Seakeeping and Manoeuvring

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Lecture No. # 19

Derived Responses and Dynamic Effects - I

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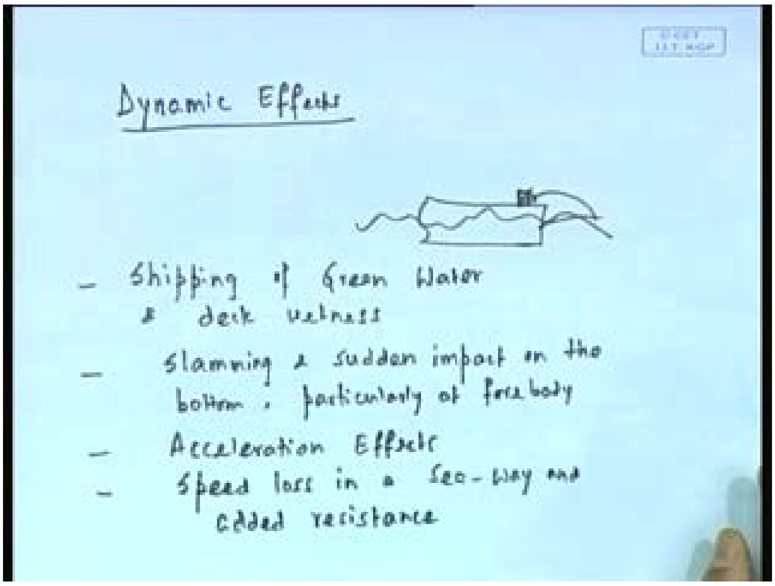

See, now we are going to talk about something very important of course, all parts are important, but important from the application point of view. What happen? What I am I term this as well you can say dynamic effects. Let me call this as dynamic effects. See when the ship is going in a rough sea that is what this sea keeping about no the ship is traveling here. You are interested in certain behavioral aspect of the ship, you want to find out how comfortable it is etcetera.

You are not really looking at motions parts say by itself what for example, what you are looking at things like, whether the water here comes up. What we call deck wetness why obviously, you know you would see some ships the bow has only come down water has rushed over it, and number of things if there an equipment there that may get washed out. There is a lot of load that comes on that etcetera. You are more interested in that.

You are more interested in things like opposite this bow may come up of water even if it did not come up it again you know hits back the water as it hits back suddenly you get a lot vibration load coming on that that is what is again more important because, you are having an impact here coming.

You have equipment here; somewhere here the load that comes on the equipment is proportional to the acceleration say vertical acceleration. So, you would like to know what is the acceleration on that because see suppose, I have a gun mount here and a naval ship some mount, which will typically be there you know.

So, it undergoes a lot of acceleration. What is the load coming on that you would be losing speed? If you go on a rough you know compared to a smooth sea for the same engine getting if you are making 20 knots you would probably make 18 knots or 17 knots in a rough sea or conversely.

This is obviously, a consequence of the fact that that you have an increased resistance. And interestingly this increase of resistance is a sea keeping phenomena rather than a resistance phenomena that you learnt in a resistance course because, here the increase of resistance is a consequence of a fact that the ship is undergoing large motion therefore, its spending energy.

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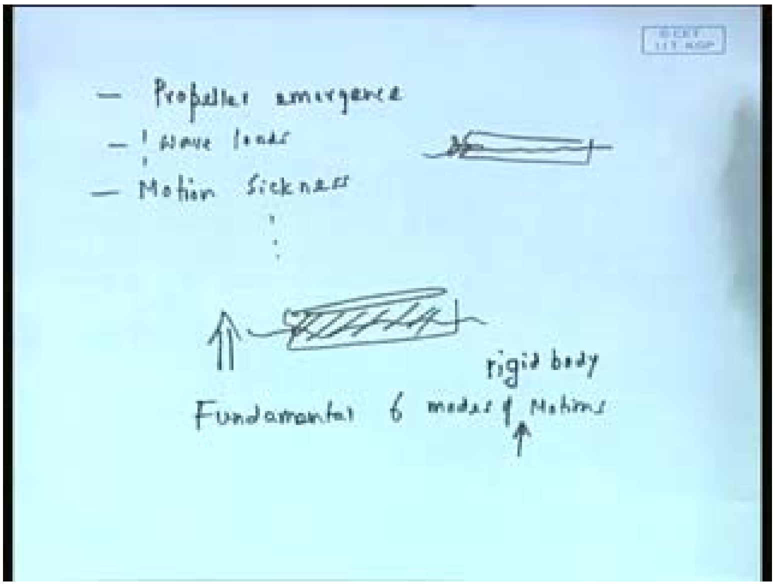

More popular emergence back side coming out of water so, there will be free racing and you obviously, lose efficiency for that and there are many other factors see sick motion sickness people tend to throw up all this obviously, and there are many more. I have wrote just wrote few; all these are water the dynamic effects effect of the fact that the ship is undergoing motions.

So, the ship is treated being treated remember as a rigid body. I have this as a rigid body this full body is not taken obviously in our study and this is also largely true because, if you take it flexibility it is going to be only a much smaller amount in terms of displacement; for example if you take a elastic deformation maybe about one feet maximum whereas, the heave motion may be few meters. So, from the point of view of so, it is important from structures load point of view beside, I did not mention also structural load the ship has to be designed to you know withstand this wave lose, but the point here is that, we have studied ship motions as a rigid body whereas, a practical person would like to know this sought of stuff much more, because they are the one that is actually, effecting you designed.

Now it can be found out that all of this can be are a function of that fundamental 6 modes of motions all of this are function of that which means all of this can be derived from fundamental those motions that we completed.

So, I have completed now so, far the 6 modes of motion actually, 3 mainly whatever the ship rigid body ship motion let us say modes of I can add here rigid body motion. What I want to know is these things, but now we will find out that all these are these are all what will have dynamic effects and therefore, since I can find it all up from my basic 6 modes we call them derived responses at times we call them derived responses because, we can derive them from the 6 modes of motions.

So, you know from computation point of view, from determination point of view R A O for 6 modes of motion will take you 95 percent of the effort. Where I kept telling every time spectrum we will take 3 percent of effort or 2 percent of may be 1 percent of effort, but if you did not do the spectrum people do not want to take it. It is something like you cooked a curry and did not put a salt you know something like that you did not do a finishing touch. So, people are not interested to look at that, but the effort is less? so, let not confuse practical importance with effort

Now similarly, derived responses if you found out the R A O for 6 months, we will find out we will slowly go through that this derived responses can be determined just with 2 percent effort, because they are nothing, but combination of this! So, we will just take for example, a deck wetness or slamming or something or say vertical lets first take acceleration at some point.

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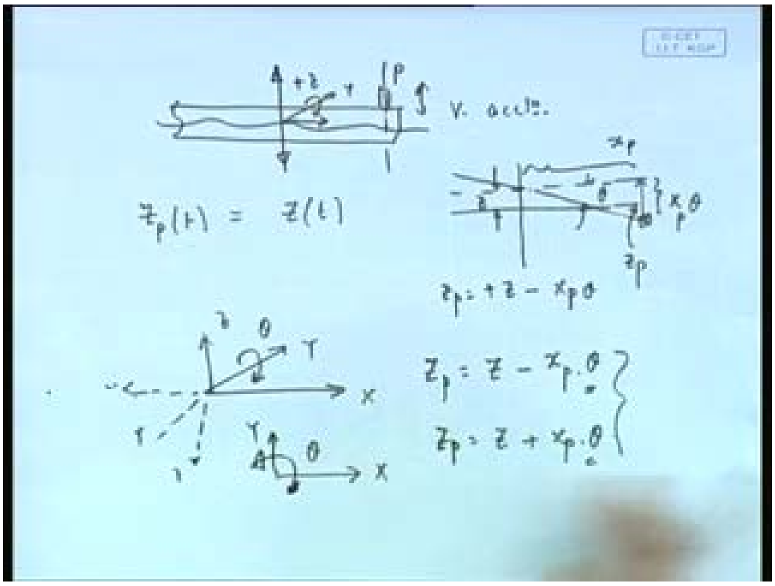

Let us take this ship here and I want to find out this some location vertical acceleration just is an example to see how I can combine the 2 there is wave coming here. Now what is that the acceleration of the vertical displacement of this point this particular say if I call this point p what is my Z p of t you will find out that this is nothing, but the heave response of the ship that is this and x into pitch because, if I call this to be x the x of the point p and this of course, is theta so, this is X p theta this is z.

So, I end up getting plus Z minus X p theta to be the displacement of the point. Now why minus that is another thing that we must we must understand. See what is happening remember phase is very important here. I will come to that remember in my coordinate system actually, speaking what we are doing is you can say here it is Z plus x theta with a proper coordinate system.

Now you see here my Z plus was this side, but which side was my theta plus. Now depending on which side you call theta plus. Now in our case here if I this is my Y axis this is my plus theta. So, if that was my plus theta that is this is my plus theta see x y Z i took.

Now, please understand this part. Depending on which side you call theta to be plus. see in this particular you have 6 degree of freedom coordinate system if I were to call X to be here, Y to be here, Z to be here, then my theta is this side positive bow down is positive. So, plus x give me minus x theta of Z. so therefore, my Z p in this case will become Z of the hull minus X p into theta. on the other hand if you are to calling this to be X and this to be Y and you call this to be theta then of course, my Z p is going to be Z plus X p into theta.

It is extremely important for us, when we do a calculation to recognize which coordinate system you are using because; when you put in a computer or your table form you are only adding numbers. After all, a negative number is nothing, but minus one time positive number or the same number in the opposite direction as for as displacement goes.

We see here normally what happened 2 D plot this is why I wanted to spend little time here, 2 d plot X Y ad you call it sorry this is not here this is this thing X 2 Y. when you go is theta, but when you do a 3 D I am using X Y and Z. if I use it and if you do not want to use it if you use X Y and Z be opposite, but if you use in fact if you use 3 D you can also use the other way like in sub mean we do we call this Y sorry this as y and this as Z, but even there minus Z plus X p theta will come it will be the same thing. So, if you use 3 D Z and X p theta are of opposite side what calls Z plus for positive X remember this X is positive if you go on the other side it will be different so, anyhow we have this so, what is happening now is interesting.

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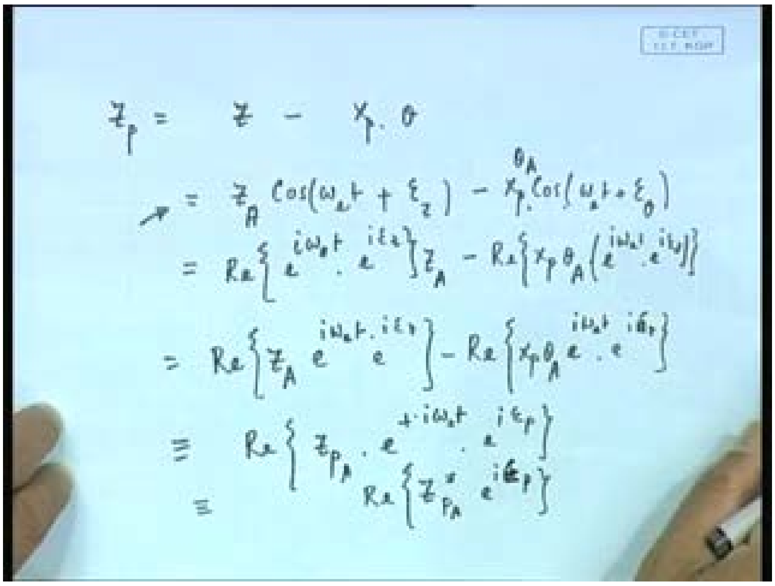

See now, I will work on many be so, I have Z p equal to Z of the hull these all function of time remember minus X p into theta now this Z of the hull this Z heave well Z heave. Let me let us put some numbers here. Z let me call it Z heave amplitude of Z heave or rather let me call it Z A. Z A is amplitude of this thing into cos plus or minus. let us see what they call minus into when into sorry I keep forgetting here into theta A.

Basically, theta is theta A cos omega t plus epsilon theta etcetera or in fact I prefer to do it in a complex domain you know I always keep let me write it here then oh I will write it again because, this whole thing can be written as you can write this here p see what I wanted to say here, you know like it is a question of manipulation only I mean I a pure algebra we I just wrote it here you can also slightly in terms of algebra. See if I add 2 cos curves. What will happen this line look at this line; this line will look, this line will come out if I were to add the cos I just show here then I assume?

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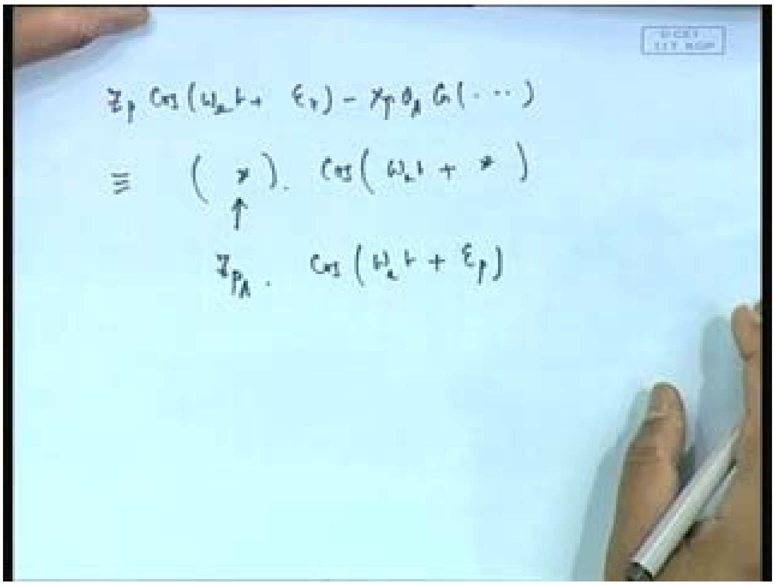

So, if I add 2 cos curves. See I let me just write it again here because sometime people do not see it. This full thing will turn out to be a turn here into cos something. It can be written in this form you can always break it and write in this form see when you have this cos a see cos a cos b plus sin A minus sin A see it will be cos omega t E t cos epsilon Z minus sin omega t sin epsilon Z here, again the same thing you combine them together you ultimately, end up getting some term into cos omega t plus some. this term is what we called the absolute amplitude that is Z p A and you will end up getting cos of omega E t plus you end up getting E p.

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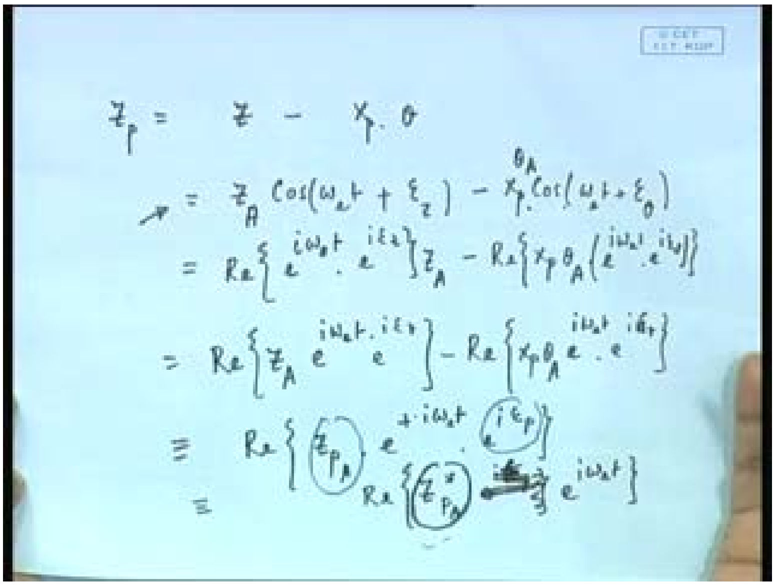

Now the same thing I am writing here in fact sorry here this is i omega t it will become. This is going to be what is happening is that here sometime you want to operate them in terms of you know complex number. If the complex number sometime operation is easier after all cos this is nothing, but real part of e i omega t plus epsilon Z is a real part of this. You add them all up you end you getting something and you introduce a something called a complex amplitude basically, this is going to become Z p A into e i beta that is this part this term is this term and this term combine, because this is a complex number so, you can write that way.

This is not very important why I am writing this way is that sometime it is easier to do manipulation or addition when you write this way we have done that before if you recall we have done similar kind of thing before in wave mechanics in when we were doing resistance wave resistance etcetera. Combining the various waves' manipulation of sinusoidal signals are sometime easier. If you work them in complex domain that is my point, but never mind the complex part you can always write it down.

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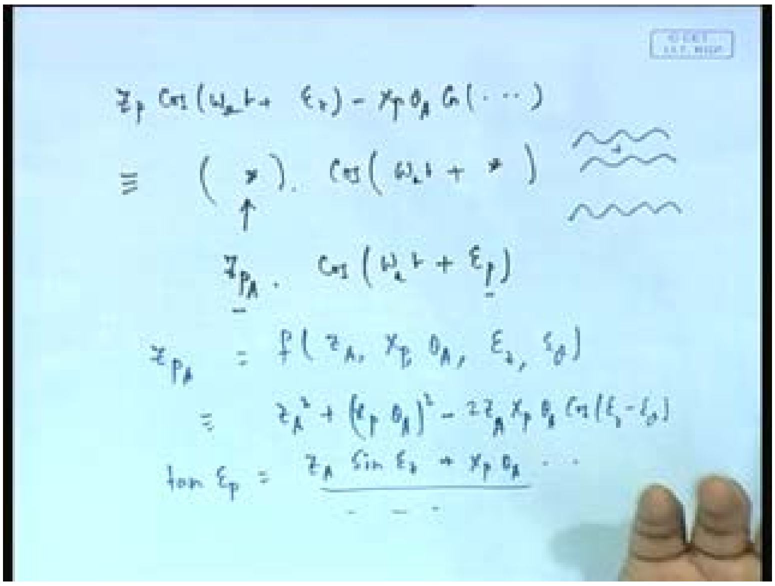

Let us say if you do not write it I can add the signs no I end up getting this. where of course, what will happen Z p A will be of course, function of you will find out this will be an expression it maybe something like you know function of Z A of course, X p theta A epsilon Z epsilon theta something like something like I am not sure it will be something looking like that plus or minus.

It may be minus here I do not know Z A X p theta A Cos may be something like it will look like that something of this nature and similarly, turn of it will look something like Z A etcetera I am not writing the full thing because, you can verify that it is a simple trigonometry there is nothing to it.

This if you write you can write in this way it is also make sense if, you lo at this from other point of view this is a sine signal this another sine signal of the same frequency if, you add it all up you will of course, you getting another sine signal of the same frequency. This is a sinusoidal signal this is a sinusoidal signal of same frequency you add them up you will get another sine signal of the same frequency. what will matter is the amplitude and the phase that is all. So, this is what amplitude and the phase you end up getting it. So, I have got this lets say now the important point is for me is this way.

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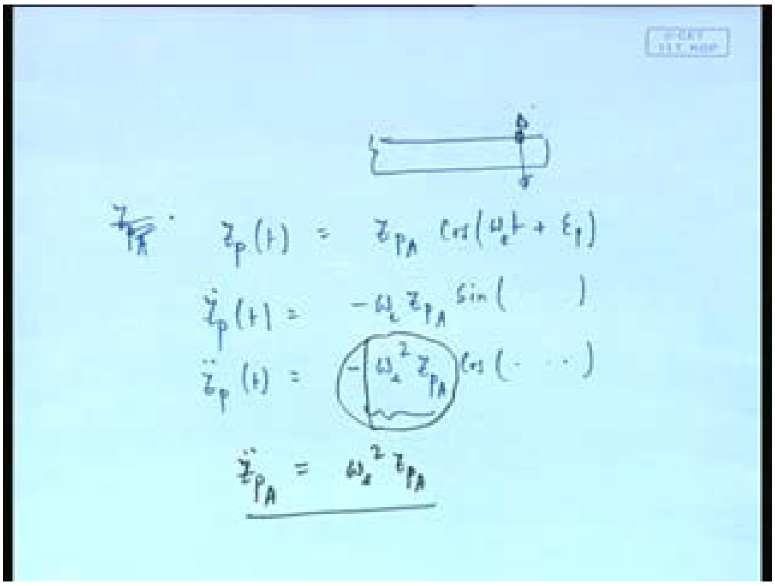

So, I have this part, I have here. so, I know now my Z p A not Z p A sorry Z z p t equal to Z p A Cos omega e t plus this I know I want to know acceleration very simple. I just have to do is minus is it no sorry a minus. So, I know this I also know this amplitude. so, I now know this now see typically what would happen, I will know this signal fully therefore, that is point 1 point 2 is that I am mostly interested in the amplitude part of it because mostly when you design obviously the maximum value that will come is this value with the minus without the minus sign without the minus sign absolute the maximum value acceleration that means if I were to call it Z p A dot, dot is going to be omega e square.

So, this is going to be my maximum acceleration. So, therefore I can easily find out what is the load coming on that gun mount. This very simple now let us lo at some example of deck wetness when is a deck wetness occurring. Now you are to actually, have this wave part also coming.

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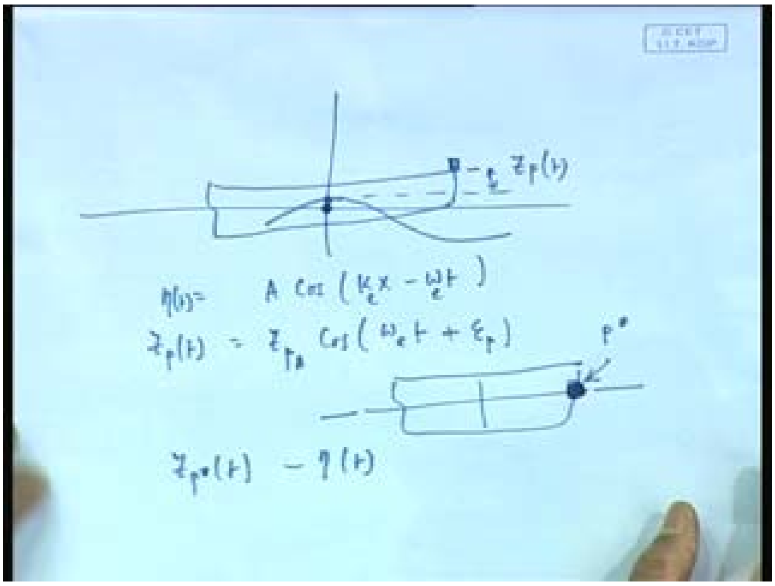

Now you see now of course, I need to draw a wave a reference point here. Now I have this ship there is a there is a point here. so, this point have moved up with respect to my reference point to an extent of Z p or whatever the reference point you call now there is a wave here. What is my eta? Eta is of course, given by A Cos K X minus omega t remember I am calling this to be the 0 phase. so, I am putting the phase 0.

So, I have got this and I have got Z p t this also t here this omega e we have to write we have to transform that to omega e remember this is K e we have to write that in terms of omega e. First of all you can change we have to change it to encounter period, that we formula we all know omega e t plus. So, what is the relative difference between the 2 for a given point now actually, here there is a the question you have to remember that we are doing it from it just be Z p t means how much a given point is going up. So, I will come to that point.

Let me say that this is becoming a I will just draw it again a difference point. this point this is my mean line obviously, vertical displacement of that this particular point which is otherwise, at the free surface or bow this particular point p star this point has having a relative displacement with respect to the water given by Z p star t minus eta t.

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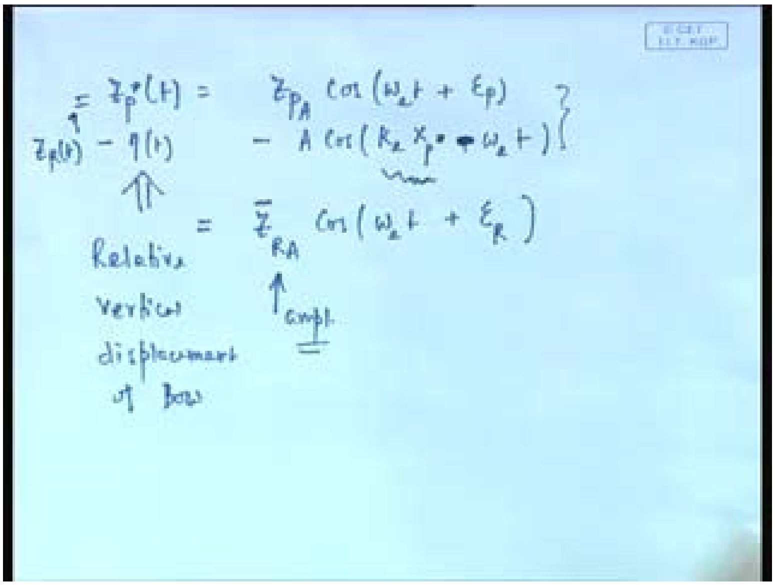

Now so, this again I can figure this out by simply working it out in a exactly the same fashion because I have my Z p t is given us Z p A cos omega e t plus eta p. so, if I will just put here minus eta t. this mix it minus a cos now if the K e x will be for p that is well we are calling p star p star which is going to be of course, depending on what you take typically lambda by 2. sorry it is typically the 4 peak point except 4 peak point. I just come to that omega e t or minus we calling minus.

Now, this X p here remember is this it is about remember I am writing is about L by 2, but not exactly because, remember this point is at c g in fact it is actually, I can call it this plus L C f I can call it that way because c g for a balance ship is going to be above L C F no not L C L C B its you know this value for a particular ship. so, once again here the interesting point will come.

See here, this 2 when I add again I have A Cos 1 Cos curve. So, this is going to be again here some kind of a Z let me call it is bar. Let me call it R why I will say why R I am calling it into cos it will again look like that. when you see just similar way another sine curve is added with another sine curve remember here X does not this part is a constant because this is by 2 or whatever this is a constant this is a constant for a given X p star so, this value is constant given X p star you will get this.

We are using of course, one single wave. So, you end up getting this value. So, what I will end up getting is here, there I will end up getting this. With this gives me like this now this is what we can call this is what we can call relative vertical displacement of bow. this is the amplitude of that this is the time this is my let me call this side now Z R t this is Z R t equal to this that is my relative vertical displacement.

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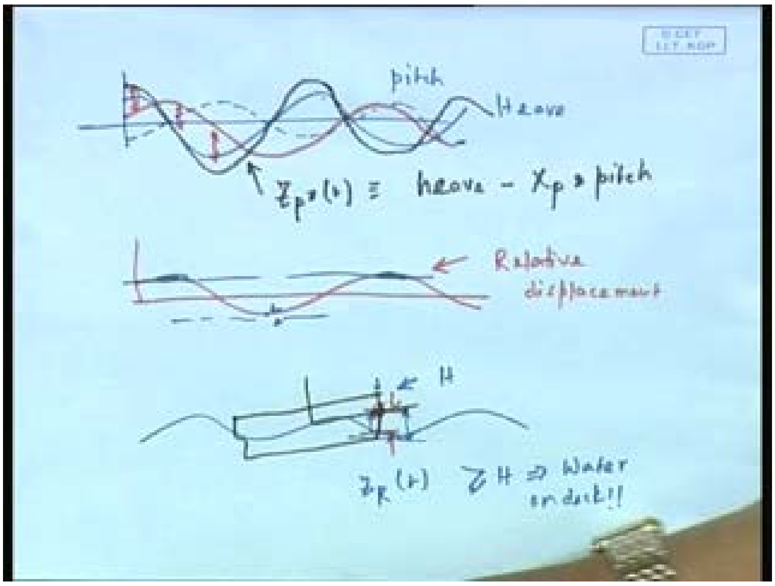

Example, heave is this, pitch is this, when I combine the 2 I end up getting a displacement looking well it I i should not draw it you know like the phase same phase say something like that this is a let us say you end up getting that.

Now on that I have got my I have to use the wave length wave at this location my wave may have been like this what is therefore, the relative displacement the difference between the 2. So, this is what I am plotting here, this is my what does it mean? this means at any given these are wave here my ship is here with this axis this point I am taking I want to find out what is this distance. If, I were standing here I will find out how much this is.

Now, we can work out the deck wetness from free because what is happening, if this distance is negative; see this is here minus coming. If it is plus and more than this distance, then I would say at that time in other words, if I will say that Z p relative exceed say this value I will call it sum say h water on deck.

So, you can see this diagram for example, this suppose this was my threshold deck limit then this instant and this instant water has come on deck very simple you know. So, I can find out this water coming on deck and relative deck. Now this is relative vertical displacement.

Now, let us look at the bottom slamming the same thing bottom emergence if I find out there is negative value that is this value is actually, this bottom is coming out just the opposite of that, I know this height so, if I will find put then what is the chance of its see opposite side here. If this is coming something like that bottom here so, I will know that the bottom is coming out. So, I relatively find out both the parts. So, what I mean therefore, is that see the interesting point is therefore, what we are doing we are combining heave and pitch that is all we are doing and because they are sinusoidal. we can always get a sine curve and once I can get a sine curve.

Now comes the question let us let us lo at this acceleration part once again. So, I have got this what about my irregular sea can I use that for spectrum what I done is of course, regular waves. You see here what we have done in relative acceleration what we have done here let me lo at this acceleration part, because we can just go from one to other.

See this, I was the acceleration this full history, I have got by adding heave and pitch the second question you want to ask is how do I get a spectrum for that? You know, well the question is that I will use this is my R A O this my omega e that is it my relevance like the spectrum let me give this as an example that is easier.

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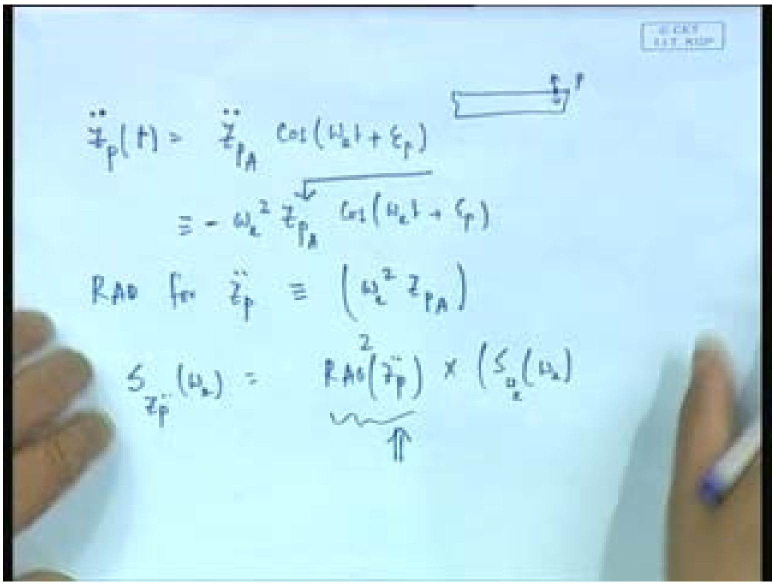

So, I end up getting we are taking up the case of acceleration here at some point. So, I have got this Z p this is the point p here star t which I have found out that is obtained as eta never mind the minus sign. So, what is R A O? So, you find out the same way. So, s simple now you may want to ask the question. where is the phase information coming is there a phase between heave and pitch like you know we have only having a number, but understand that when I got this value when I got this value this has the proper phase between heave and pitch combined; for example if heave and pitch were of such a phase that they will give large Z p A then I will have a much Z p A and once again this sought of example.

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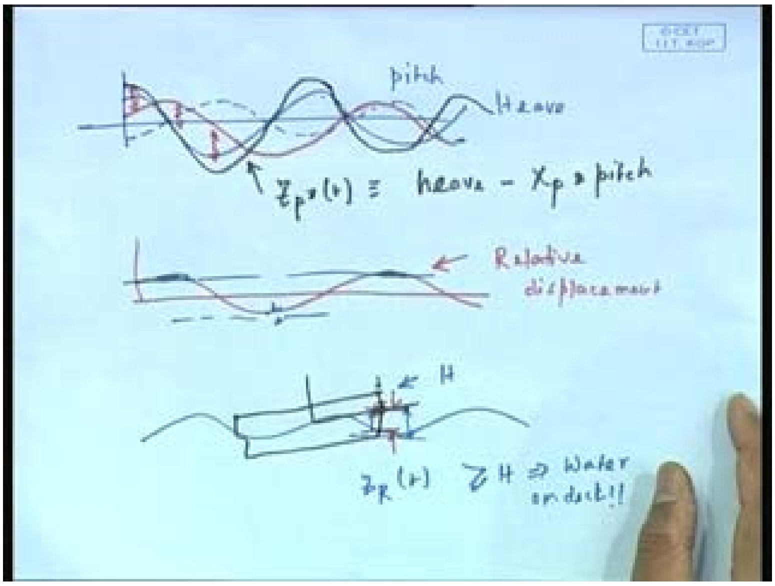

See if the heave displacement was like that and the pitch displacement here, I let me write this here pitch displacement here because, you know easier X let me plot X theta directly if X theta was in phase like that what do I get, I get a graph which is like this. What I mean is that see when heave blue line is that is vertical displacement due to pitching only at that location if they have happened to be in same phase obviously, this has the phase information between the 2 then I get this red line.

On the other hand, well I put the other way round anyhow well, if the blue line was suppose happens to be opposite, then what do I get I get my red line to be smaller may be here therefore, what I find out that my Z p A is a function. Of course, you have seen that function of Z A theta A X p importantly very important for us to understand this Z, see this is important location is important why I am mentioning that you know there is a reason for why I mentioning, because you see some of the students some people always confused in one thing when I do this one this spectrum we say that there is no phase information.

We keep saying see this term phase is very important. when we do this spectrum you know I am saying then I am adding waves 1 2 3 4 5 with random phase there is no phase information in between.

So, quite often people students have confusion here you he is saying there is no phase on the other hand, if that was the case to find out you know like I stretch it like in correctly one step. If there is no importance of phase when it comes to response in irregular waves then when I want to find out relative sorry the heave and pitch combine motion why should I have a phase of heave and phase of pitch important?

You see I am in one and I say for it so, when I want to find out the acceleration spectrum of a combine heave and pitch motion why should I have phase information in the (( )) because I am saying that after all waves having no phase the difference is like that.

See, the most important part is like that what here I said is that I am adding this by getting this by adding regular waves and different phase. But for each regular wave I have a heave and pitch; and this must have that phase information for the given regular wave between heave and pitch. So, when I want to do this phase information, we have to understand that this phase information is indirectly there for a given wave see phase information is there for a single sine wave. What I do not have is the sine waves have been added separately, but for a given sine wave I must have a phase, because if I did not have a phase as I said here if I did not have a phase my this 2 line would have given me different kind of response.

So, if that was the case if I had a heave of say one meter amplitude pitch of say 2 degree amplitude then I would have had regardless of the phase information. I will be always getting at a given X the same amplitude, but that is not true for example, we will see this long wave why this phase information is again important.

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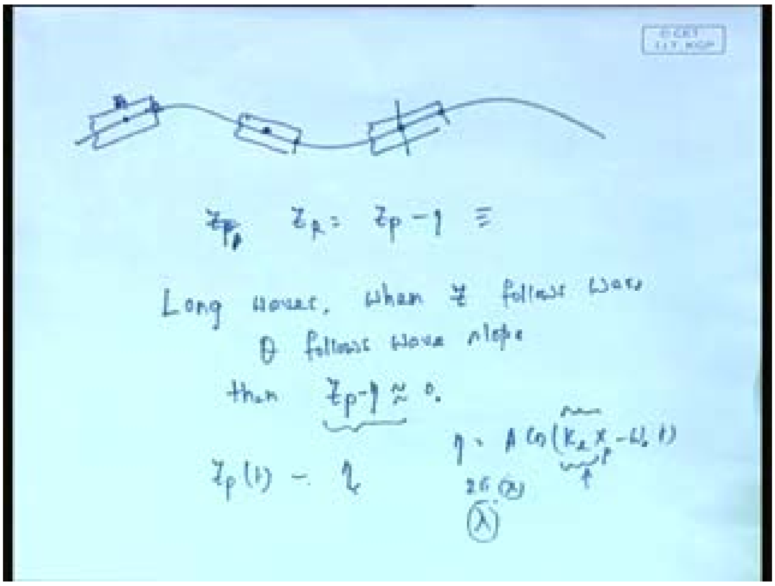

Just see that that phase information is there this long wave. My ship is going like this. interesting here, I will leave to you to work out for the long wave part find out that my relative displacement of this relative displacement that is Z p sorry Z R this remains constant is an assignment problem for you. Find out in long waves when Z follows wave theta follows not Z p. Sorry I will tell you when you do that you end up getting into one problem of K what will happen I tell you. You are going to find out this and you will find out that here there is no response, but what will happen is that you are going to do this.

See when you use Z p t minus eta and eta you will write eta equal to A cos K e X minus omega e t. when you use this term you will end up you will probably think that there is a problem, but because what happens strictly speaking when this was 0 only then this is 0. But when this is not 0 you will you know I am just giving you a hint see strictly speaking this point is following that when I take another point here my X is not 0 actually, what happen I meaning is that Z p t minus eta at X equal to 0 will become strictly speaking equal to 0.

For when I use at X equal to X p some number will come, but what is happening is why I want to tell you is that see remember what we say long wave what is K e K e is actually, 2 pi by lambda and this is X. so, this is very high with respect to this going to be very small. So, this is going to be very small close to 0. this is the approximation that you will have to find out.

See after all I have we have started saying in this particular you know calculation that my long wave which means my K e tend to 0 at that limit my Z tends to a amplitude of wave and theta tends to d eta by d x and if I were to plot this all up I will end up finding that my Z R which is Z p minus eta will tend to that is very simple because you conceive from this picture.

If the ship is following this obviously, this point if you are standing here, you are going to find out the water wave 5 meter below all the time 5 meter below, which means with respect to you wave does not vertically displaced. In fact, this is one of the thing why now you will understand why short waves or inertia dominate motions are more important in some sense then long waves because in long waves you find out I do not have the risk of risk of my green water shipping risk of my bottom coming out is very less. Whereas it is the other extreme end where my motions or inertia dominated when added mass and damping are not ignorable at that time my phase is opposite my relative motion is different ship comes down water comes up etcetera and the interesting point are more interesting point you see that.

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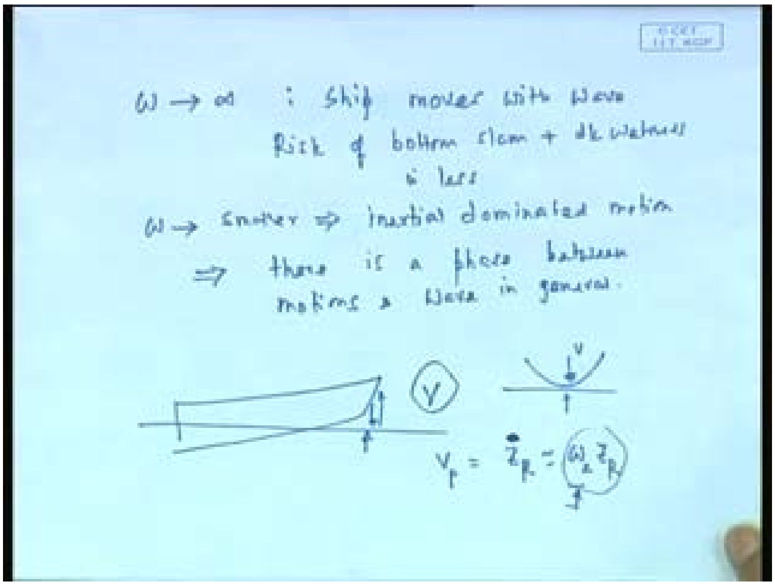

That I will tell you this when omega tends to infinity, ship we will just discuss this part physically agreed, but when omega tends to, but I would not say small smaller ship has a phase with wave why I say phase of course, it is also is a phase, but that phase is 0. there is a non 0 phase what I mean you know like understand that when I say phase means they are basically, closer to more to that to outer phase of course, it is never out of phase fully this will be 0 and this will probably 90 degree 70 degree like that.

So, there is a chance is more, but there is one more point there you see the other point is like this. This I will discuss in the next class later on. But usually bottom slamming you take bottom slamming part this part has come out, then it hits back what do you think this impact load will depend on.

It will depend on the well at strictly speaking velocity the how fast it comes in. you know if you do an impact study if the thing comes out very fast that is this velocity v that becomes important from impact load acceleration is the load itself. Remember acceleration is the load itself; it is if you are going to go very fast impact it see on a free surface if you have to impact this body at a certain velocity v you would expect the force to be more. So, what I am saying the slamming load will obviously, depend on which we will discuss next class the threshold value and all that on v what is v v vertical of this point is actually, Z of the point relative velocity if I take into dot dots sorry and this is going to be omega e times Z R that means omega is important.

So, here comes a situation. When omega is higher I have a chance of this slamming more and because omega is higher my slamming load also is more you get the point see when I am going on a tsunami very long wave. I do not bother whatsoever for ship motions because, it is such a long wave you do not even feel it. you that is why we do not speak of ship motions or sea keeping in such long waves. I mean, I am giving a practical derived response or what nothing you do a tsunami type of wave may be having 20 minutes period. If you are going to take a roll 20 minutes time you cannot feel it. you know you drink your cup of tea you do not even know there is a wave that pass by or whatever.

If it is an extremely, small wave then also the energy so, less that a large ship does not feel it is actually, always this everyday wave somewhat on the lower side of higher side frequency lower side of period, where I have all kinds of problems and that is where I have to do sea keeping.

Why I am saying this repeatedly is, because this is important that we are always turn of sea keeping between a given range of frequency or waves we do not talk about very short waves ripples you go to any ocean you will find small ripples. you do not care you talk of large waves very long you do not care for a ship.

There are certain large wave you have to care for you know like, offshore structure you care primarily for these waves and you have seen and we have seen in our in your ship strength calculation you always have chosen what trochoidal wave is not the point. Well that is that is one point what my main point was length what was the length he chose. why do you chose length is there no other waves beyond the length of the wave ship.

So, who says that first of all who said that there is maximum and minimum wave? Where did you get the information? So, you think you know obviously it has come from experience most calculation. I have shown that if the wavelength is similar to the ship length then there is large bending moment comes in load becomes larger. Which means the effects are much larger of course, you draw a nice picture in fact, the present theory tells us it is not exactly lambda equal to L it is about 1.05 to 0.1, L where the maximum comes, but here nobody knows it will be around that.

See, what I am now giving information that modern research shows that when lambda is approximately little over L about 5 to 10 percent over L that is where largest bending moment occurs, not when exactly equal to L, but that is a variable number; so when you do a conservative design, you obviously cannot do not know, what is the number?

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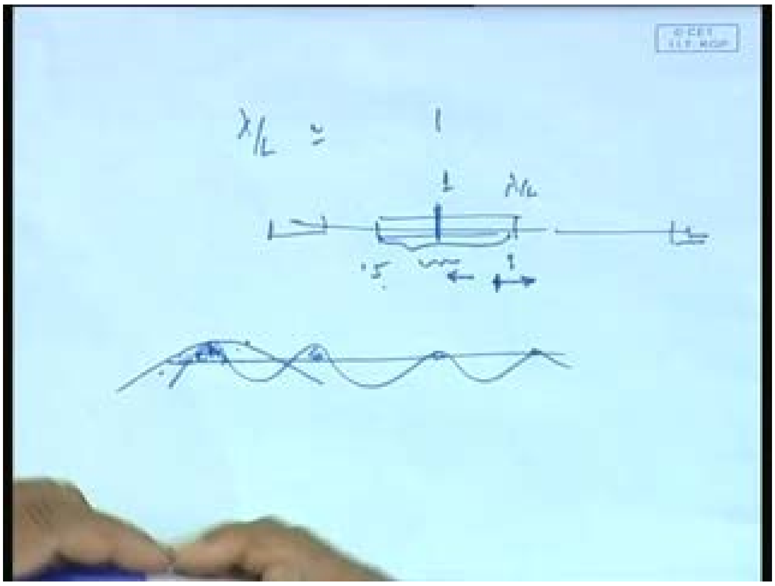

So, you to L, but main point is that it is around L or if lambda by L around 1 or if it is 1 if I call this to be 1 then of course, waves around this may be around 0.5 times to say 3 this range lambda by L is where you would expect most effect coming tsunami waves here or whatever very long do not bother small ripples here you do not bother. So, this is a now here again, I am trying to say this as you go this side farther my slamming and all are less important as I go this side little more around this area my slamming and all are more important.

Fortunately unfortunately, if it was this side slamming more important I had also omega lower so, my load would have been less. See not slamming important what I meant if you go this side my chance of bottom coming out or deck getting wet is itself. So, the question of my load does not come this side this happens more. So, there is a chance of its coming out more on top of that having come out it will reenter it will do much faster. So, here my goes like that and every time bottom comes out and impacts. So, it comes out and impacts over a short time. So, this time as more then you would have a bottom coming out and impacting lower time and the impact load would have been less. But unfortunately this is happening and this one I do not have so much.

So, I just wanted to tell you know this aspects so, we will discuss you know next class onwards important part of the other thing that slamming deck wetness what do you want from the spectrum normally, you do not want how many times you know like what is the chance of slamming etcetera, but you will want deck wetness that in 100 or 1000 cycles or in a 24 hour day how much time you may think that the deck will be wet.

So, the thing that you want is something else that we will discuss how do you get those quantities from spectrum. that is it will say that in 1000 cycle how many cycles you expect the bottom to come out and slam, not the slam load itself how much percentage of time you think that the deck will become wet. these things can be also obtained from the spectrum which we will discuss how we can statistically derive those.

But the today's lecture was the main point, which I am going to end with saying that see all this and more we will discuss sea sickness etcetera. All are functions pure functions of those 6 modes of motions R A O for all those derived response.

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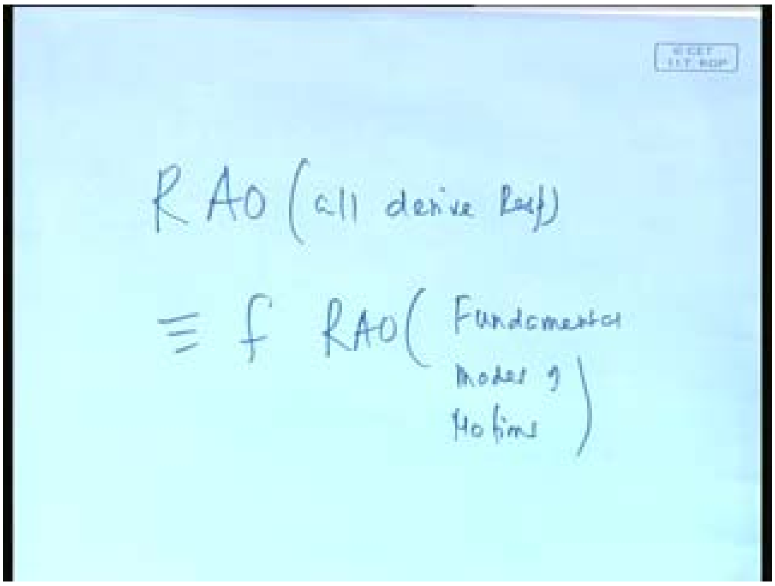

Well, if I were to write R, this is the last one for today. So, it is this that was that calculation lies these were the application lies. So, with that I will end today's class.