Performance of Marine Vehicles at Sea

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Lecture No. # 35
Hydrodynamic Derivatives and Stability Criterion - I

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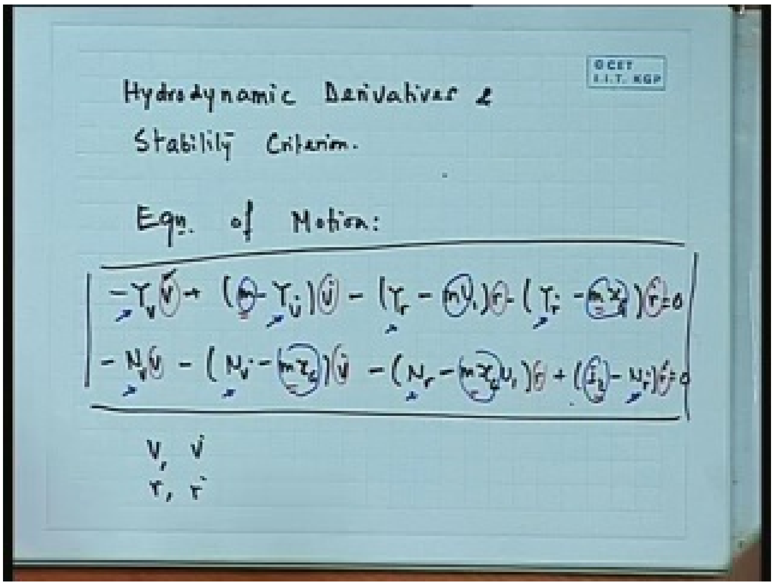

Today, we will talk about Hydrodynamic Derivatives and Stability Criterion, see yesterday we actually ended up in, what is called equation of motion?

Now, the equation of motion we actually had, I have just write it again, it was something like Y v v plus m minus, I think Y v dot v dot minus Y r minus m u 1 r minus. This was one, this is sway and we had.

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See, we had this two set of equations yesterday, that we have found out represent a body or a ship moving initially along a straight line and was disturb slightly. They are governed by this equation, when v and v dot r r dot sway velocity, sway acceleration, yaw velocity, yaw acceleration.

Now, what is meant by stability criteria and of course, I will talk about the hydrodynamic derivative also is that, first of all if you see that this equation, you see this is the velocity. In fact, let me put a different colour, this one, this one, this, this, this, this, this, this are the two velocities and two acceleration (Refers Slide Time: 03:04).

This is my rigid body mass, this is my rigid body mass this is my rigid body moment of inertia; these are rigid body mass rigid body mass. So, I have got the blue ones, let me put them as blue, this rigid body mass this is rigid body mass term, this is rigid body mass and you know the geometric term rigid body mass and centre of gravity then, rigid body mass moment of inertia, rigid body centre of gravity velocity like this.

The other terms that comes in the equation are, this one, this one, this one, this one, this one, this and this. These are what we are going going to call them hydrodynamic derivatives that, I will explain concept behind that the term why, it is called hydrodynamic derivatives (Refers Slide Time: 03:48).

But, before that, these two things which are interrogated, you see the solution for that equation; if we can find out we may not be able to find out the exact nature the numerical value, but the nature of the solution would tell me, if the ship is going to be stable or unstable, how? Because, it has got here something into v something v dot something r something r dot something v something v dot something r something r dot.

This is what is known as a set of linear differential equation, you know some kind of equation, now from there if you can tell how v and r changes with time that tells me whether the ship is going to be stable or unstable, I will discuss that again, but normally what happens, first of all, people write this equation in a non dimensional way, because if you see this equation m etcetera, m is mass of the hull, so it is you know like may be 20000 tons. You may be, you are may something like 15 knots, this becomes all dimensional values.

To make it non dimensional, which makes makes it easier, because first of all remember that all of them must have same dimensions. So, you see m into v dot m into v dot, let us look at the dimension part of m into v dot.

Mass meter per second

Is mass into acceleration, which is actually the unit of force, therefore all of them must have unit of force Y v v etcetera etcetera are should have unit of force. But, then it becomes a sometime difficult to write them in a dimensional form, so what people do is that, first we will we will sort of write them in a non dimensional form. So, that everything is divided by some non dimensional form and then the non dimensional form the ease of it is that, the numbers are of same order regardless of ship size.

And in fact, for a same scale shape, it will be same, you know if you take a geometrically scale shape, it will same numbers, it is exactly same as trying to tell you resistance coefficient instead of the resistance r and c.

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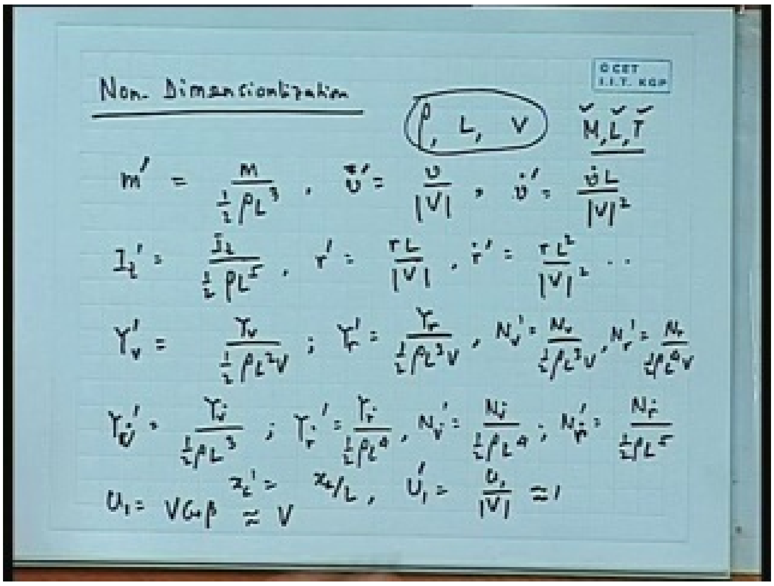

Now, the non-dimensionalization that is done

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This is done with respect to normally rho L and V, these three are used to non-dimensionalize, that is density which will see; you remember that all of them has the three unit, mass, length and time. Most you know like, all parameters at least in what we talk and we will have a dimension of either mass or length or time, this three.

So, this will have a mass term here, because this mass by you know L cube, this is of may having with, this will have the term T. So, normally this is this T are used combination of them to non-dimensionalize. I will actually show only few of them, because this is a whole lot of non dimensionalization, no point of showing that.

For example, mass first of all we use the what dash in our student days, we used to call this subject is full of dash and dot you see, the dash will represent non dimensionalization, whenever we put a dash here non dimensionalize. So, this is actually M by half rho L cube, this is how it is defined normally there can be other ways, similarly v dot is no not v dot I am sorry, this is v by V, that is v dash is and v dot is v dot divided by…

See you if you see that, v dash are v by V, because this meter by second meter by second goes away, v dot is meter by second square, so this has a unit of see v v dot by V into v by L that is why it comes v dot L by V square. See, when there is a time there then L by v square comes in, it very easily you can see, if you want to combine this three, this three to non-dimensionalize the acceleration, it will always become acceleration by v square by L or into L by v square something like that.

Similarly, I z dash will become, always this half is used for some convention like, they are also half rho s v square, this half where somehow come to stay. Then r dash becomes again, this is r L by V, you will find then r dot dash becomes r L square by V square, it will become this is these are the mass and the velocity parameters. Then let us say Y dash v this will become Y v divided by half rho L square V, Y r dash will become Y r Y rho L cube V, then N V dash becomes N V by half rho L cube V and N r dash equal to N r by half rho L 4 V.

I will just I mean tell you an interesting point of.

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Like that, you see if you see that you will see there is an L square V L cube V these two remain same, L cube V L 4, there is an you know increase of whatever this into L this remain same, another L in a L cube L 4 L 4 L 5, it is actually easy to work it out you can if you, I mean go to that you will find it is quite easy. Now, x c dash will become x c by L, U 1 is basically dash is u 1 by V, which is equal to 1, because you see V is actually the forward speed with a small change, basically u 1 will be V, u 1 equal to V cos beta or cos of heading angle, but the heading angle is taken as small side becomes equal to 1.

See in other words, u 1 is V into cos of the angle of attack, which is equal to V. So, that u 1 by V becomes equal to 1, you know when you take a dash part. In other words, this I will tell you in next slide may be why it is so.

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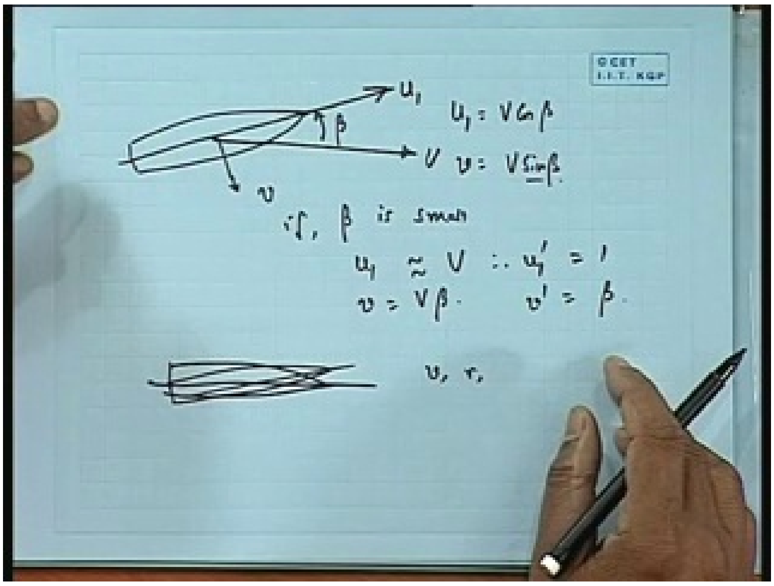

See, whenever we are talking of a ship here, this is my u 1, this is my V, this is my v, this is my beta u 1 equal to V cos beta and v equal to V sin beta, beta is small u 1 V, v equal to beta, sorry no here v equal to sorry v beta. So, this is what we do, because normally the heading angle will be small, you know you do not have a ship going like this 45 degree angle, it will be may be 10 degree or so. Although, I write for the sake of this thing a ship will not travel like this, you know it will travel with small angle only. So, beta is normally 10 degree or so not much unless you make a very large simulation.

Remember here of course, it is even small because, we are looking at only small participation, remember ship was going initially along a straight line. You are going to small participation obviously, it is a it would have make a small angle, it is not making a 20 degree angle, then it is going away very far from your initial, you know equilibrium.

Therefore, to make an assumption that beta is small for this, so called linear equation, see this equations are linearised, anyhow the very word linear equation implies that V dash is small V is small V small means that you know sin beta is small means beta is small. So, this is very I mean what I am trying to say that is very consistent, there is no ambiguity here, because we are looking at small values of V, small values of r etcetera it automatically means that beta is small.

You cannot have large beta, because if it was large beta you could not use this equation up to only first order, you know then the Taylor expression had to go for higher order, anyhow, so having said that, this I hope is kind of clear.

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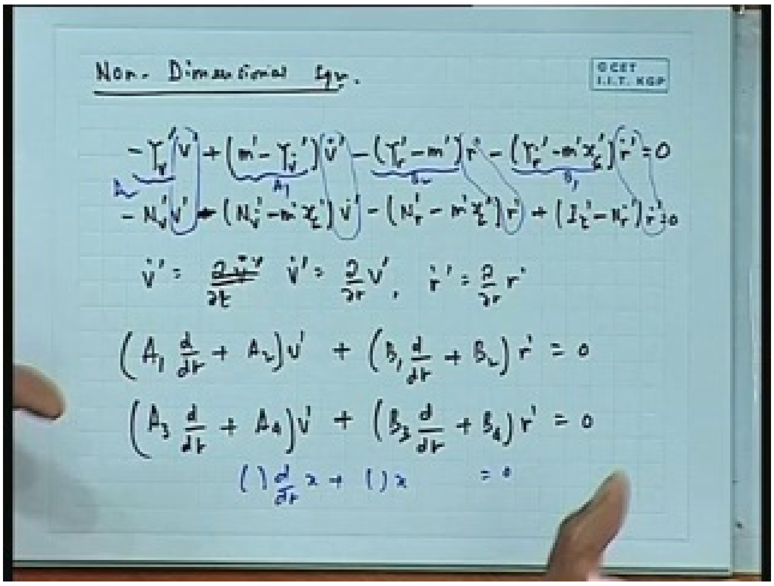

We can write these equations in non-dimensional form and the non-dimensional form simply becomes, you just you know, it will become all that that happens is the gets two dashes here, I had let me see one equation. See, u 1 was there the u 1 has become 1, that is why this you see m u 1 has become just m dash and this is, this is minus is not very important that, now if you look at that see I can call this to be, I will tell really one thing that this equations as look at this v dot and V, I can write them in a form that a into V plus A 1 into V plus A 2 into V dot plus A 3 r plus A 4 r dot. Something into V plus something V dot something into r plus something r dot, is it not? It see here, I have got just look at that this should have been written a different colour, I have got here this two are coming here, this two are coming here, this two are coming here and this two are coming here.

So, it is something into V plus something V dot plus something r plus something r dot, something V you know of course, non-dimensional something V do something r something r dot, we can do actually even better. You see V dot dash equal to d y d v d, d y d t of v dot sorry of V dash, in other words V dot dash equal to d y d t of V dash, r dot dash equal to d y d t of r dash, etcetera.

So, what happened, I can write this you see if you write it in a more form, then it turns out that that supposing I call it A 1, so I can write this two equation, I will just write that and then tell I can write this as like this d by d t plus A 2 into V dash plus B 1 d by d t plus B 2 into r dash equal to 0 and A 3 into d by d t plus A 4 V dash plus B 3 into d by d t plus B 4 into r dash equal to 0.

You see, what we have done now this is interesting, what we have done see I have I wrote that first, I can show you this is m dash minus Y V dash this term, this is A 1, A 1 see here, this is my A 1 into d y d t of V, that is this term you see and A 2 is this. Similarly, B 1 is this sorry B 1 is this, B 2 is this. So, we have simply written in a never mind the mathematical manipulation etcetera, but what I mean is that, this is an equation how does the equation look like, you see the equation look like something, something into d by d t of x plus something into x equal to 0.

Basically this is how the equation look like, there are two terms like that this would have been one term, but I have got something into d by d t x into something into x plus something into d by d t y plus something d y equal to 0 and another one like that. So, I have two set of equation with two unknown, but the two unknowns are related, I have got you can say four unknown V dot V r dot r, but V dot is d d V by d t, r dot is d r by d t. So, if I invoke that I end up getting something d by d t into V dot plus something into V dot V dash, plus something into d by d t r plus something into r, something into d by d t V something into V, something into d by d t r something into r.

We can write in this form as I again say that never mind the exact mathematics part of it. The reason of writing is this way is that, this kind of equation we will have a solution, where you can express V and r in terms of an exponential function, just like in any differential equation.

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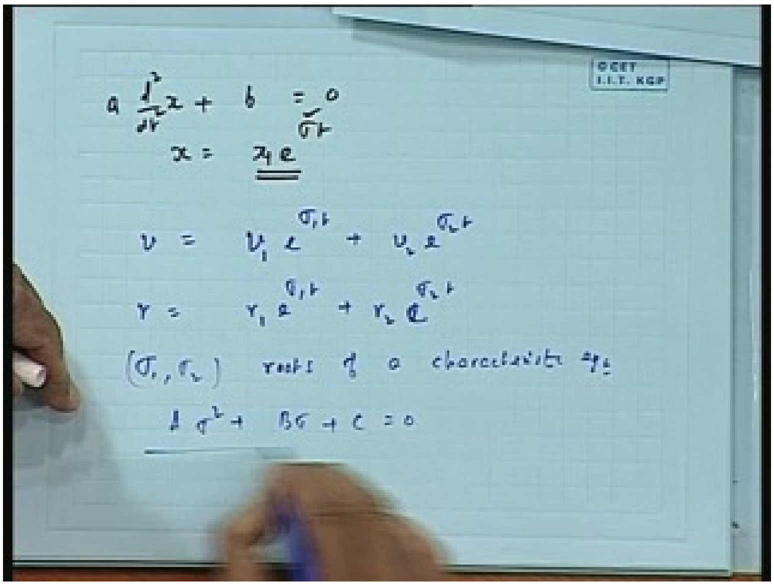

See, we will we will come back to that, now you look at then an equation something like this you know, that d by d t of x plus you know some a of d by d t plus b equal to 0. What people will do you will assume a solution that x equal to x 1 into e power of something like, e power of sigma t or something. And then you will try to find out what is my x 1 of sigma, because it is or you can have actually d Square by d t square or d by d t whatever.

Whenever, there is a differential equation, you assume the solution to be an having an exponential form and then try to find out what is that root? That can be imaginary in fact, if it is a double double it becomes imaginary means it basically, it becomes sin, if it is not imaginary its exponential, these are all very standard part, so we did not worry about that.

We need I my purpose is not also to kind of sort of give you a detail discussion on solution of linear differential equation, but what I want to say is that, when I look at that I have got two part, these are all differential equation with the differential coefficient, it is very well known that you can express a solution in terms of a conventional exponential function.

It is known that for this equation, you can write the solution as the v can be written as v 1 e to the power of sigma 1 t plus v 2 e to the sigma 2 t and r can be expressed as r 1 e to the power of sigma 1 t plus r 2 e to the power of sigma sorry e to the power of sigma 2 t, where sigma 1 and sigma 2 are called roots of a characteristics equation, which is looking like this, but this is form by taking a determinant of that, actually I will just tell you, that I mean this is all very very standard stuff see if I if I write this equation again I will write this in a matrix form, that there will be easier.

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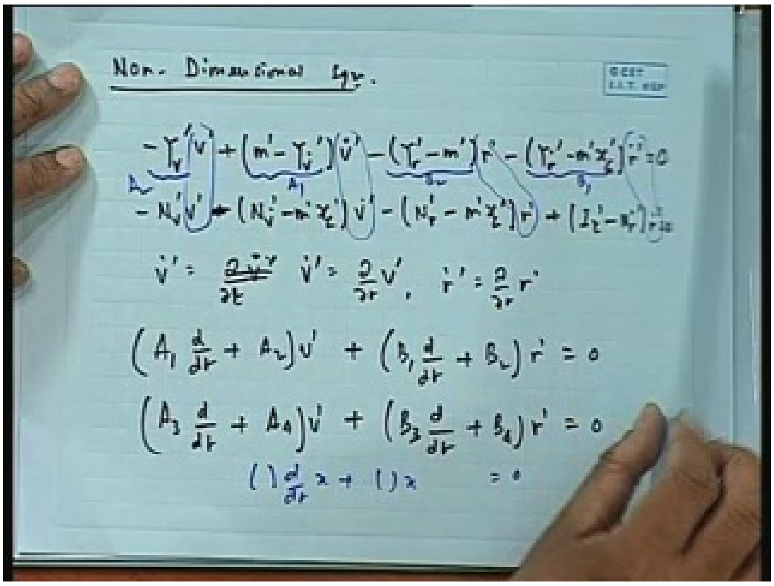

See we look at this equation, I am going to write this equation in matrix form like A this, this, this. So, what we are writing this equation I have got A 1 d by d t plus A 2, this is one term, B 1 d by d t plus B 2. Here, A 3 d by d t plus A 4 and B 3 d by d t plus B 4. This into V dash r dash equal to 0, 0, this was my equation see this into this pluses this 0 this into this plus. And the characteristic equation is found by taking the determinant of that.

And if you take a determinant of that something like, when you say A sigma square plus B sigma plus C equal to 0 and A actually is the term having proportional to see, if you expand that there will be term proportional to d by d square by d t square. So, the A 1 B

3 d square by d t square plus A 3 B 1 d square by d t square, that means basically you are going to have A 1 B 3 plus A 3 B 1 d square by d t square like that, something into d by d t plus something, this is what we will be call A this is what is called B this is what is called C. I mean again we are not going into the detail of the numerical method of solution etcetera, etcetera.

All that I want to tell you is that, this kind of equation has a standard solution expressed by the solution of them will look like that when I of course, I do not know what is V 1, I do not know what is V 2, but it will be exponential with sigma 1 sigma 2 on top, when sigma 1 sigma 2 are suppose to be roots of this quadratic equation.

You

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Characteristic equation, this A now this we are finding out from here, see this is this this is this is A, this is B, this is C, and the characteristic equation is a sigma square plus B sigma plus C equal to 0.

Obviously I know what is A B C, A is A 3 B A 1 B 3 minus A 3 B 1, B will be of course, much longer term because B will be d by d t see it will be A 2 B 3 and then A 4 B 1 then A 3 B 2 and A 1 B 4, it will be four terms coming and the other one will be of course, A 2 B 4 A 4 B 2 and again remember A 1 A 2 A 3 are all actually long term, because they are all in terms of this big coefficients.

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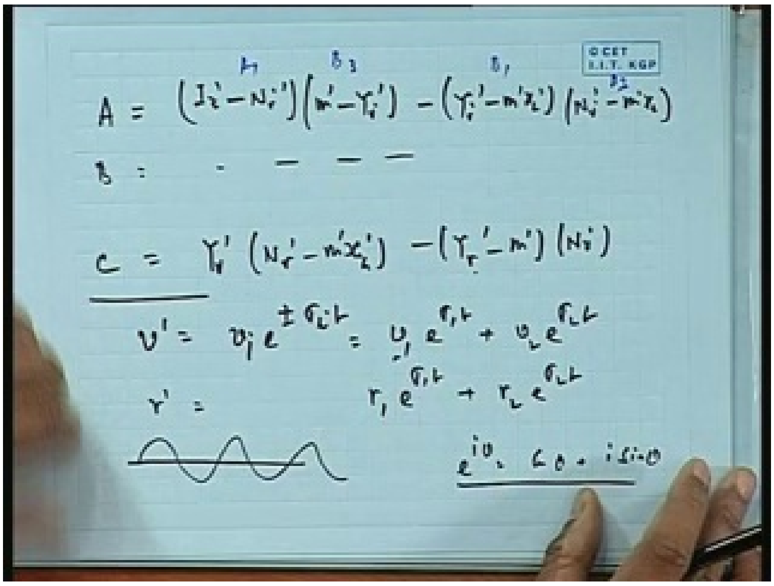

So, you end up getting actually a characteristic equation where A B C is long. In fact, I will just write what is one of the term of A, you see A for example, will turn out to be I z dash minus N naught dot dash, in fact that is how it is into m dash minus Y v dot dash minus Y I dot dash minus m x 3 dot and N v dot dash minus m dot x 0 something like that.

Let me see, whether this is right because this let me see this A 1 A 3 now, this will be Y dash minus this into this, let me know A 1 into we had into this one, m minus Y v this into this. See, this is A 3 A 4 B 3 B 4. So, A 1 B 3 is ok, and A 3 B 1 is ok, see that is how what it is see, this is my A 1, this is my B 3, this is my B 1, this is my A 3, like that you know.

So, what I am trying to say that, it is only longest algebra, but there is nothing conceptually difficult about it. It is simple you know you might have a long algebra, but there is nothing more difficult I will write that see B is actually much longer, so we do not write B B because B will have actually here are two terms, but there we have four terms, so it goes for a long time no point.

You can write like that say C, I write C is Y v dot dash into N r dash minus m x c something like that, minus Y r dash minus m dash into N v dash something like that. In fact, you can make it out from here also, because here actually it is this one this one into this one.

So, N v you can N r minus sorry why it is Y here Y v into N r minus N x g, this first term this two and then this one N v into this one, Y r minus m dash. See this is this I mean you can make it out if there is really not, there is nothing conceptually difficult on that it is it is very straight forward thing. So, we end up getting this.

Now, come to the stability criteria that is very interesting, you see now I have got now we have we have to look very carefully. See, we have got here solution of v dash equal to v 1 e to the power of say plus minus sigma i t, I can write or say v 1 e to the power of sigma 1 t plus v 2 e to the power of sigma 2 t and r dash equal to r 1 e to the power sigma 1 t r 2 e to the power sigma 2 t.

Now, you tell me see what we want we want the ship to be stable, what should be the criteria for sigma 1 sigma 2, that is what we have to now look for. Now, no now what we see, now let us take one by one, if sigma 1 is real sigma was imaginary; that means, sigma 1 is now i sigma, then what happens the solution is a sinusoidal then, it goes like that.

See when you have e to the power of i theta that is cos theta plus i sin theta. So, if this is imaginary, then what happens you do not have a decaying solution, you may have a decaying solution, but you cannot actually say this part would not give a decay can only be from this side.

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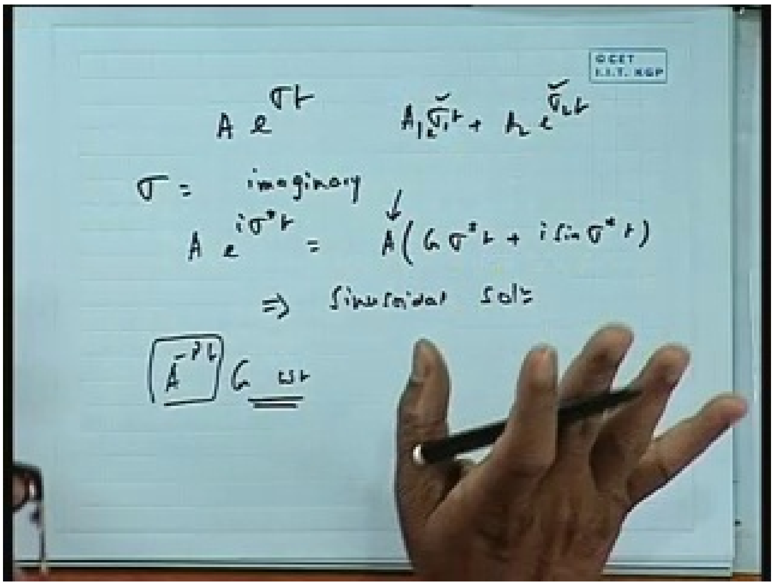

See, we will be look into that one by one with one one part, supposing I take a condition of something into it was sigma t, what is sigma? Say sigma is imaginary then what happens? This becomes A e to the power of say i into say sigma star t this is nothing but, a into cos sigma star t plus i sin sigma star t or it because of sinusoidal. So, this becomes a sinusoidal solution.

There is no decay, remember the decay would have been if A was decaying, if A was having a sigma t, which is what happened the damping case, you know a in damping case, you know you have got minus t into cos omega t. So, this decays, but this is not decaying this is the sinusoidal curve.

So, remember that, if sigma therefore becomes imaginary then, you cannot have it does not decay now I have got see, but my case is actually A 1 e sigma 1 t plus A 2 e sigma 2 t, so I can have one of them imaginary and one of them real, but even though even if one of them is imaginary, I have a decaying you know like a sinusoidal solution. So, I cannot, I do not want it that is number one. So, I do not want sigma to be imaginary either one or both.

Or now, let us say what is a sigma 1 value of positive negative, let us say one of the sigma 1 is positive, then what happen? This one will grow suppose sigma 1 is positive, then with time this one grows; that means, r and v are increasing, even though the another another is negative, remember that one part is positive, so it is going to grow.

So, the only possible solution that, I want for the ship to be stable is that both sigma 1 and sigma 2 must be real negative. This is we are trying to talk about now, we have to find out what criteria causes that to be real negative and then find out that translate to what characteristic of the ship. This is what we have to we are looking at, but this is a very important concept.

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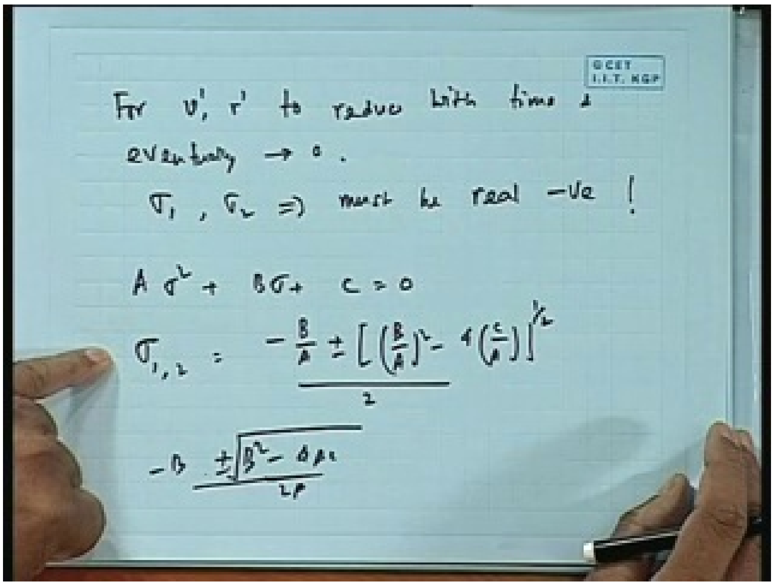

So, you see we must we must sort of emphasis, that for v dash and r dash to reduce with time and eventually becomes 0, approach 0, sigma 1 sigma 2 must be real negative, this is very important. That means, my solution this see I have got this, what is my solution for this equation, see what is sigma 1 and 2 equal to minus, you see B by A plus minus by 2, this is everybody knows now, see the know actually I know no this is.

Solution of quadratic equation

Actually B square minus four A C by 2, there is a this is there is a root over of this root of r right. Basically, a solution of I mean I wrote this solution, but actually it is B square minus 4 A C by 2 A.

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No no.

Sir.

B

Minus B plus minus into B square

Something like that, it is a standard thing. So, I just wrote that by B by 2 A, I mean etcetera, etcetera, the reason is because we want to know what is what is the characteristic of B by A and C by A, because you see it can be rewritten in terms by B by A and C by A. We want to make sure that this is all real negative, that is all we want to make sure that.

Now, we have to find out, now we will write it down again in next page, because I want to write very carefully and you have to understand, what must be the criteria for C by A and B by A for this to be both to be negative, that is what we have to find out.

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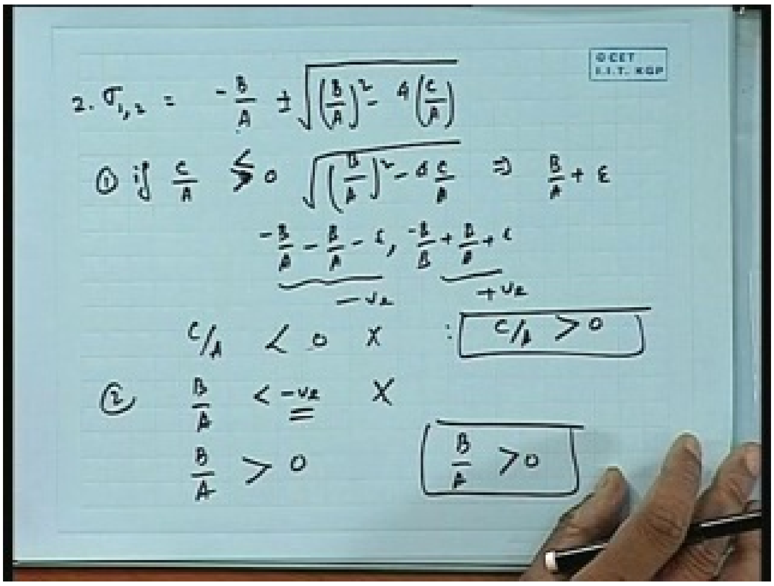

See, again I will write down we have got sigma 1 and 2 is equal to minus B by A, let me say two times of that because, you know that two I can always take this side. So, that I do not have to this bottom two again B by A square minus 4 C by A, that below two was there, I took the two this side. Now, you see we want sigma 1 sigma 2 to be all negative, now this is negative remember, so now, I have got the choice let me, just think of the cases, that you know see I have got number B by A and C by A. So, I can have B by A positive, C by A negative, etcetera; I mean positive positive, negative negative, positive negative, negative positive, let us think of all that thing (Refer Slide Time: 32:24).

Let us see, about say C by A say C by A is 0 greater than 0 no no let me say, C by A is less than 0, now if C by A is less than 0 you see, minus 4 C by A becomes a positive number.

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If C by A is less than 0, then this becomes a positive number B square by B by A square is a positive number.

Square equal to positive

So, this is a positive number, now you have got a positive number, now you tell me what happen? This is a positive number of a magnitude more than B by A, because you see its B by A square plus another number, so suppose B by A say two then this is going to be say more than two.

Now, here I have got minus B by A, minus that number and minus B B by A plus that number. So, there is one. See this, in this case I can write it that B by A square minus 4 C A root of all, it is B by A plus some epsilon, some small number obviously, it will become more than B by A.

Therefore, the roots become minus B by A minus B by A minus epsilon and minus B by A plus B by A plus epsilon, this is negative, but this is positive. So, I end up having one positive number, I cannot have it. Therefore, C by A has to be negative, that is point number one. Two this of course, is obvious B by A B by A obviously, has to be your, this thing, here the B by A, what B by A should be, now B by A has two choice positive and negative.

Let us say b by a negative

Then one thing from a positive

Again then what would happen? This becomes negative means square here minus something here, then whole thing becomes positive as you say, therefore this is not possible, so for the criteria, I must have B by A to be positive.

One thing straight way put that b square square minus whole square equal to zero.

No, that is ok, what we want to know.

What is zero we will get negative.

Which one?

Real negative B B by A whole square minus 4 A C is 0.

Then we get the whole part as negative.

That is then you have got minus B, no that we do not know, you see what we are trying to find out we do not know, that what we want to know what we can find out is that see first one I found out that, if C by A is less than 0 then I have one part solution. Therefore this cannot possible therefore, C by A must be this thing, this one of the criteria C by A must be more than 0. See, if C by A was less than zero, I found out that one of the solutions, one of the roots becomes negative, a positive we cannot have it. So, if the both both the roots must be negative, then C by A must be positive.

Now, B by A if B by A is negative, we will found out that this negative square of course, this is a positive number minus, whatever this number is negative number, so this can be actually smaller than B by A or larger see now we have got C by A to be positive. So, therefore obviously, B by A square minus see we have said that C by A is positive now if this is negative number. So, negative square this is positive number obviously, and this one, so again the same criteria will come, because this term will become more than B by A plus epsilon, because you see when you take a negative square becomes positive number.

So, if B by A was negative then, again I end up getting one solution which is positive. So, B by A also this is not possible, so B by A also must be positive why because if B by A is positive remember that, then this is negative. So, this this negative minus negative,

negative minus another number smaller than that, so we we end up getting like this, because this is a actually what happen remember this, this is actually positive therefore, this is a less than that.

So, you end up getting the criteria that, my both sigma 1 sigma 2 will be your negative provided provided sigma 1 and sigma 2, I mean I will let me do a negative, if B by A is greater than 0, C by A is greater than 0.

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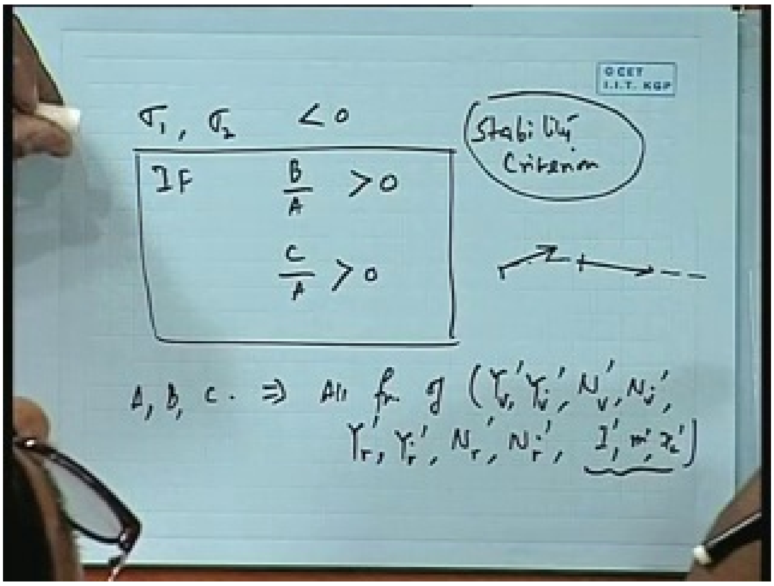

This is this is my criteria, we will keep that, right now this B by A greater than 0, C by A is greater than 0; and we will discuss that little later after we talk about hydrodynamic derivatives at little more detail. What is B by A, C by A, B A C are all function of Y v Y you know dash N v N v dot dash Y r Y r dot dash N r N r dot dash plus of course, I dash m dash x C dash etcetera these are of course, rigid body parameter, so we are not I mean this is a of course, important, but rigid body parameters, but these are the terms which actually tells me, how a fluid force reacts or acts, if there is a flow around it.

Now, what we need to do is to actually talk about this at slight greater length that, I will want to talk about that little bigger length see we understand this now. Now, let us we will come back to the as I say stability criteria, we can say this is my stability criteria. For a ship with control fixed, controls are fixed I do not have control line, but in such a case for the ship to have the come back to its original path of straight line, remember

remember that it is only straight line stability, because when v is 0, r is 0 which means it is not further turning, but it is not changing its heading.

See, the ship was going in this direction, now you have got a disturbance. So, it actually eventually comes back and begin to go in a straight line, when it goes to a straight line you have got v dash 0, r dash 0. So, it simply ensures that the ship can go in a finally, it goes to another straight line only, that is important because it is not positional stability directional stability, but straight line stability only.

All that we are saying is that, if there is a disturbance the ship could have actually gone heave ward, but instead of that it when you remove the disturbance it actually begins to go again along another straight line. Because going along with straight line implies, v dot 0 and r dot, I mean v and r both there is no v.

Motion in the y direction

Now, motion in the Y direction now motion around Z direction

Z

All that

So, we have to therefore, relate this condition with the, with those parameters and let us now look back at this parameters little more deeply, because this is what is called hydrodynamic derivatives.

Then, I will come back because we have to relate the stability criteria with the derivatives. Then, what happened if you can find the derivatives, then you can tell that look this ship has this derivative and this satisfy this, so the ship is going to be stable. Just like when k g and g m you know like g m is positive, the ship is stable.

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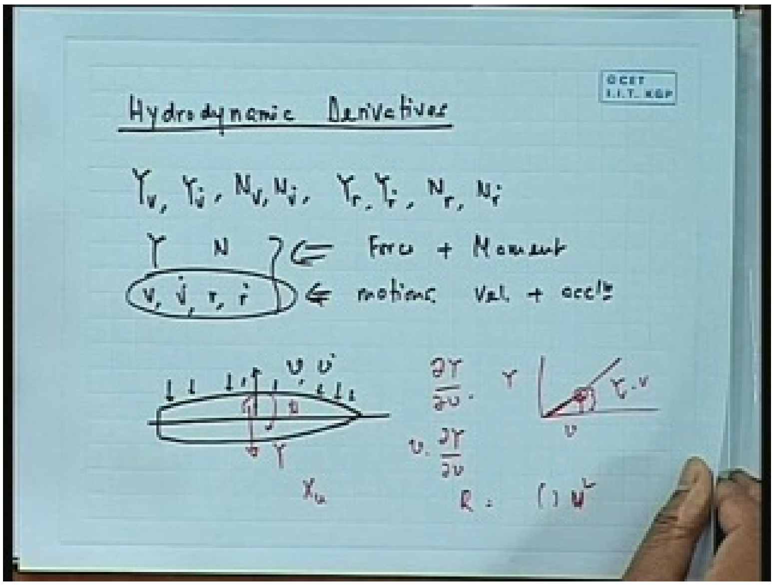

Now, you see all this term, I am not writing here that this thing, if you see here we have got Y and N and you have got v, v dot r, r dot, basically derivative of this with any of them is my hydrodynamic derivative. Yaw moment or yaw force against sway velocity yaw force against sway acceleration etcetera, etcetera. Now, these are called the hydrodynamic derivatives, because they represent basically a hydrodynamic force on the hull, because of any of this motion parameter, these are my motions velocity plus acceleration, this is my force and moment.

So, derivative of force and moment against any of the velocity and acceleration, you know of course, yaw and sway is what we called hydrodynamic derivative, what is the meaning? Take a ship here, I try to give a push, I try to give a v here, moment I try to give a v here or v dot here, say v dot here, I am basically shifting it that side, fluid is going to give a pressure, this net pressure will add up to a Y force.

So, given v, I have got a Y, given v dot I have got a Y, given v I have got also may be an N depending on the direction and given v dot I have got an N. So, if I now plot this, v against Y, v dash against Y and take the slope then I am getting getting this derivative, because when I say Y v it is d y by d v. So, that means, that if there was an actually velocity of v is my force would have been this into this, right because you see what we are doing is that, this is my v, this is my Y, this is my slope here. So, this value is Y v into v, because Y v is the slope, this is what the idea is.

So, hydrodynamic derivatives essentially or hydrodynamic force is that, are introduced on the body, because of introduction of some motions. In fact, you can call the resistance to be also in x u hydrodynamic derivative, because you see if the x force because of u velocity. In a sense one can always tell that, you know that, see it is that the resistance is something into v square or something, so that means, there is a v there because if there is a v of u square, let us say forward velocity r is there; that means, you can say that is a coefficient of v square is one can also think in terms of a derivative, it is something similar to that, we do not use the term derivative, because derivatives are suppose to be small numbers, but it is something similar to that.

What we need to now do is to now check one by one, what would be the typical magnitude? We do not know it, what may be the typical magnitude and what may be the typical sort of sign plus or minus sign for these derivatives. You see we can find out by an study by qualitative study, which is what we will do now for next sometime, which direction Y v is that mean, all this term is Y v positive or Y v negative.

Number one question, number two is Y v a large positive or is Y v a large negative for a typical ship, we will find how that, regardless of ship some of the numbers are always large, some of the number are always negative, some of the number are always positive regardless of what the ship is? Because, if that is the case like, if you can find out then you can actually use that to this stability derivative, because this B and A as you know are long terms this B equal to A 1 B 2 minus etcetera; and A 1 B 2 each one of them is again long derivative, so this turns out to be a large number of derivatives.

See B and A, if you look that A and B are in terms of A 1, B 1, A 2, B 2, A 3, B 3, so that means, B may be B 2, B B B 4 minus A 1 A 4, etcetera. And each of them again is you know like depending on m v Y minus. So, if you write this it will become a large expression, so we want to now.

Since, we know these two criteria, we want to reduce that to a more selected criteria based on the hydrodynamic derivative idea, because some of the derivatives you will find out has some typical number. It is of is there a large positive, large negative, etcetera, etcetera. That is, why the concept of derivatives is important, so we will just do start on that go one by one; let us look into first Y v or Y v dot and Y v.

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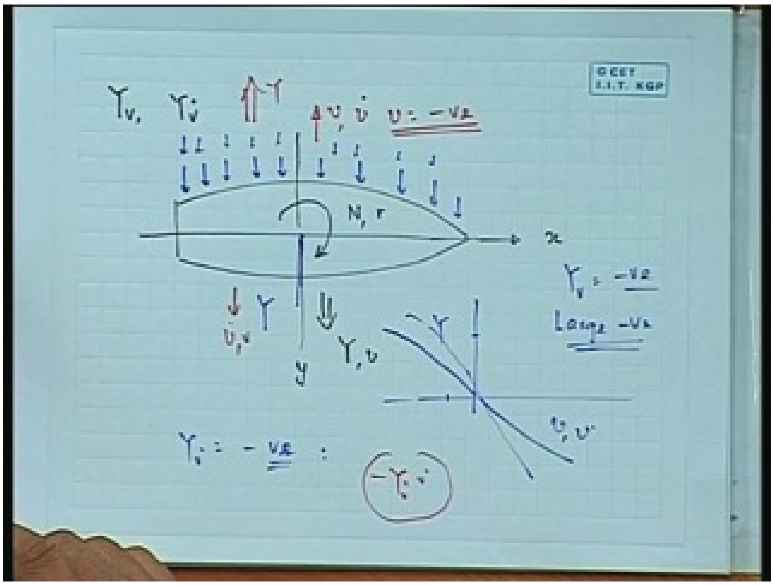

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Now, you see it is very important that we have got a proper axis system drawn. This was my x this is my y and rotation; obviously, would be x to y direction, so this is my positive y force, positive v direction and this is my N and r direction. We do not need n and r right now, so I need not have written N and r forget it, but this what it is? Now, think of Y v, this we are doing going to do slowly.

Y v is what is my Y given a v, now let us say that I give a v, which is negative I give a v in a negative direction. So, v is negative, I have pushed the body on the other side, what would happen? You are going to get, all that forces acting over the entire hull in this direction that is agreed.

Then, what happen you end up getting force, which direction the force will come force will come this direction. So, you are going to get a positive Y for a negative v, in other words if I have to plot here now v here and y here I will get a positive y for a negative v; that means, the graph is going to look something like this, that is one.

Therefore, Y v is negative, no question about it, is it large or small? Question is that here at every point let let us calls this to stern region, let us call this to be you know like stem region, stern region forward region aft region. Forward and aft in entire part my force is acting in one direction, entire force is the full fluid is going to push it in one side, so what happens? It becomes a large negative, so this becomes a large negative.

See, now what happened that, as I am going in this direction, my fluid is getting I mean the entire fluid is trying to push it on this direction, this push acts over the entire part of this longitudinal length, the full length gets push down. Now, let us say we can call it separately, say that this plus, this plus, this plus this, all are added up obviously, when you add them all up, then you get a large number supposing this was pushing and this was pulling and it was this plus that, that could have been you know some number, minus some number could have been either positive or negative.

But, in this case it is not so. The entire hull each point on the side facing gets a push, so I have got, I get a large force when you when you add them, I think I will explain that more with a v dot rather than v, because that be more easier.

So, if I give a v dot here, see if I give v dot here same thing I am giving acceleration. So, I am again going to get, you know all these forces on this side all of them. See, I am trying to accelerate that, accelerate that side, so I get all the forces this side what would happen? If I draw of v dot also I get a large y.

So, I get Y v dot to be large Y, negative, so I get Y v dot to be negative. Now, is it large or small? I want to answer you this question, see Y v dot is nothing but, like an added mass Y v dot is actually, because I have given acceleration this side, there is a reaction force. So, you can say that the full fluid gets trying to get accelerate on that side, which will give you inertia for opposite side.

Because, you see if I took this body and I try to accelerate on this negative acceleration then I get a mass into acceleration force on the negative direction. So, that is why I get minus Y v dot v dot, I get a force of minus Y v dot v dot, this is like added mass into acceleration and added mass in sway and surge are of the order of the mass for this because.

Why we are translating v and v dot as negative sir.

No, it can be positive, I because I give an example where if I give a v dot negative then I get Y positive, you give a positive v dot you will get a force on the other side, this is more debate, I have to end now, see if you give a v here or v dot here then you get a force on this side, the question here is that.

Will be in opposite direction

Whichever, direction you give v, Y is on the other direction, anyhow we will pick up on that again in next you know like class, because this lecture time is up we will pick on that again. So, I will end this one at this point.

Preview of next lecture.

Lecture no. # 36

Hydrodynamic Derivatives and Stability Criterion – II

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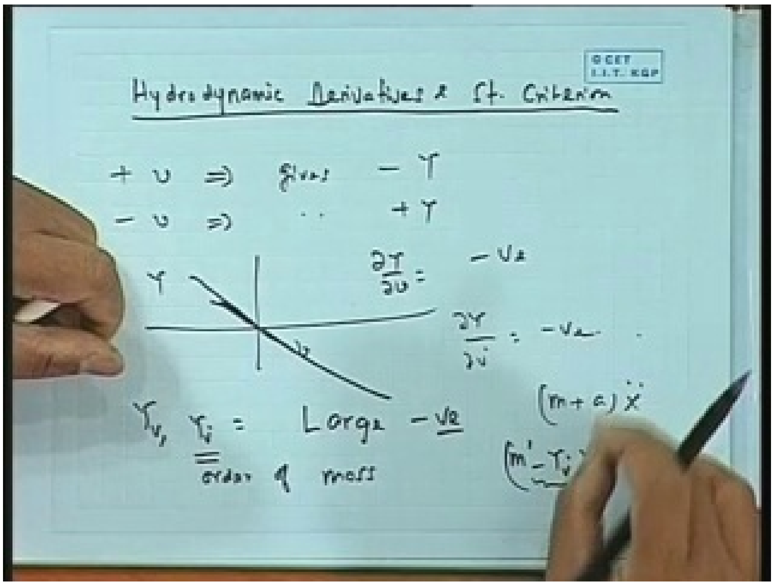

We will continue our talk on the same topic Derivatives Stability Criterion, this is a you see this is this is the directional stability you know. So, again I will just bring back my last class and the last lecture this slide. The reason I want to bring it back is to tell you, that we what we were talking that whichever, direction you give v and v dot see normally what happens? If you give a velocity in direction one, then the Y is going to be opposite direction.

If your motion in v dash direction will be opposite direction, therefore number one is that both Y v and Y v dot are negative see this this and this both are negative, that we know.

Sir why we have to make this

Why, now I understand your question, why I am 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. So, if you do a plot here v and Y, the plot will look like this like this slope d Y by d v is always negative, minus by plus by minus is always negative, that is why similarly, d Y by d v dot always negative this is why, it is always negative not only that that we know it is always negative it is also a large negative.

Large negative

So, it you see 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 you know it is sway moment of linear. In fact, you see that equation is written written m dash minus Y v dot v dot. You see you would have actually you know it is interesting because, you would see in our, is our other equation it was mass plus added mass into acceleration, that was the equation.

So, this is become the added mass minus Y v dot is added mass not Y v dot see Y v dot is negative, so minus Y v dot becomes added mass the analogically analogically, if you compare with say heave and you know sway and all, see if you look at their equation of motion, if you actually look you know I will I will just give more example, see we have got here m z dot equal to minus.

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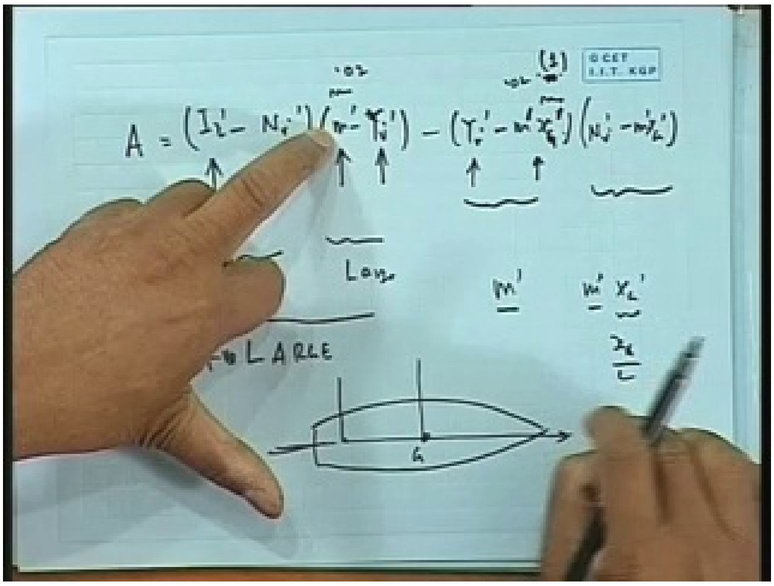

In fact, that origin is not coinciding, you remember one thing is that see that, if I took an axis here then my stern stem definition differs and then I have got large x g dash, normally if I took the x g dash here then see x g dash is such a point from where the stem and stern almost same distance.

Therefore, the origin that we take from that x g dash is very small, therefore this can be small and in fact, I can neglect that if I took the origin at x g dash. In fact, sometime people do that and if I took the origin at g, g is not 2 5, you see g is not say 20 meter ahead of mid ship may be 2 3 meter 3 meter ahead of the ship, that is also true.

So, if regardless this becomes a small number and this also becomes the small number, because this n v dot does not matter, even if though it is little larger so, but this is small, see this is much large, this is much large this will be much smaller to compare to this terms.

So, whatever happens to this and this term

M dash you have to bring large m dash g dash why it is more sir.

M dash into x g dash m dash is larger where x g dash is very small.

Probably zero also.

It can be zero also in a see.

Zero then have we got

No, see this is large by this see let let me put it this wave, let us not take the dash term, so let us take that suppose now ton now m is actually say mass.

Mass

20000 ton this is 20000 ton multiplied by 2 meters also of course, is non dimensional, so there is a v term that l term comes in effect if you take that.

(( )) it is twenty thousand

No, the units are not taken, see 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 you see this is 20000 ton in a 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 that 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 0.02, this is supposed to be large because you are multiplying with half rho l q.

This is 0.02, but this is going to be 0.00, because it is x g by l you see 2 meter by 100 meter or 2 meter by 200 meter, so it is 0.001, something like that, so that this becomes much smaller, regardless of that suppose, unless it is of the order of one, this will not cancel with that, see 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…

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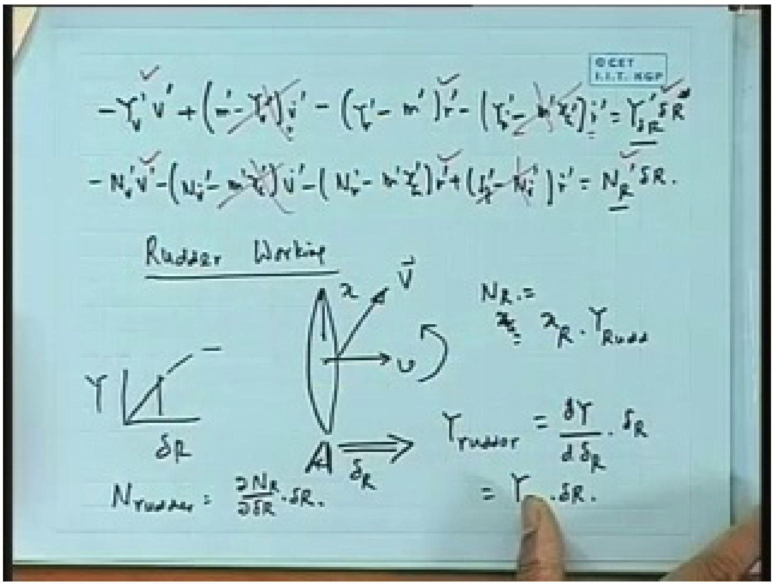

Such that, we will find out later on that, this will cause if I give a Y r, you know if I give a delta to be negative the ship is going to turn on the other side. It is actually device such a way that, you know if you turn it this side the ship on turns turns on the other side. So, that analysis we will do afterwards for a steady turn, if you want to actually show the transient you have to solve this full equation, which cannot be solve, so easily. You can solve in a time domain, you know like step by step stimulating like you know give a force, see how they are trying to this.

So, this is about the radar part and I wanted to say say that, actually if here you will find out an interesting part, that the 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 my stability criteria.

The stability criteria if you look back, I will just show you little bit, it contains of n r y v n v y a minus n, that is that is, where it is n r y, now y v here, this v dot, N r what I mean is that we can actually show that there, there will be a there will be a this r dash see n r and y v, this multiplication and this will come, one can show that basically this criteria have a relation with this radar angle.

In other words, only for a stable ships we I will I will do that afterwards, only for a stable ship, you will find out that if you give a radar this side, the ship turns that side in other words, you are actually assume there is a stability involved somewhere. Anyhow, that we will discuss in in the subsequent class with respect to our, you know definity maneuvers, but this is where I will stop here.

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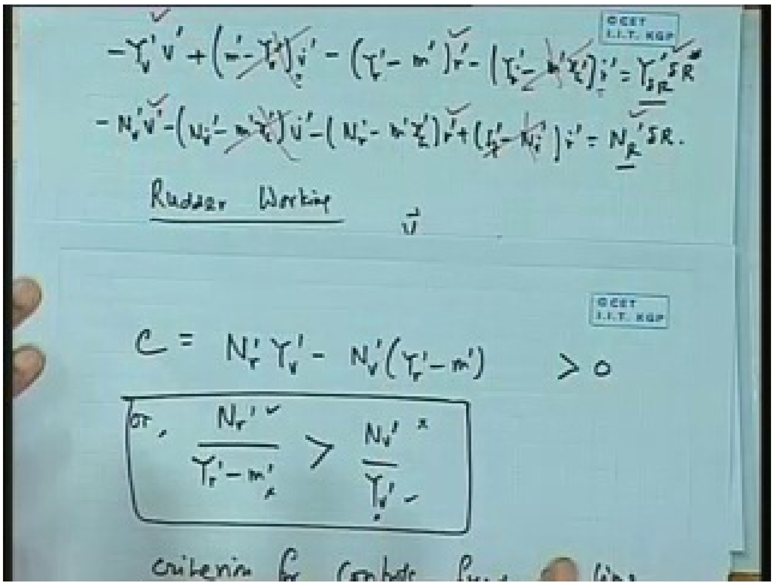

So, what I want to sum up here, therefore is that we should understand that, there is something called stability criteria, which is an intrinsic property of the hull these are intrinsic property of the hull.

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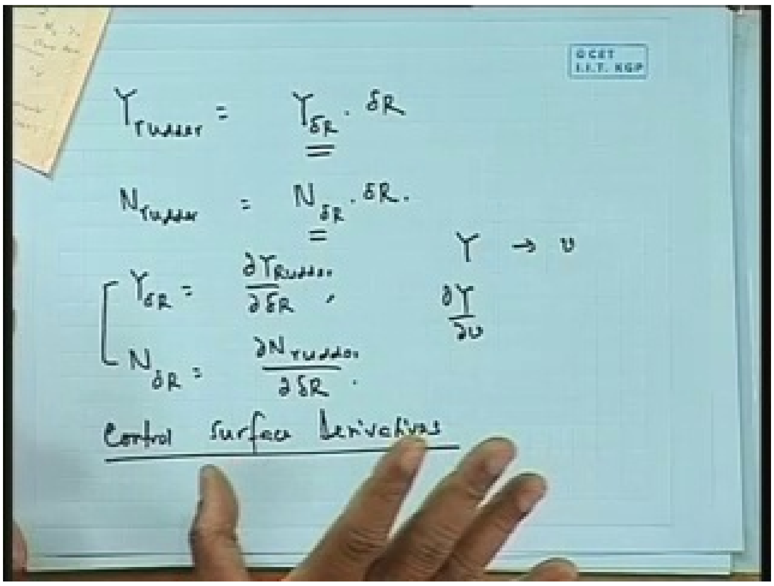

So, therefore, if you have a bad hull design, which has an intrinsically unstable hull then; obviously, you will need much more radar control.