Performance of Marine Vehicles at Sea

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Lecture No. # 32

Derived Responses

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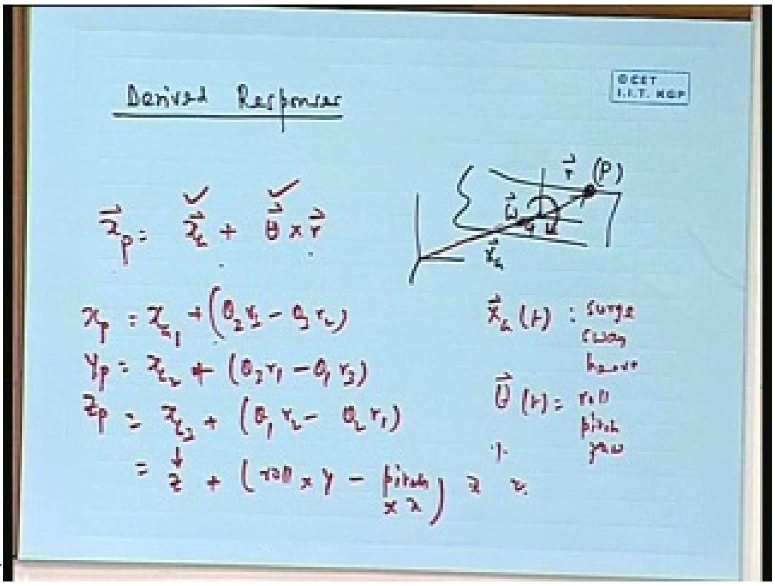

This is going to be probably the last lecture on the topic of ship motions. What we will talk is, briefly, the Derived Responses. What does it mean? So, far we talked about the primary ship motions, that is, heave, roll, pitch, sway, surge, and yaw.

But, normally the practicing engineers want information of ship behavior in terms of other quantities like how badly it slams when it goes, like you know, hits bottom, how frequently the water comes on the deck, how much the propeller comes out of water and performances deteriorates, etcetera. etcetera

These are called Derived Responses. I will talk in a minute. Before doing that, I just want to general formula to be told. Supposing you take any point here and I want to find out what is, suppose this point is located at the vector r and this is moving at omega, what is the you know for any given point motion?

Now that I told beforehand actually, the reason I am mentioning is that Derived Response says what would happen is that, you might be interested to find motion and various other points and not at the primary point.

See, this is my centre of gravity and how the centre of gravity supposing with respect to an coordinate system? This is my vector x g. how much x g moves up and down with time is what actually been told, by say, heave roll pitch yaw etcetera, sorry, the linear motion.

See, this is my centre of gravity here and this vector with respect to fixed, let us say, is called x g.

So, x g as a function of time, if you take how much it is moving vertical direction, see if you take x g, this is my linear motion surge, sway, heave and if you take this rotation vector omega, and if you take the angle of that, actually the you know the angular orientation of that say say big theta, then this omega vector's derivative, it is actually this sway surge and roll. You know, like sorry sorry roll pitch and yaw.

What I mean is that basically, you can find out the displacement of any point p at any point p in terms of x g plus a vector called your theta dot cross r something like that r cross theta whatever.

In other words, this is a very simple thing what I want to say here, is that see if you knew the 6 modes of motion, this and this ,you can find out at any point whatever ,of course, r is a known location. So, you can find out motion at any point. It is a very simple thing; actually you can work it out. I can just tell you that x p the x of that becomes actually surge x g 1 plus this becomes theta 2 r 3 minus theta 3 r 2 etcetera. etcetera

I mean it is very simple; let us not get in to that. that Let us say, let me write the other 1 z p z p is this y p here, which is I am writing plus 2 3 3 2 is 3 1 1 3 2 3 3 1 1 2 it becomes then x g 3 plus theta 1 r 2 minus theta 2 r it may be incorrect, but something like that 2 3 1 3 1 2.

It is very cyclic you know. If we write a program, we never make a mistake. You will see there is 3 2 1 like a cycle 1 2 3 if you take 3 2 1 or 2 3 2 3 1 3 1 2 like that it goes.

Basically, this 1 for example, can be written as this is heave plus theta 1 is actually roll roll into r 2 is actually the y coordinate of the point minus theta 2 is pitch into x (( )) .

Its it is a very simple thing, or you need not worry about the mathematics I have actually done that at 1 point of time. But, it is very simple that if you could find out roll all the 6 primary motions. What you we have effectively said is that, I can tell where the ship is at any point of time. That means, I can tell where it is. Therefore, I can tell where which which point it is.

Therefore, I can tell the displacement of any point. Then by derivative I can take this acceleration, then I by double derivative, I can take it’s, you know, velocity acceleration etcetera.

So, I know all that thing. So, this all these are information about motions at any point of the hull, can be derived from the 6 primary motions.

So, you can say that they can be derived from the 6 motions. So, once you know the 6, it is a 1 line operation. You just line the formula, just plug the numbers and that is it, ok?

But, what happens? you may be interested more on that information. For example, you might want to know what is an acceleration at a given point, because, you might have put here some kind of instruments say a gun mount for a naval vessel that I will act as a force. Moment of inertia in to inertia force is mass into acceleration

Suppose your housing is here. You would like know what is the acceleration of that on that house because, your body is subjected to that, you know, depending on where you are sleeping. This is the reason one of the reason why people sleep this way, now of course, now a days they sleep breadth wise also.

But anyhow, this is all kind of derived things. Let us now look at the various kind of Derived Responses 1 by 1.

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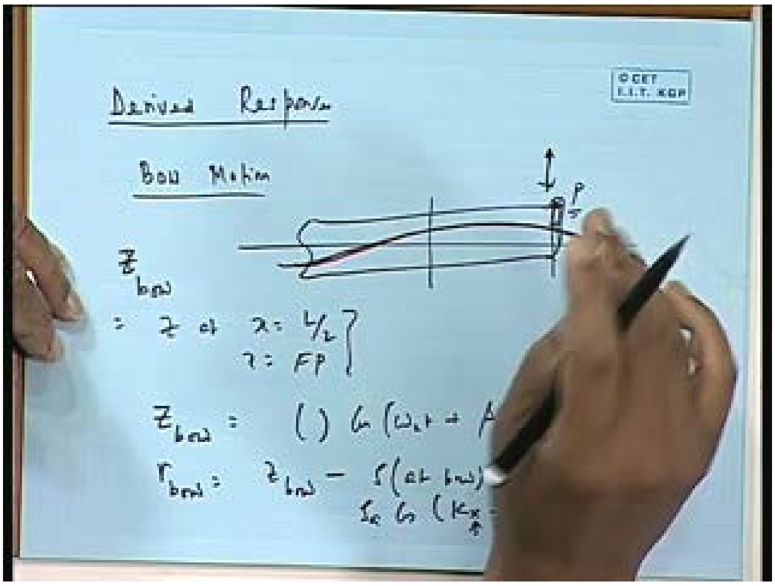

I just want to say very quickly, 1 of them you can call Bow Motion. What is Bow Motion? it is actually, this is a ship here, you take a bow point say, f p what is the vertical motion in f p? Fine, that is no problem. You can just find out vertical motion by combining given pitch. You know, all you are doing is that you what is the motion? what is my z motion at bow, means, what is my z motion at x equal to say L by 2 or whatever something like that or at x equal to f p?

This is my Bow Motion. You understand why why people want to know Bow Motion. Because, you want to know how much bow is going. But, that is not the important thing. What people want to know is relative Bow Motion. That is, if there is a wave here, there is a there is a wave here.

Now, you would know, I will know, my Bow Motion z at bow. This will be given by sub formula say something into Cos omega t plus some phase angle, something like that, I will get that by combining.

Now, relative Bow Motion relative Bow Motion is going to be z bow minus the wave height at the bow minus say zeta at bow that I know what is zeta at bow. Because what is zeta at bow is nothing but it is zeta a into Cos k x minus omega t with take an x as L by 2.

So, you see the principle is very simple. principle is very simple Here, the ship has moved so much up and there, the you know the wave has moved so much up. So, you can find out how much the, you know, the relatively this point a given. Actually, here you have to take a particular point z bow. Instead of z bow here, you take a point here. Say, I will take a point p here.

Then, I can find out a point on (( )) on the 4 4 peak. For example, how how much it is from, with respect to wave; see, something like this.

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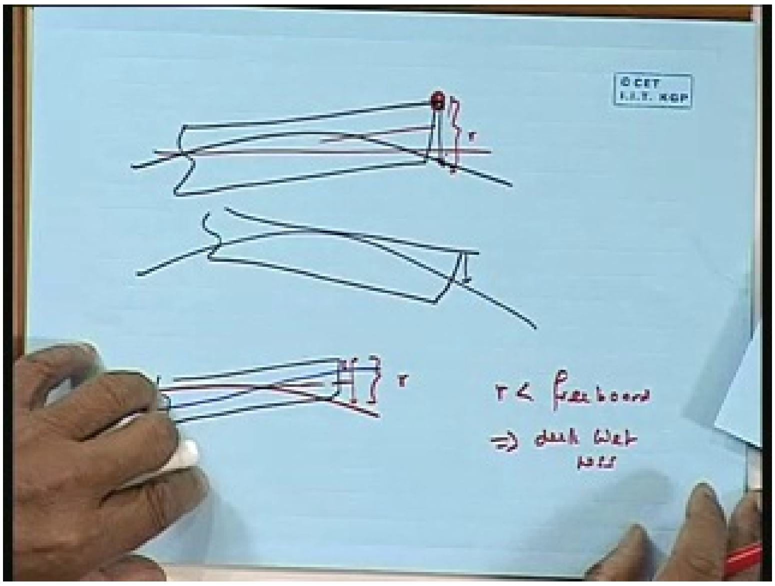

I can tell at any point of time, this point, how far it is from this, because it can be next instance and you see the phase information becomes very important. Because, supposing, they this diagram is interesting, supposing I, my wave is here one case, let me use other color. So, I can have a wave going like that or I can have a wave here, at the, my this thing is very short or I can have the wave actually going like that. Then, I have got very high.

So, you see, what this of course, depends on the phase. when the see Just think of it when the wave is rising, ship might be going down. Then, my basically what happens is that that the relative Bow Motion will may come down to very small value or may become a very large value. So, it will oscillate between small to large value.

Now, what happens is that, here comes the interesting part. Now know this value, say r. Now, what I will do? I will find out, you see, at any point of time this r is becoming less than the free boat. See, after all, there is a free boat here, ok?

If r become less than the free boat, then I say that if r is less than say free boat in some sense, then I say that take (( )) occurred is it not?. Because, what happens that, you see, that there is so much gap.

Now, the wave has gone up, the ship has come down. So, the gap between that the the the height of the point with respect to wave height is suppose to be actually some number, but it has become less than some threshold number.

We can work the details, but the principle is very simple. There is a particular point, it is actually with respect to absolute value; so much height. So, with respect to wave it is so much height, but it must always be above the wave height.

So, you can find out if it becomes 0, if supposing this height, if I call this r, if this r has become negative. Actually, here, this is not same as minus free boat that is again using another reference; but just think if this point with respect to the wave.

I am I am I am saying that the distance of this point above the wave height, above the actual water surface, this r that is relative motion of this point.

In fact, they call the relative motion of the point, actually at this location. That is why this free boat comes in. But forget it, just think the concept. I take a particular point as a representative point, I will say that if that point comes down below water, then it is the deck is getting wet. Let us draw this another picture in a better way.

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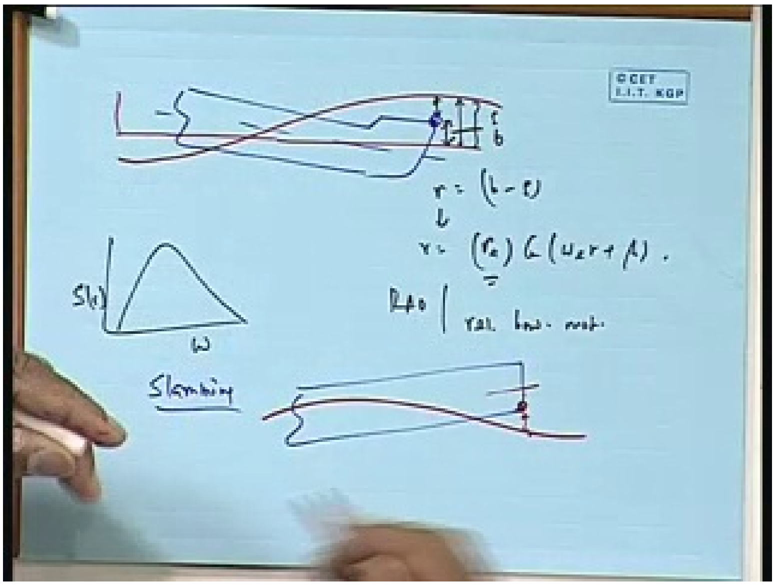

So, I have a point here, let me see, a I just draw this

(( ))

Yeah, if I take this point actually, now supposing, I have this point, and this is my wave height and this is my reference. See, some reference is like this is my reference. Now what happens, see here, you can say free body, mean water line, whatever some this thing.

Say this one is my Bow Motion, how much is going, and this one is my wave height and this much is my relative motion, and you are doing negatively in this case. You see that r which, if I take this, see supposing I call this to be Bow Motion p and if I call this to be zeta b minus zeta and this is becomes negative.

You know in other words zeta has become more than b. So, therefore, the take is weight. So, I can find out. from the again Since I have got now, what I will do is that I will take for this r a spectrum, because you see this r is nothing, but again a sine motion.

So, I can find out see r. If you expand, that r will turn out to be equal to some amplitude into some Cos omega t plus beta, something like that.

So, I can find out basically RAO, for you know RAO for relative Bow Motion and I can draw a spectrum.

Then, I can, from a spectrum find out what is the probability of my r becoming less than 0. You see, I (( )) the spectrum, know I know the value of s etcetera and as I told you that from there you can find out all quantities of this Response whether it is less than. So, and. So, what is the chance it will be more than. So, and so.

What How many times it'll occur once in so many years, all that you can find out. So, you see very simple, I mean formulas, I am not going to the formulas, but the principle is important. You can find out very easily just by another 1 line formula, what is the chance or what is the probability or what percentage percentage of time r becomes negative.

So, you can tell suppose it is 25 percent of time in that particular sea state r becomes negative.

So, you say that (( )) 20 percent of time people actually say in terms of cycles the you know that can be that can be said that how much at every how many seconds r will become negative

So, you say, let us say that is 5 seconds. So, you will see that every 5 second I have got a deck getting wet every 5 second the deck is wet like that all information that you want statistically you can find out from there for this

So, again you see this is the Derived Response because how did I get r r is nothing, but Bow Motion minus of wave motion which all are available to me and again as I mentioned before it is again a sinusoidal wave motion

Now, exactly same way, I can find the step of probability of slamming. What is slamming? The other way round, slamming would be, in in in a case of slamming, it would be, I do not say slamming right now, let us say it is the probability of bow coming out of water. Again, you take this point or some point and find out again. It is you know, relative motion the other way round, if you take this point for example.

If this point is above this height then, obviously, it is the deck has come out the fore peak, has come, you may call fore peak emergence, fore peak has come out.

So, you can find out how much time the fore peak comes out, of course, slamming is a phenomena that is connected to the impact.

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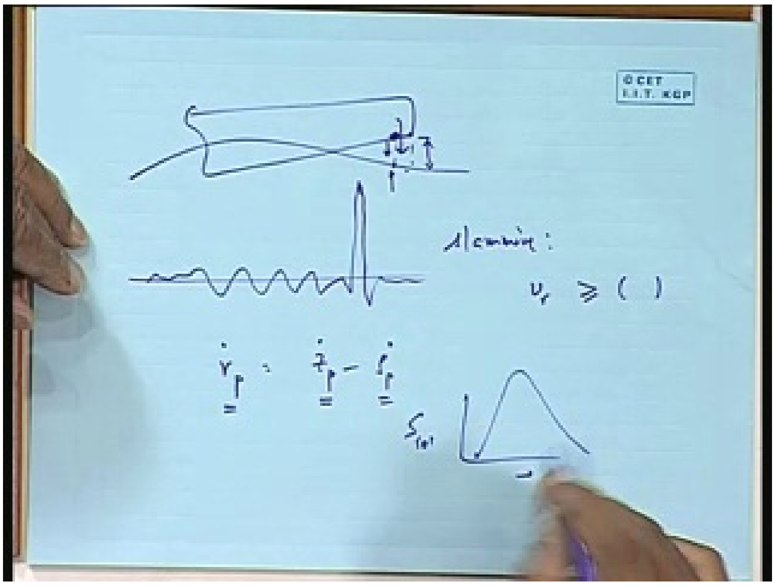

What happened is that, sometimes it turns out that that the ships fore peak comes out like that and it when it comes down, it hits here and if you actually take a point here and make a pressure, you'll see that pressure is going like that like that, suddenly goes up very high.

When it hits here, it becomes very high. This is called as slamming and people, specially the society people wants to know slamming pressure.

Now, or you want to find out probability of slamming, how much you know or what kind of time it will slam.

Now, you see the chance is that the bow will emerge, as I said you can find out by again finding out the chances of this point coming out of water exactly same way.

But, for slamming, there is you know, people have given many speculations slamming occurrence. It turns out, (( )) see every time it hits, may not slam, you say normally that the see this is coming down with the velocity and this particular water also coming up with the velocity.

So, the relative velocity of impact, the relative velocity by which it is entering water, say, I call it v r, you know, of the bow point of this some point, if this is exceeding some some value, people say that slamming has occurred.

So, in other words you actually introduce a criteria that you say that I will tell slam has occurred, provided the rate at which it is meeting this surface, the relative velocity of that particular point exceeds some (( )) values, something like say, point 3 g or some some numbers is there. ok?

Let us just take the principle of it. Essentially it is found out that it is connected to the rate at which, see, after all the ship is coming down slowly. It see Think think of this, the ship has come out of the water fine.

So, you can tell, it has the bow has emerged, but when its coming down, its coming down very slowly. As it comes down very slowly, all though it is coming down, it may not give that pressure.

So, slamming normally is, you can imagine initiatively it is related to how fast it is coming down. You now, If you take a stone and throw like that, it gives much more impact. If we just drop, it will be much smaller.

So, you know it is connected to velocity. So, in here, the criteria that is derived is that, what is the I mean, rather, I will say other way around.

If this point is the relative velocity of that point with respect to the water surface, or you may say that the relative velocity of this point at which it is entering water exceeds or is more than some number, then you will call that it has got it has got slamming.

Now again that you can find out, because, you know now velocity, see, I know the distance. So, I know this point's location. So, I know the relative distance of r, you know of this point particular p, which will be of course, the z of the point p minus xi at the point p, the wave height sea.

I can find out the relative displacement of that, just like I had done before; which is the z value of the point p minus the wave height. Then if I do a dot, I will get the velocity of that that also.

So, I know again exactly the same way the velocity distribution of that point. I will know that by I can draw the spectrum again, I can have an RAO of that velocity.

See, these are all Responses. Case number 1, I did Bow Bow Motion displacement 2. I did relative Bow Motion. Now, I am doing, say relative bottom motion of the bottom point.

Now, I am doing relative velocity of the bottom point. So, I say now. So, I know how much the relative velocity; how it occurs. So, I know this is my relative velocity, this is s relative velocity spectrum.

From there again, I will find out what is the chance that it has exceeded. So much so, Then I say that, it is, you know slamming percent is so much. In fact, again, everything I can find out, I can tell slamming would occur once in so many cycles.

See, I can find out what is called a, you know, average period. Then I find out that it occurs at every, say hundred second; now average be at 10 seconds. So, I will tell that every 10 cycle, that 10 times it it it slams. People like to know that you know severity of slams. This is a subjective decision, there is no objective.

You are sitting on a ship, you find that it is banging. banging You have to quantify that. There is no hard and first quantifications.

So, you tell in terms of some kind of statistical term, you say it is bad, it is bad for you, but not bad for you. So, you say I will tell that if it is more than this, is bad like that, there are some criteria. So, here you'll say that if you say you know velocity is more than this, it is the slamming.

Similarly, once you know, now now you define slamming, to. so and so. Then you can find out the chance of slamming, number of times it slams in 1 hour. Normally, people like to know this, actually how, what is the number of times it may slam in 1 hour.

See, you can find that out also. Because, if you know it slams once in hundred seconds, then in thirty 6 hundreds, thirty 6 time it will slam.

So, all this you can find out. this we I am not going through that the typical way of deriving. But you can find out this again. Derive this much same way, I will have to go little quickly, slamming is gone.

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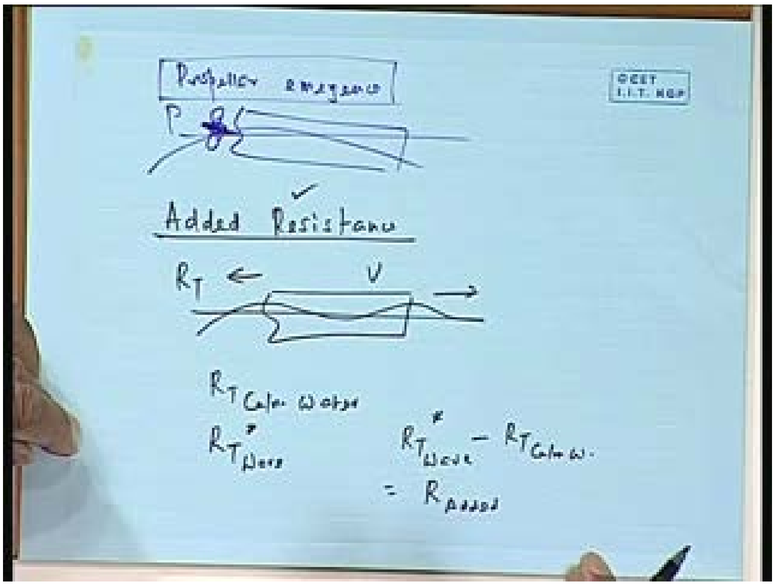

Then propeller emergence; some time you want to do the same thing, that propeller is coming out of water. Again, you will say that propeller location, the centre plane of propeller, you define and find out relative motion. What is the chance of this coming out of water?

See again, here you take this particular propeller point, this point as p. Find out what is the chance that it comes out of water. Same thing, there is no difference.

Then some people will want to know this is propeller. You can relate this propeller emergence with with propulsive performance, because, you can now tell that if it emerges more than this thing, my first I get is so much.

So, you can relate, you can say that, look since my propeller emerges so many times, and if every time it emerges, my thrust goes down. So, my there is a reduction of thrust.

So, you can relate that to, you can say that I am going to get average sets in a sea state 5. I am going to get 20 percent this thrust.

In an average sense, (( )) at 6, I get 40 percent (( )) etcetera. etcetera The important thing that is actually, more important for us is a quantity called Added Resistance. that I i should they are little bit of this.

This is another Derived Response. You can say, see this is actually interesting because, it is a part of resistance, but it is actually a sea keeping phenomena.

You know, if you now a resistance, sometime they add this thing as a some thirty percent factor of safety. All comes like that you see, if you have ship here moving in calm water, what happens? It gives a resistance R T. So, R T is calm water. You have done that in the early part of this course, fine?

Now, now you take the same speed, going at same speed, but now it is going in wave. What happens, it is going to give you R T star, in wave let us say.

Now, if you take difference of this minus that; that means, R T star in wave minus R T in calm water, this is called R added.

In other words, how much more resistance the ship will experiences if it is going in a wave compared to if it is going in a calm water?

Now, the question is that, why it is a sea keeping phenomena? you may say. But that is only a simple phenomenon of resistance. You know, instead of calm water you have got wave, but no, it is a sea keeping phenomena. I will explain you that.

But, you understand this concept first. You see, everybody understood this, that in rough weather, to sustain the same speed, you have to have more energy. Because, the resistance goes up or what you the people experience is, the reverse; that in rough weather automatically. If the engine r p m remains constant, the speed falls down.

You would have experienced that in rough weather, speed has come down. You did not do anything. Engine is set at that r p m because, the drag has gone up.

Why the drag goes up is a question that I will just very briefly mention and that is called Added Resistance, that that comes out from sea keeping, not from resistance calculation.

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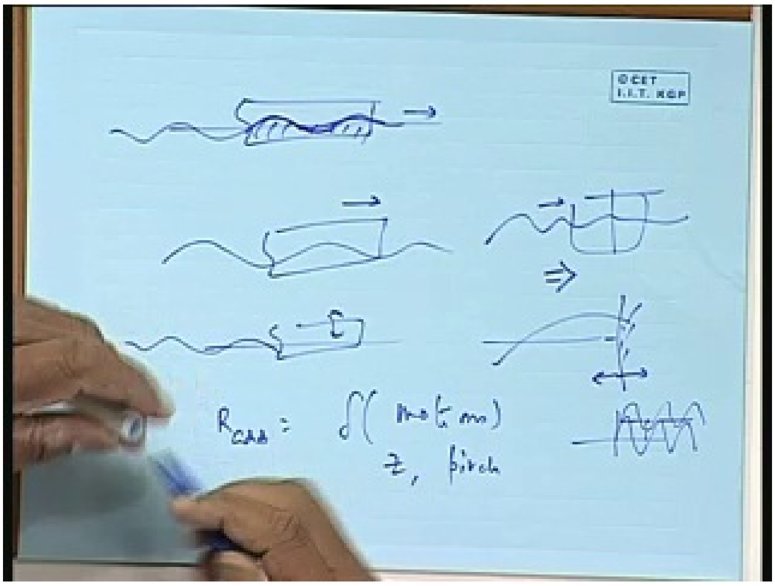

You see what happens? You think of this case when the ship is moving in calm water, what happens? It makes waves. When it makes waves, we say that it has expanded energy. It has expanded energy and that energy shows up at wave resistance. That is what we say.

Now, you see already existing wave there. As the ship moves, what it does? It is heaving and pitching, right?

Now, you consider a ship heaving and pitching in calm water. You just take a ship which is heaving and pitching. What will happen? It is going to (( )) another wave.

So, by the fact that the ship heaves and pitches in calm water, it creates waves, which is a loss of energy and that energy shows up as Added Resistance. You see therefore, Added Resistance is coming out because of the fact the ship is heaving and pitching; and the ship is heaving and pitching because it is (( )) waves. It is not so much because of, you know, that change of weighted surface. Because of that and all, because weighted surface change normally gets compensated plus minus. (( ))

Because of what happened, the net (( )) area does not change very much. So, people may think that when it is going in waves, I have a different weighted surface. It would not be very much different because, the buoyancy which is somewhat connected to weighted surface remains more or less constant.

So, you know if there is some part he goes up, some part comes down. So, if you take a mean surface and an instantaneous surface, there is a difference, but not much. The Added Resistance is not primarily for that. the You know, why I say is, that you may think it is going in waves.

Therefore I have got so called weighted surface. Changing (( )) skin friction will change, that is, what a first impression of a beginner might be. But normally, that is not the main issue.

Main issue is that is not seen, is that the ship is going with an up and down motion. As it goes up and down motion, it actually makes waves, which show up as a loss of energy, this is actually tapping.

And therefore, you can express Added Resistance as a function of motions, where expression, where you can find out that Added Resistance expression is function of basically heave and pitch motion. Basically, heave and pitch motions and damping and all that.

You can relate that there are formulas available where you can find out that Added Resistance is something p square, something this thing and that. In fact, theoretically it is a complex phenomenon, because, it is known as what is called non-linear or second order phenomena.

I do not want to go in to the detail, but this is known as, this is more difficult to estimate. It is called a non-linear second order force. It is equivalent to a drift force. If you if you keep an offshore structure in place, if waves keep coming, this will have a force coming up and down. But, in addition, there will be a net small force in 1 direction. People do not see that if you have a wall here. For example, if the waves comes and hits here, there is a there will be a pressure this way and there is a pressure that way.

So, if you want to draw the force, you may think, it is like that you know, at point force is plus minus. But actually, (( )) it is not. (( )) The force is actually like this. It is about a steady part and that part is called a drift force.

There is a net force that comes 1 side. Same as this net force that comes on the ship; which is actually given to this Added Resistance. It is all complicated phenomena. I do not, I would not get into the detail.

But, it is an interesting phenomena that in waves and all. If you keep a body and waves come from 1 side, then it is not only up and down force, there is still a net force in that direction. Small net force comes in that direction that is not ever seen normally and you cannot explain that from what is called simple sine wave, simple first order pressure theory. You need little more sophistication for that.

But, it is a reality you cannot see. As long as is reality, just because math is complicated, you cannot say that I am not going to be bothered. See, after all we have to kind of predict reality. Our aim is to predict reality with as simple math as possible.

But as somebody said, in fact, Einstein said everything should be made as simple as possible, but no simpler.

You cannot make a simple enough when the phenomena is not there. So, this resistance, Added Resistance is a real phenomenon. You cannot say I would not be bothered with second order force or whatever, because, then you have no Added Resistance.

But then, reality it is there. Anyhow, the point of that by this part is that, it is also Derived Response. It is not a part of resistance generally in to find out Added Resistance. You have to solve or you have to know the ship motions.

So, Added Resistance arises because of ship motions. This should. Obviously, this is a Derived Response; purely a Derived Response.

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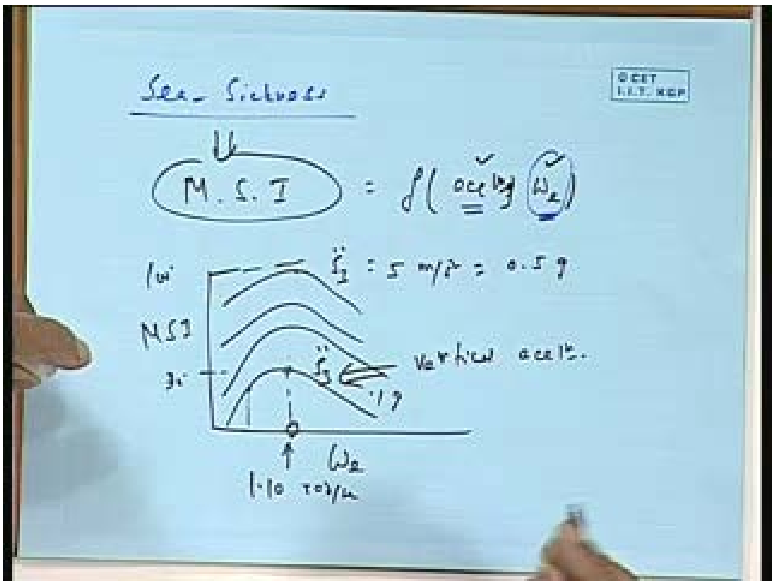

Now comes next thing. This is again as I say, one of the Derived Response. Let us say sea sickness. This I talked little bit earlier. Again, this is a, see, it is found out again, it is somewhat subjective, you know.

We have (( )) sort of found out if people find out by taking lot of study of subjects. You know, you take ship hundreds of people on a ship, monitor the Response and find out how many people have vomited.

Like that people have done and (( )) that is, they call it some motion sickness index, some term they have actually used, motion sickness index.

This turns out to be function of actually acceleration. At some point where you are, you know, that the housing is located and frequency. It turns out that a certain combination of frequency and acceleration, you actually have large motion sickness. I will show you that definition in the diagram.

So, in fact, a the motion sickness looks something like that. If you do this, if you say motion sickness index incident, it motion sickness incident means so many. This is hundred here, it looks something like this, is all xi theta that is actually acceleration that vertical.

This may be some value say, this may be, see, I gave an example. What it turns out is that there is a, you can actually draw a graph frequency versus motion sickness index for various acceleration. It turns out that the graph looks something like that. That means, for a lower acceleration, say, this may be actually point 1 g say point 1 g.

If you know this is percentage, may be this is actually thirty percent. What it says is that naturally, if this acceleration is more than this at this frequency, then, so many percentage of people have become sick.

If higher frequency or lower frequency, same acceleration, less fall sick. So, there is a combination of that. See, it is depending on a function of you know, acceleration, sorry, this is acceleration as well as frequency.

So, at a if for a given frequency, your body you know, the place where you stay, you exceed certain acceleration. You have certain percentage of people falling sick, fall by M.S.I

For example, here according to this diagram, this thing it turns out to be about 1.1 0 radian per second. This peak peak occurs around that.

For most people, the you know many things, it is found out that around that. That means, if your this 1.1 0 means 2 phi by T means about say 6 seconds around 6 second period 6 second, you know you tend to have the largest M.S.I. Statistics shows people who are on (( )) do not show up. I am talking of passengers you know, this crew comfort passengers. comfort

And if it of course exceeds about say say point 5 g at that thing, it turns out almost, theory shows almost hundred percent people fall sick 90 percent or so.

This is how you study again. Why I am saying that because, if you look at the motion sickness index, to study again, it is a part of a Derived Response. Why because, there is acceleration there at a given location. You get that from the point you find the displacement of the point and acceleration.

And of course, omega e so, obviously, if a small result for which you have got lower omega e normally in a given free state and it is accelerating further, you tend to fall more sick normally. Obviously, you know like if you take a small boat, it will have a lower natural period and lower natural period also gives you larger acceleration because its omega e square times.

So, you have a larger chance of falling sick in a, if you are travelling in a barge in ocean then if you are travelling in a large tanker in the ocean. I mean this is a normal phenomena. I think you know much more than I would. I am only theory, theory I am telling this is what it is.

But my point of saying here is that, even this can be found out by sea keeping calculation motion. All this happens to be basically a derivation of ship motion or result of ship motion.

Fact that the ship is moving, not a steady you know, like platform, all this arises. In fact, now a days there is a large number of studies going on this, because it has been found repeatedly that all this ergonomic behavior. You must have done in management that you perform far better, you know, there can be some may be subjective curves and all provided your working is better.

In long, in Russian submarines, where there is only small cramped space that we have Indian navy, your your performance much lower than the modern nuclear subs where you have a much, you know, nicer place. You can go for a longer time, you perform better in emergency, it has all been kind of proven.

So, the design, obviously, as we are progressing, we should try to keep you know, we should try to design as better as possible working environments.

(( ))

Yeah yeah that is That is obvious because, you see, if you look at this, acceleration acceleration is much more connected to, you see, not only that.

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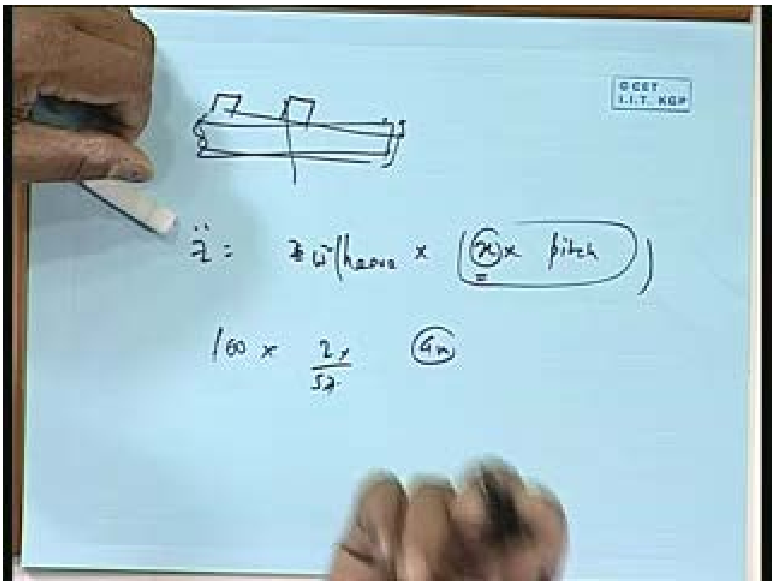

See if you no it is very interesting as you say, if you take a, if you are standing here, if it you know, if it pitches, the pitch has much more this thing because, why happen the the the the z value is z is heave plus x into pitch,

So, you see, x is a large number in order of length therefore, this has a large inference. So, normally, the pitching contributes to large of, you know, this thing and if you do; obviously, dot dot this omega square will come, then this contribution is larger. But if you have (( )) of mid shape, maybe it is not. So, if you are in a somewhat in.

Nowadays accommodation, see nowadays your accommodation is at the end. If your accommodation is at centre, may be it is not that bad for pitching. But, see most modern ships, you probably have gone you have been at the, (( )) most likely mid ship accommodation is almost obsolete.

Therefore, your (( )) is larger therefore, obviously, it is pitch that causes more, (( )) that is obvious you know, and pitch also is more dominant. See, even though it is pitching 2 degrees if the ship is say, 200 meter long, it is 100 into 2 degree.

So, you can you can imagine that hundred into 2 degree means you know, in radian if you make 2 into what by 57 say 57 types. So, it is almost 4 meter of you know, like if it is going down 2 degree at a distance hundred meter, it is basically going down 4 meter what a lot and in fact, heaving may not be 4 meter, heaving may be 1 meter. So, pitch contribution is normally more, that is the fact.

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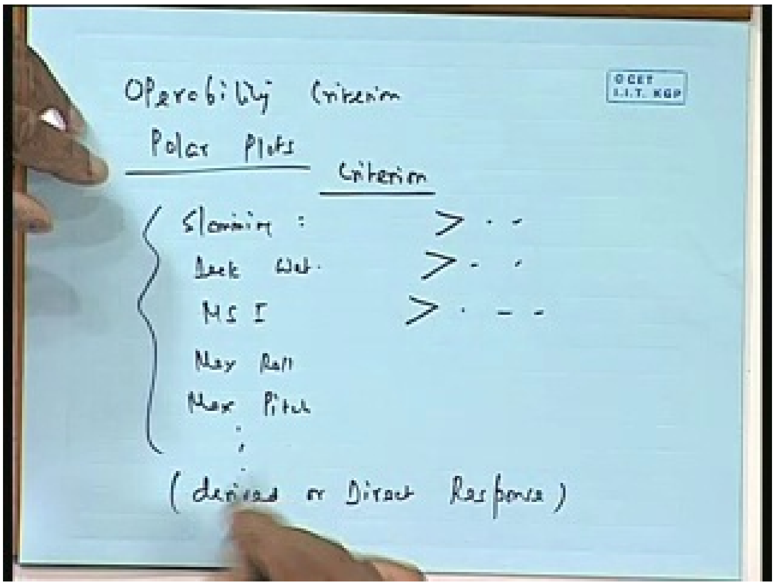

Now, at the very beginning, having done all this, there is something called polar plots and Operability criteria. I just that is the last we will do. Operability polar plots, see what happens for almost all (( )) you have got number of index. See, I have got slamming deck wetness motion sickness index maximum, say, roll may be maximum pitch like that.

Many ship owners would actually tell you, will give you a criteria. They will give you a criteria saying that, look my ship cannot operate if slamming is more than so and so numbers; deck wetness is more than so and so number; M.S.I is more than so and so numbers, etcetera. etcetera

They can give you a number of criteria. All are actually Derived Responses or direct Response you may call, and they will give you a set of criteria. For example, people will say that maximum pitch should be less than 3 degree, maximum roll should be less than 10 degree for the vessel to operate, for suppose it is doing some operation motion, sickness should be less than so and so, deck wetness should be less than 1 per so many hours, etcetera. etcetera

Now, you have done all this calculation, there is a set of criteria given. What we can do in a polar plot is something like that.

See, you draw a diagram here, where there is heading angles are here, this is all heading angles you know, this various angles.

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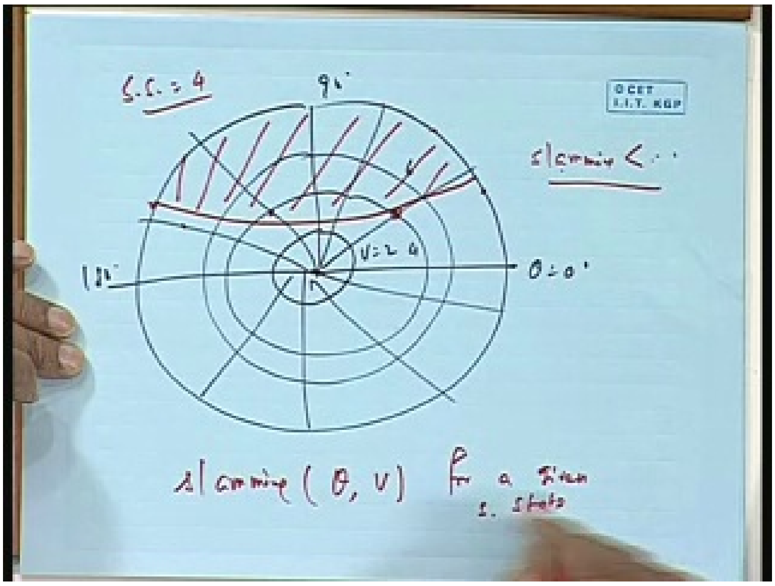

This is say, say theta equal to 0 degree like that, 90 degree 1 8y degree, you have got speed lines here. This is v equal to say, 2 knot v equal to 4 knot v equal to say, 6 knot, etcetera. So, you make a diagram like that.

Now, you find out, let me say, slamming, my slamming should be less than so and so; that is my criteria.

Now, I find out that at this particular speed, that exactly slamming becomes so and so, provided, it is at this speed, at this you know, at this heading angle, at this speed, my slamming is just like that, and this speed at this heading angle, my slamming is just like that. Like that, you that you have the boundary in this graph.

Then what happened? I will just very briefly tell you you can actually join them, you find out that look, if the ship is operating in this zone, this combination of heading and speed, then my slamming is going to be more than what is stipulated.

In other words, see, I have found out slamming. This will be for a particular sea state number equal to 4 say, some given sea state slamming as a function of angle heading angle and speed. Obviously, it depends on this 2 criteria for a given sea state.

Now, I have I have I have to determine, see now I do a long elaborate calculation. I do a calculation of all this Derived Response, for all possible speeds of the ship and all angles, all sea states.

Now, for a given sea state, I will find out which combination of theta and v, my slamming exceeds the limit.

So, I will say that if the ship is within this range, my ship is now going to not meet the slamming criteria. So, this is my operation zone.

In other words, I can operate in sea state 4 from the slamming point of view, provided my v and mu are within this range. This is the simple polar plot, what is called because, you would like to know this. is I will give you another example, probably better in terms of roll.

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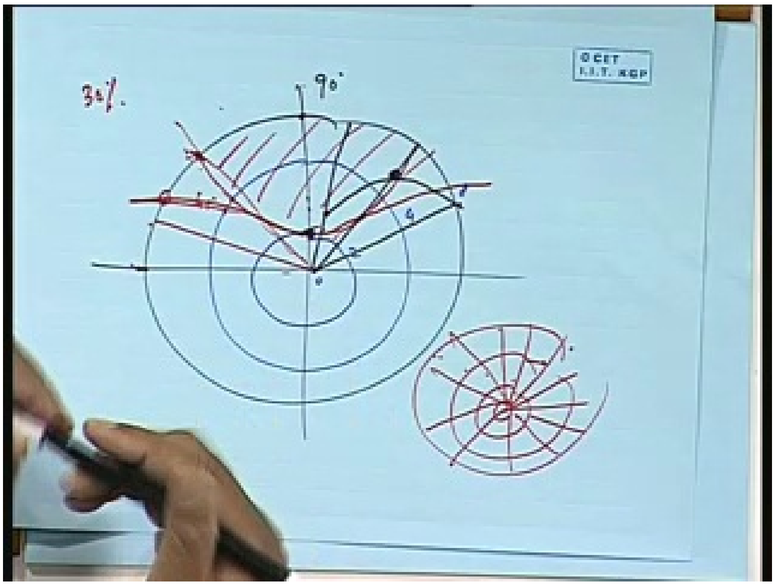

See, this roll may be better. See, this sea states another sea state, this is again 90 degree, the normally you will find out that 90 degree roll is very high.

So, you will find out that the ship at very high speed and 90 degree, it may be something like that. What does it mean?

See, this is, lets us say, this is 2 knots, this is 4 knots, see this is 0, this is 2 knot, this is 4 knot, this is say, 8 knots, like that. What it means it is that, at 90 degree heading angle, any speed more than 2 knots, the ship is going to roll. More than 10 degree means it is not going to meet the criteria.

But at 90 degree, if your speed is lower than 2 knot, it will be quite. Now, obviously, what happen at this is this angle is, let us say, is a, you know, 45 degree this line, now it'll tell that.

But at 45 degree angle of heading, I can go up to 4 knots and at 90 degree, sorry, and at, this will probably straight out. In fact, normally it'll go like that.

Now the angle, see you are plotting there, see you are actually finding the boundary points and then joining them together. You are actually, what you are doing, you see, you have again, if I do that, you have a diagram. Here, you have actually calculated for every v and every mu, and then you find out which v and mu combination it is, just having the threshold value.

So, this boundary of this curve, you find out by some rough, it can be rough interpolation. You see, for example, you found out, let let me give an example. See, you have done a calculation for 45 degree and for say, 90 degree you find out that at 45 degree, you know like my slamming is so and so, 90 degree slamming is less.

So, you kind of interpolate, see, let us say my slamming should not be, and not occurred more than say 30 percent.

Now, you find out that at 0 degree heading angle, my slamming does not occur, but at thirty degree heading angle say, at some heading angle here, my slamming occurs 50 percent at 10 percent time.

At these, it occurs say 40 percent time. So, you can interpolate and find out thirty percent time will occur at what what heading angle.

It is some kind of an approximation as far as interpolation is concerned. See, please understand this way. Other way round, I will show you another another graph. See, you have a got a slamming here, some slamming with respect to say v.

So, this graph goes like that. As the speed goes up, slamming also goes; it goes like that, now your slamming criteria is this.

So, you'll tell that my if my speed is this, is for a mu equal to some degree say, some say, 45 degree.

So, you'll say at 45 degree, if my speed exceeds this much, then my slamming is going to be more than that acceptable limit.

Similarly, now you do that for another angle. Like that, for each angle, you find out what is my threshold velocity or the other way round. Therefore, in this diagram, for each angle, see, this is my angle, I will find out up to what velocity I can go without slamming.

Here, I will find out, say, here I found out this next angle. I find that up to, I will say that this line here, I find out this is this line.

So, I join this, then I know that I cannot go on that. Another diagram is necessary, see, you let us see from this diagram only.

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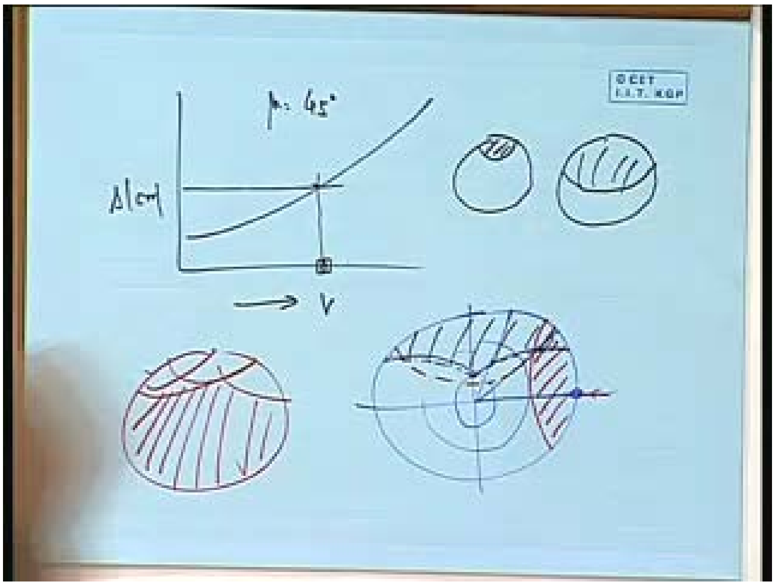

So, what I did is that, simpler case, we shall take, where as velocities diagram are there. Let us say this is like that. Now, I find out that at this particular heading, I can go up to all the speeds. No slamming at this angle. I can go up to this much speed beyond that, it is going to slam.

At this angle, I will find out that I have to go up to only this speed; beyond that it slams at this angle, I can go only up to this speed. So,.

That means, I must be below this zone. So, similarly, I finish this side. So, what it happen is that, if I am in this zone of operation, if this zone of operation, then it is going to slam more than what I prescribed.

So, my slamming must be lower than that. that Now, I know that this is my area where I can operate without the slamming. So, this was slamming.

Now, you do for that for all. So, actually you can do in a same diagram all this area. So, now, this is for slamming.

Now, you find out that pitching, pitching (( )) for for pitching, because pitching normally will be more here. You cannot operate if it is with this range. Let us see.

For another Response, you may find out you cannot operate within this range. Now, you over lap all of them, then, you will, whatever is remaining area, you you can tell that the remaining part I can operate which satisfies all the criteria. This is what is called operability criteria.

See, if you have given a set of criteria a b c d 10, you find out a is possible. It is this combination b is possible, this is the combination c is possible. Then you add them up; you can tell that in sea state 3 I can operate up to, you know, in this speed and this heading.

Why this is important because, if you have that and if you had a bad motion experience, you can actually from there estimate and try to change your speed and heading angle.

This is why you have operability. See, if you have a roll operability index, you know that you are suddenly meeting very high waves and very this thing.

So, you can approximately estimate which you know what kind of angle and speed I should reduce in order to eliminate. That you do by experience, but this helps as a guide.

From the design point of view, you can actually find out by the percentage area. See, the remaining area. If you have done all that you know area area etcetera, whatever is remaining, this as a percentage of the full area will tell you what the percentage of the operability area that you can operate.

In a given sea state, obviously, what will happen? This is going to be actually become less and less as the sea state goes up. Because you have to do that for all sea states, see if, see for example, sea state 3, you find out this is my non operation area. In a higher sea state, you may find that this you cannot operate, you know.

Obviously, as the sea becomes rougher, you you your operability goes up, you can then, there is no end to it. You can further combine now, you know, that in sea state 3, I can operate in this combination 4, I can operate this 5.

Now, sea state 3 means h is equal to 3 meter 4 means h is equal to 4. Now you combine, you find out that in in in a long term 3 meter height occurs only 10 percent time.

So, this into point 1 4 meter occurs 20 percent time this into point. So, you can again combine that 2 with a long term weather statistics

So, there is a lot of statistics you can generate. You can make lot of graphs, but essentially statistics means just finding out percentage of occurrence of certain ships motions within certain, you know, like percentage of operations of certain motions or Derived Responses in a given sea state and combining them in some fashion. This is more of an algebraic operation if you keep your minds straight within, with common sense you can work it out.

What you cannot work out, is finding out the Response itself. That requires mathematics and some hydrodynamics.

But if you have the Response found out by some means, you know that you know 10 degree or 5 degree, to tell that you know, like the limits. That is a more of a common sense, you know, you know 10 degree occurs at 90 degree heading angle at 20 knots speed.

But, if you make it fifteen knot speed, the angle will come down to 60. So, you can make it out from there, it is very common sense. See, somebody says that, look, I cannot allow the ship to roll more than 8 degrees, then you find out that 8 degree would occur when the ship speed is 16 knots, but if you go more than that, it becomes more. (( ))

So, you know you know like by your experience. So, basically this polar plot, that v 2 is a plot that you have just to synthesize. You may say what you have done, if I if I tell another thing.

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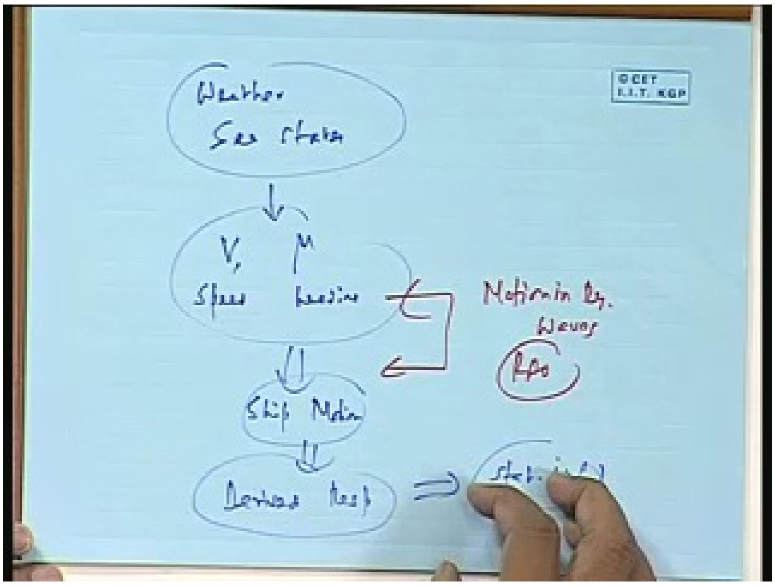

See, you have got various weathers, that are sea states. You have got number of weather a number of weather conditions, you have got number of combinations of speed and heading angle, speed and heading. For all this, you have got ship ship motions.

For all this, you have got Derived Responses and for all this you have got the statistical information; that that is, you know how much percentage (( ))

So, you all (( )) combining all the 2. So, it is a lot of repetitive calculation, repetition for each sea state. For all combinations, you find all the ship motions and all the Derived Response and all what you require by statistical analysis that you know, you repeat that. You have got a large chunk of information.

Then you just put them together in various forms; that is all we are doing here. So, you know this part is a post processing part; it is actually playing with large numbers.

Lot of people have window based programs nowadays. You know where you can do that, but as I said, to find out ship motion, the most complicated part actually still arises here, in fine motion, in regular waves that is, or RAO. This is the most demanding task from evaluation point of view, but from practical point of view, you would like to see this results.

But, if you have that, my point is finally, is that, if you have that. To get this part may appear to a beginner complicated, but really it is not complicated. It is a tedious, long calculation.

But not very complicated if you keep your mind you know focused, that is all. Sea keeping is viewed to be complicated subject, but what the part of sea keeping you view as complicated is actually the simpler part. I mean with that, I will end my lecture today and we will formally close the ship motion in waves part of the lectures. Thank you. Polar plot you.

Preview of Next Lecture

Lecture No. # 33

Ship Controllability

Introductory Notes

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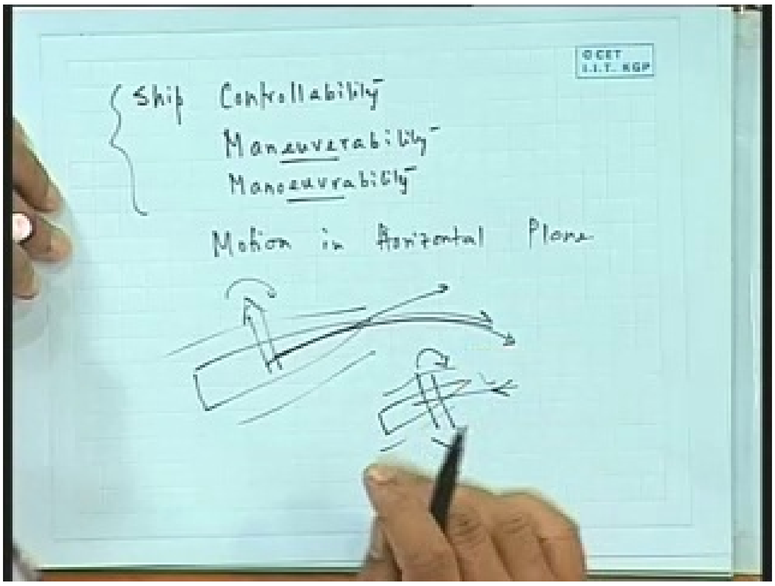

Ah, see, today we are going to talk about a topic of Ship Controllability, or you may say, this Maneuverability. Well, this is the American spelling, this is the British spelling, e u r and o e u v r a. I am just writing because, we may change 1 to other, so that we have no confusion.

Basically, this thing are more or less same topic. We are going to be discussing this part of, the you know, ship behavior which is related to, you may say, maneuvering controllability course keeping, etcetera.

Everything related to a ship trying to move in the horizontal Motion, in the horizontal plane. Earlier, I spoke about more of motion in the vertical plane, that is, under wave action.

But here, what we are going to talk about is that sea is calm, there is no waves, etcetera. Ship is moving and it is trying to turn. It is trying to, it is, when it moves along the straight line, you study the subject of resistance.

But, here we are trying to find out how it turns. Should it turn, what forces are necessary to make it turn easily or what should be the characteristics, so that it does not turn for a simple, you know, like simple forces, external force, or if it has turned because of a wave or some disturbance, should it come back to its original line.

All this things are a part of, what we call, Maneuverability Controllability and this sometimes, they are kind of, you have to understand the beginning contradictory. A ship which is highly maneuverable means, very highly you can turn it very easily, becomes less controllable because it is always trying to turn. It is just like your scooter or vehicle which is always trying to turn and if you want to make a steady course, you have to hold it tight.

So, there are 2 kinds of aspects. Again, I mean if something is, you know, it is a tanker going on a straight line, you cannot, you give a rudder, it does not turn. It absolutely is having a very strong directional stability. But then, it is not controllable. This is the part we will talk in general. Before that, let me tell you about this; why the forces come.

See, again looking back at that at that now, what happen as you try to turn a ship. See, when you are going on a straight line, the force is symmetric. There is no force coming in y direction, no moment coming in this direction. Force is absolutely along x direction only.

So, the ship is moving exactly on a straight line. But, here what happen as you try to turn? Naturally, there is an asymmetry developed. The ship is not symmetric anymore, as if it is having a motion and the flow is coming in this direction.

And then what happens? Obviously, the flow goes various ways and there will be a different set of pressure, and therefore, there will be some kind of force coming, some kind of moment acting on that and it is that which will cause the ship to turn.

In other words, the only mechanism that you have to cause force on a ship which is not restrained is fluid forces, because of the flow, because the way the flow going past it. These are the forces that will cause it to turn, you see.

You give a rudder, what happens when you change the rudder? What happens? Because you change the rudder, the flow past that develops a different pressure system and that is why there is a force.

Why I am saying that is, because, in order to study controllability and maneuverability, we have to necessarily study fluid forces. Because, it is that forces which will cause the vessel to turn or whether the force is very large, etcetera, we will decide if the vessel would remain steady.

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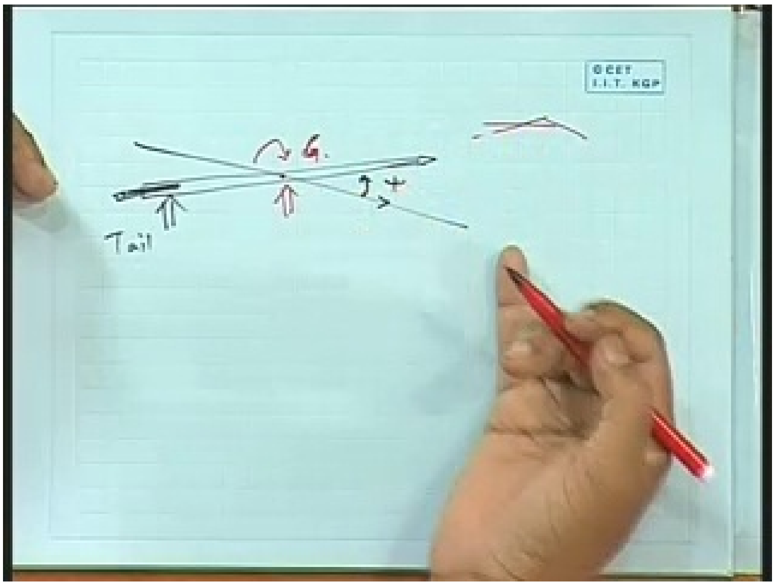

A simple example is given by this, (( )) which is what I will just briefly mention. See, suppose there was an initial trajectory of a line and there is a particular, you know, line, small line, with a, what you call, a large tail. Let us say, there is a small thin plate with a large tail here. The tail is like that, that is the one that produces a force.

What happens? It is suppose to go this side, but now it has turned. By some means, it has actually turned by an angle xi. Then what would happen that would, obviously, cause even it is going on a straight line, the flow was going past it.

But now the flow is going past. I am just considering this part of it major. It is going to give some kind of a force. On this direction, this force is equivalent to, if let me say, c G, this force is equal to this force plus the moment. You know, any force can be translated back to another point or rather this force will give a moment about this centre point, that is say, c G point, this is say, c G.

What it does therefore, this part, this red part of the force will cause that thing to move up because there is a force here acting on the sea. So, it's going to go up and this moment is going to make it turn like that.

So, the you would expect the vessel to actually, I mean, this tail actually gone slightly up and then begin to, turn begin to turn.

As it turns, now think of that as it turns, this angle becomes small. So, at some point, it has moved up and then begins to turn. As it turns, this angle has become small; as it becomes small, the force becomes less. So, ultimately there will be a point when the force has become 0. So, it becomes straight line.

So, therefore, your then you're the behavior is guided by the fact of how much force is coming on that, which depends on obviously, angle of the attack, which of course, will keep on changing, as the angle of attack reduces.

So, as an introduction, we have to realize that we have to study the forces coming for a general body moving in a horizontal plane. If you want to understand even the elementary maneuverability later on of course, we must talk about rudder. What does rudder do?

The most common mechanism for keeping the ship in force is rudder as we know and if you want to turn, you might have an additional device like bow thruster or thrusters on the centre plane, etcetera. etcetera

In other words, you have to introduce a force on external mechanism. That we will come later on, but to do that, we have to, we should we should understand what kind of force come on the boat.

Ah, let us go to a very basic definition of what is called course keeping. Now, there are there are certain things that can occur for a course keeping. First of all, let me introduce the word directional stability.