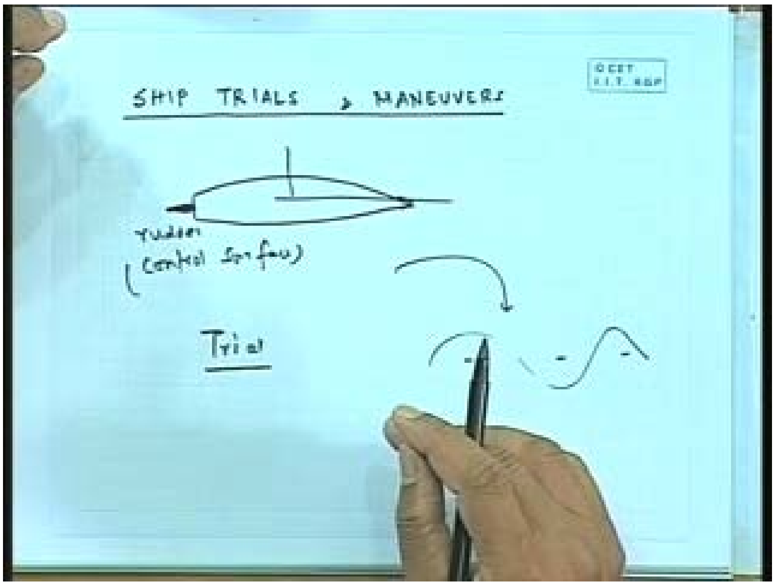

Earlier, we have talked about this fact that if there is a ship here, you have fixed the control, you we have studied the mass behind various forces that act on it and try to find out or try to describe the properties or characteristics necessary for the ship to maintain a straight line; in other words, 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.

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 wanted 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.

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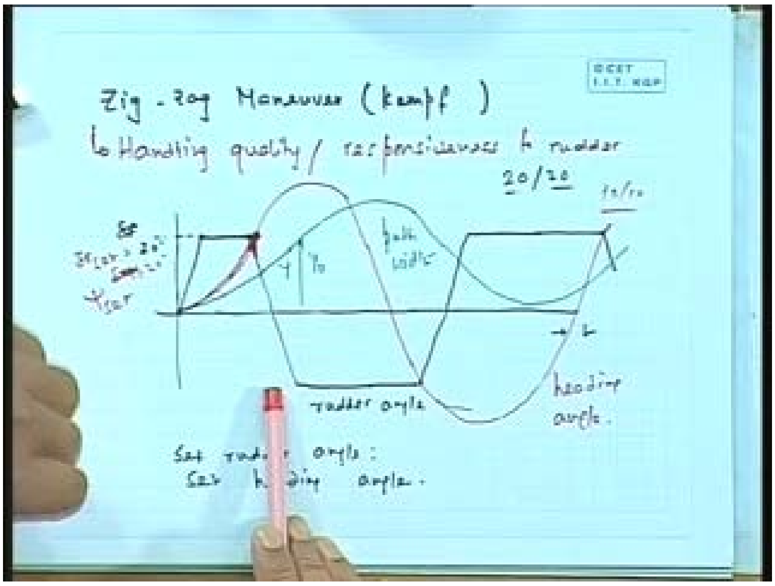

Here, just do the opposite - just reverse it again back to plus twenty and hold it fixed; this is going to go up again, down again eventually and begin to turn again on this side; this is going to be like this, again at this point you turn it back; we do not have time for this now, but… and then this also you are measuring - this path with… this will also…actually it may go like that - something like that; this is my, say, y zero or path with… I can - 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; 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 swinging back again; you keep on turning like that. You can do that for long time, but normally two or three swing is good enough; because, eventually it is supposed to reach a steady state and you keep measuring; the rudder angle, of course, 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 in a canal the ship was going this side then it would come to this side then it come back and 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, soon; in the next lecture I will pick up from this diagram, because the time is up for this one and see what to be measure and these measurements mean what. I will stop this part of the lecture, but we will pick up from this diagram in the next hour.