Numerical Ship and Offshore Hydrodynamics
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Lecture - 58
Including Non Linear Forces in BEM Code

Hello welcome to Numerical Ship and Offshore Hydrodynamics today is the lecture 58.

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Today we are going to discuss how we can incorporate some kind of non-linear wave loads for example, green water into the BEM solver. Now for today's class I select that impulse response-based method as a BEM solver and there actually we can incorporate the green water loading.

Now, the BEM solver you can take anything you can take the time domain panel method also no problem ah. But here for sake of simplicity we have taken the IRF based solution ok.

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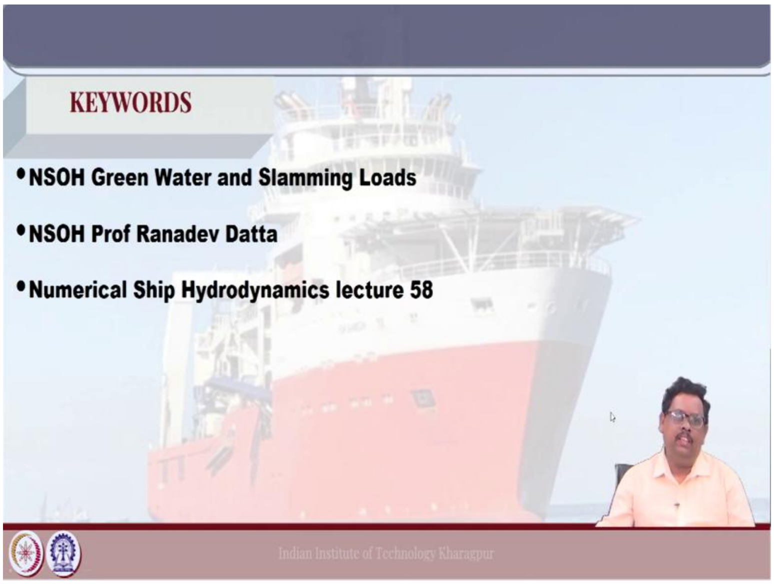

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Now, this is the key word that you have to use to get this lecture, now let us start. Now, first let us try to figure out what is the slamming and green water just from this video this video has been played before also. Now, again we have to see that when actually slamming occurs and when you have the green water load.

Now, you can see here the bottom part of the ship actually heating the water surface heating very badly you know and that phenomena called t slamming ok. Now you can see that how dangerous this is and it can damage the bottom part of the structure anytime.

Now, let us see that what is the green water now here also you can see that wave is coming and heating to the deck main deck. Now here also you can see that it is also become it is a very that is also very rough. In fact, this also sometime leads to the structural damage of the ship. So, therefore, considering these two phenomena slamming and green water is really very important.

Now, frankly speaking both are not very easy to capture ok; however, you can see the importance from this video. So, it is very important though it is very difficult to compute still we need to at least you know give you some kind of idea or some approximations based on that some formula we need to develop to figure out what is the slamming load and the green water load ok.

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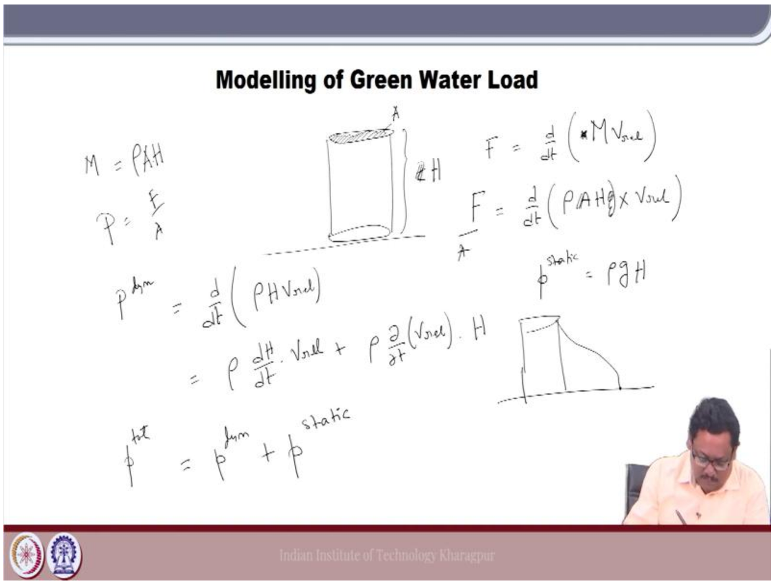

Now, here let us try to model the green water load in very simplistic way I will tell you that this the way I am showing it may not be that well to see every detail of the green water loading or the green water phenomena. For example, this method cannot capture that air trapping phenomena, like or it does not capture the actual flow field the plunging effect everything, it is very if you really study the green water in very deeply that time you will come to know all these things.

Now here what actually; however, why it is important? Because at least I could get that what would be the amplitude of the green water load, and which is essential to solve the ship motion problem or wave interaction problem all I need to get that what is the response of the vessel that what would be the magnitude of the green water ok.

It may not be that how the water is actually flashing on the deck or how it flashes on the structure superstructure of the ship. You know we that is also important study for that you have to do very rigorous CFD analysis; however, for this fluid structure interaction problem we attack this problem and only our botheration is what would be the magnitude of the green water load, ok.

Now, let us see how actually it is possible to do. Now, what we can assume here there are lot of models are available we are taking a very simplistic model we can. So, lots of methods are available we are taking the very simplistic model here we call it is a dam break model. Now, what we can see is let us assume A column of water and let us take the height of this column of water is Z and let us take the area of this column of water may be some A ok.

Now if you use the Newton's second law of motion. So, it says that $F = \frac{d}{dt}(MV_{rel})$ ok. Now how I get the mass because this is a water column right.

So, definitely the mass the expression for mass should be $M = \rho AH$ ok. So, that would be the total mass.

So, then I can write this equation again this $F = \frac{d}{dt}(\rho AH \times V_{rel})$ right you know is really easy. Now pressure is $P = \frac{F}{A}$. So, I can call this as the P dynamic. So, the dynamic pressure can be written as now if I divided this by A. So, the it becomes $P^{dyn} = \frac{d}{dt}(\rho H \times V_{rel})$ right.

So, now here we can say that $\rho \frac{dH}{dt} V_{rel} + \rho \frac{d}{dt}(V_{rel}).H$. Now, that I can think of this would be my dynamic pressure.

Now, my total pressure so, you can say this the pressure total $P^{tot} = P^{dyn} + P^{static}$. Now, what is the static pressure? The expression for the static pressure is $P^{static} = \rho g H$. So, this is what we are assuming like. Now, physically what actually I am doing as follows; now suppose I am having I will just take an axis over here ok.

Now this pile of water actually I am releasing I am releasing and then I am allowed it to break it here. So, that is something actually I am doing. So, it is a combination of static component and the dynamic component. And so therefore, if I replace the both ok. So, if I replace the both then I could get the expression for the total pressure right.

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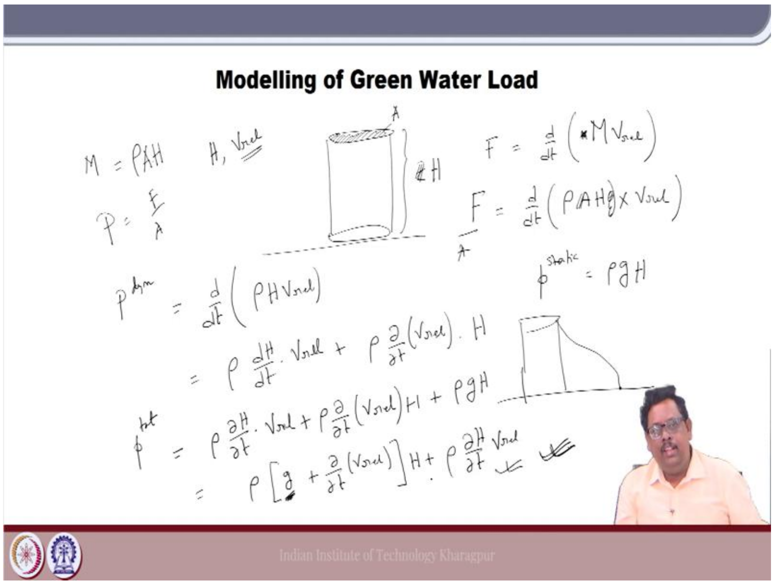

So, now so, then the total pressure that p total equal to. So, I have to $P^{tot} = \rho \dfrac{dH}{dt} V_{rel} + \rho \dfrac{d}{dt}(V_{rel}).H + \rho g H$ ok. So, it becomes $P^{tot} = \rho \left[g + \dfrac{\partial}{\partial t}(V_{rel}) \right] H + \rho \dfrac{\partial H}{\partial t} V_{rel}$. So, this is the expression for the green water.

So, this is how actually I can model the green water this here this mathematics is not very complicated and direct it is coming from the physics. So, derivation also easy however, the derivation of slamming is not that easy. So, when we discuss the slamming, we can only go with the final formulations anyway. Now this is fine now even if we have this expression, it is not that easy to incorporate into the code.

Now, here you can see that we have lot of parameters that we need to find out for example, or we need to know the definition. For example, so, this is a, this is a pile of water pile of water is there in the deck and sometimes it is actually breaking it into the deck, it is fine.

Now, how we can define this parameter this for example, the H and how we can define the parameter V_{rel} right. Now let us see how we could do that for that actually we need to understand some basic ship geometry.

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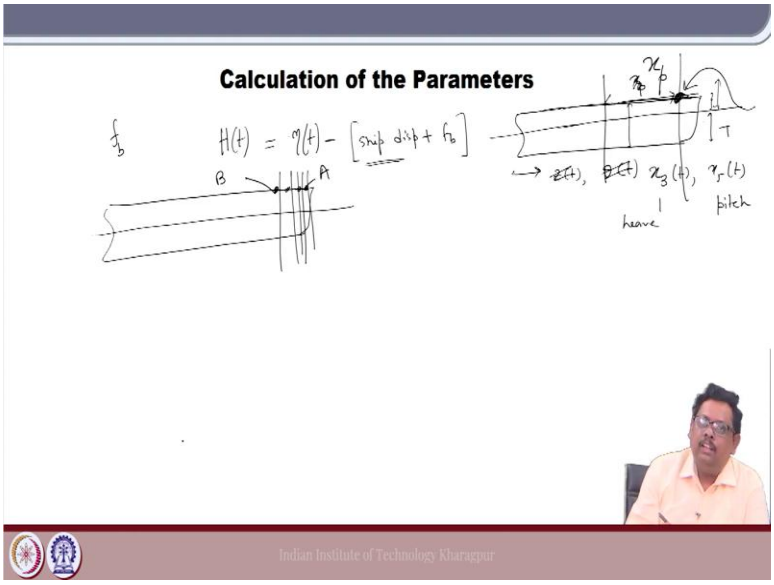

Now, if you draw the profile view of a ship ok. Now we have this is called the design water line and this part you called the draft T and this is called the free board and then total it is we can call is the depth and this is called the main deck. So, this is the basic geometry of a vessel. Now this we can let us take we can define the free board as small of f_b ok.

Now, this water when green water is happening now if this wave is coming. So, if the height if the height of the water is more than the height of the free board together with the height of the ship; that means, because here you have to understand that this ship is not in static position now ship also is a dynamic position. So, therefore, this ship has vertical motion you can call that as a $z(t)$ and also it has a pitching. So, it has let us say you can call it a $\theta(t)$ or $z_5(t)$ as I mean the way you know that ok.

So, let us see that in our notation we call let us say $x_3(t)$ and then $x_5(t)$. So, this is heave and this is pitch ok. So, it means that that vessel let us take this mobile like this vessel actually it is not still it is moving and it is moving with a in heaving as well as the pitching. So, in that way it is going.

So, then I need to figure out when the, this green water phenomenon will occur and when and how we can compute this height $H(t)$. Now, clearly this height $H(t)$ is nothing but if I take this amplitude or you can say this $H(t)=\eta(t)-\left[ship-disp+f_b\right]$. So, that would be the resultant high resultant height should be the height of the water column right.

So, we know we understand this one. Now, thing is that how to get the ship displacement. Now we have to understand one thing that we need to figure out that at which point I am interested to get the, I mean that green water load. Now suppose I fix a point here, now let us take the distance from cg to this point let us say it is something x_p ok, let me write in very bigger so, we know this.

So, x_p so, this is the, this is the distance between the point I am interested where actually the green water can happen ok. So, the distance of that point to the from the cg is let us say x_p. Now, thing is that this point x_p also a variable point right for example, now this is this is my ship over here.

So, this is the ship now it can happen this green water normally since the water is piling up and falling here. So, it can fall over here, here, here. So, any point it can this can happen, but I mean in fact, all point it might happen may be the intensity is different the intensity it is slashing here at this point A may be when is slashing at the point B the intensity is different, but; however, it is possible. So, it is run from A to B.

Now, to again we are going with very simplistic way let us approach to this problem. So, we are not taking the multiple point ok. So, here we are let us take only a single point and we try to calculate what is the green water pressure or load is I mean acting at that particular point and then we can repeat the same phenomena for different point also. So, you can get a series of green water load along the length of the vessel ok.

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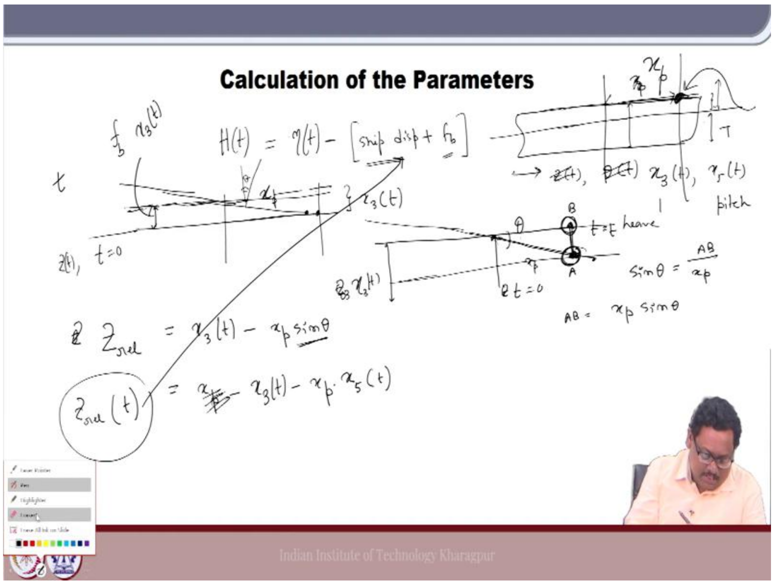

So, now, let us take now let me draw this again now I just draw this, the main deck and now let us take this is my cg and this is the point I am interested. So, it is and then distance is let us say x_p, now suppose it undergoes some kind of heaving and pitching. So, it means that let us say that you know it approaches to this point. So, this is the, at any time at any particular or instead of time t. So, now, this is we can call this may be the vertical displacement and you call the x_3, fair enough.

So, now, at some point say it is this point it is at you know at it is that it is the *z(t)* at you know $t = 0$. So, this is the primary position of my and with respect to this I am trying to calculate the whole thing. Now at any point at t. So, it moves from here to here so, this displacement this from here to here let us call $x_3(t)$ ok.

Now, it undergoes some tree more. So, now, let us assume that that you know bore down is positive. So, then; so, now, if I draw this picture here little bit this is the point after actually, I am pushing from $t = 0$ and it is from there are some $t = t$ it has this much of displacement.

So, I can call it is at $x_3(t)$ and here it has some kind of trim or you can call a positive trim. Now, if this is the point, I am looking for so, this is my x_p and let us I am interested about this vertical point now. So, this would be my final point it first it is approaching here and then it has bore down. So, it down θ let us say or here we can ok, let me go with θ only because we have this notion now, I do not want to put this $x_5(t)$ here it might confuse you.

So, it has a θ , bore down and finally, this is my actually the relative position of the vessel ok. Now, how I can measure this point it is very easy from very basic trigonometry I know my, the $\sin\theta = \frac{AB}{x_p}$ right. So, therefore, this distance $AB = x_p \sin\theta$ right.

Now, here now with respect to this if I now draw then what is the Z_{rel} let us take this definitely $Z_{rel} = x_3(t) - x_p \sin\theta$. So, this is the displacement of the point now this point it is AB point let us. So, this is the displacement of the point B at any time t.

Now, I assume this θ is small because otherwise if I do not assume θ is small, I cannot write g over here, I have to write $g\cos\theta$, right? Because here also you can see here that it is a slanting. So, g so, it is the component of g is actually acting which is $g\cos\theta$ now if. So, this angle is θ if this is θ so, this is θ so, it is $g\cos\theta$, but since θ is very small. So, $\cos\theta$ approaches to 1 so, that is why I write here g.

So, when I write g it means that I am assuming that θ to be small now, if θ is small then $\sin\theta = \theta$. So, finally, I can get $Z_{rel} = x_3(t) - x_p\theta$. Now θ is nothing but my pitch motion. So, therefore, I can simply write $Z_{rel} = x_3(t) - x_p x_5(t)$.

Now this is my Z_{rel} at any point of time t ok. So, this is nothing but this is nothing but my you know ship displacement, clear? So, therefore, that is how I get what is my displacement of the vessel and that must be added to my, the free board right ok.

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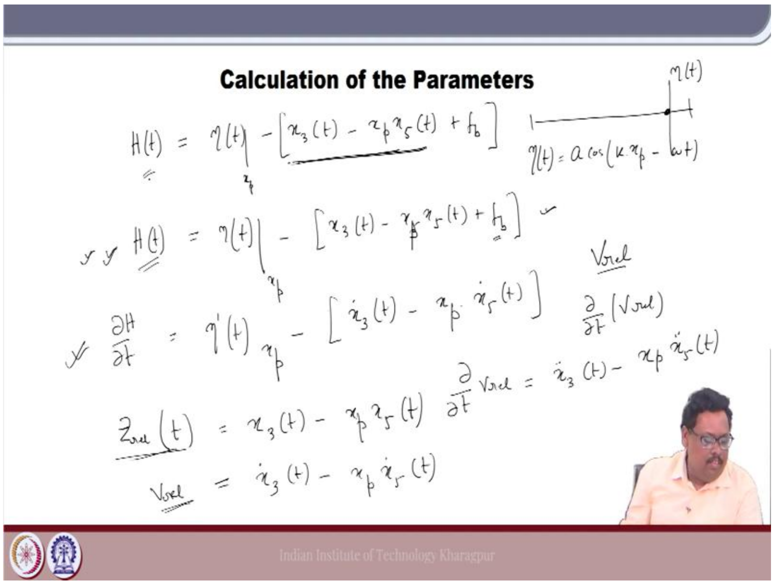

So, therefore, now I understand. So, now, I understand that if I try to write that *H(t)*. So, $H(t) = \eta(t) - \left[x_3(t) - x_p x_5(t) + f_b \right]$. Now, I know what is the expression for $\eta(t)$, right? So, inside this $\eta(t)$ is not I mean you have to find out the $\eta(t)$ of that particular point right. Now, again if I just draw the main deck and now if this is my point of interest this point. So, at this particular point I need to know what is my eta t.

So, I can write my $\eta(t) = a\cos(kx_p - \omega t)$. So, here I am just writing $\eta(t)$ at the point x_p right. So, that is how my relative this displacement $H(t) = \eta(t)_{x_p} - \left[x_3(t) - x_p x_5(t) + f_b \right]$. So, now, this is the *H(t)* I am getting right. Now, if you remember the formulation that the dam break model formulation. So, I know, what is my *H(t)*.

So, if you remember I need to know what is the $\dfrac{\partial H}{\partial t} = \eta'(t)_{x_p} - \left[\dot{x}_3(t) - x_p \dot{x}_5(t) \right]$. Now there is no free board because it is constant. So, if you define with respect to t it is going to be *0*. So, now I know what is my H I know what is my $\dfrac{\partial H}{\partial t}$ ok. So, now, I need to know what is the other two parameter.

Now, how to calculate the V_{rel} and $\dfrac{\partial}{\partial t}(V_{rel})$. Now if you remember I just see that this expression is nothing but this expression is nothing but the relative displacement. Now, I just write the relative displacement at $Z(t)$ or $Z_{rel}(t)$ and this is nothing but my $Z_{rel} = x_3(t) - x_p x_5(t)$. So, this is my relative displacement.

So, therefore, $V_{rel} = \dot{x}_3(t) - x_p \dot{x}_5(t)$ and therefore, the last component that I need to know that which is $\frac{\partial}{\partial t} V_{rel} = \ddot{x}_3(t) - x_p \ddot{x}_5(t)$. See now you see you have this Z_{rel} you have this V_{rel} you have this H right and you have this $\frac{\partial H}{\partial t}$ all term you have.

Now, only thing is that you substitute everything over here you substitute all this value here at each time t and then you will get the and the green water load at that particular point x_p. Now, today we are going to stop here. So, in the next class I am going to show you that how I can use this green water load into the IRF based solution ok. So, till now.

Thank you.