Numerical Ship and Offshore Hydrodynamics
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Lecture - 21
Frequency Domain Panel Method

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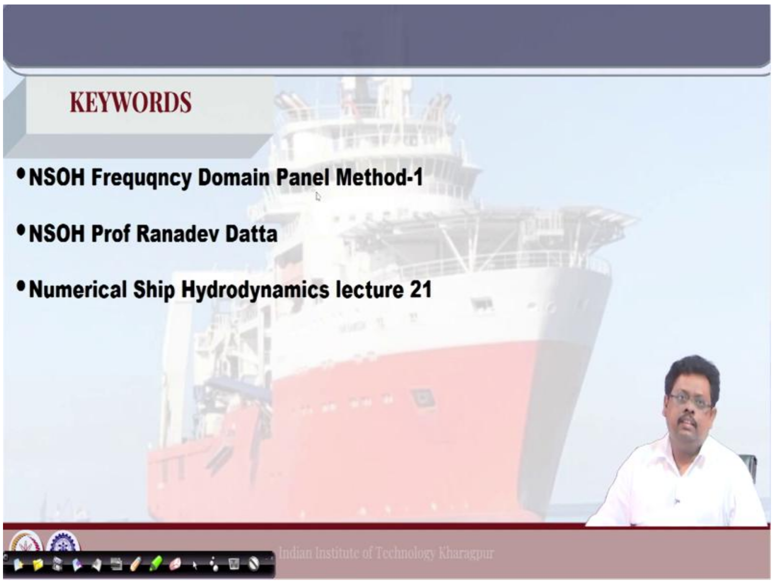

Hello, welcome to Numerical Ship and Offshore Hydrodynamics. Today is the lecture 21. So, today we are going to discuss some about the Frequency domain Panel Method. Of course, today is the introduction to the frequency domain panel method.

From the next class we really start the theory; but today we will see that various things, various aspects frequency domain, and what is the other method exist in to calculate the you know the wave induced loads and motion for a floating bodies ok. These are the keywords that we are going to use to get this lecture ok.

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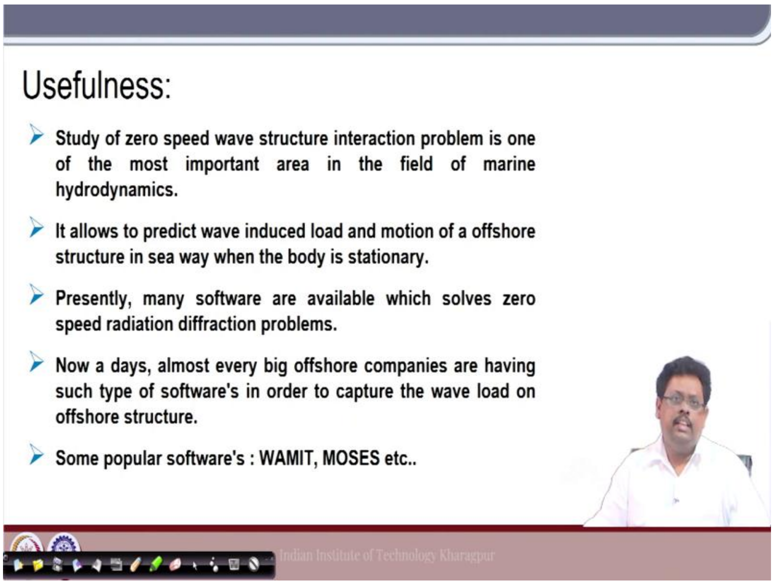

So, let us see that what is the usefulness of the frequency domain panel method. Now, in case of a zero speed of course, it has importance, because we have lot of offshore structures are there for extraction of the oil. So, normally, you know take any semi submersible is one of these.

And then you have suppose, let us say some offshore structure is damaged inside the ocean. So, some vehicle has to go and then people are trying to do something over there to fix the offshore structure so, then that time that another structure is floating. Third one is suppose you have some tension like platform right. And suppose also sometimes suppose you are taking extract the oil in offshore, some you know some platform and then you try to fire take this oil.

Nowadays, you can say that it is always through some pipes like, but however, sometimes if you need to take some oil also. So, then what is happening, then you have a big platform and side by side you have this small vessel, where actually you can take in the oil. Now, during that process what is happening that there is a fluid internally between two platform like suppose, I have one let us say this is the big platform over here and then the ship is here.

So, then we can take the oil from this the big platform to here and then this start oscillating and this also already oscillates. So, some so, therefore, sometimes that internal the fluid between this becomes very excited and that can damage the structure. So, there are many many you know application again most nowadays, the major applications also, in case of a you know energy devices right.

Now, we have many wave energy devices, we are designing it. And then in order to get the induced force, because of this the this let us say oscillatory water column. So, inside it that water column is coming up and down and all this comes into this zero speed frequency domain method right. So, main some of them are listed over here. So, just you can read out that the for the zero speed wave structure interaction has some use in offshore industry very much.

And frankly speaking, all this software I mean all this offshore industry, they have some kind of some many versions of the of this I would say the zero speed frequency domain panel method code. Everybody have now some example I have written over here, the WAMIT, the MOSES and there are many. I just mentioned 2, because these 2 are most popular nowadays, but I do not say the other also not popular.

So, everybody has this now the problem is I have a software; let us say WAMIT, I have the WAMIT and then I do not have the sufficient knowledge of the frequency domain panel method, like I have some working knowledge on WAMIT. So, I know that how to make a grid using WAMIT and then you know how to take the different files ok; some input files, I know how to prepare the input files like they said like take the some GDF file for the geometry and other things.

I know all these things, and then I make it and then run it and I get some results. Now, problem comes like when this result is not favourable. Not essentially, all the times your results will be favourable, because many times you made some mistakes on input. Most of the time we make mistakes in input, like what are the input like that one is the machine, we call this panelling in case of a panel method and also the moment of inertias values, then this coefficient that c_{33}, c_{35} that we discussed here before.

So, there are lot of inputs you need to give right. So, maybe if something goes wrong and then definitely this code would not work. So, and also so, this today not today during this series of lectures from today, we try to understand where things can go wrong ok; and where we need to be very careful.

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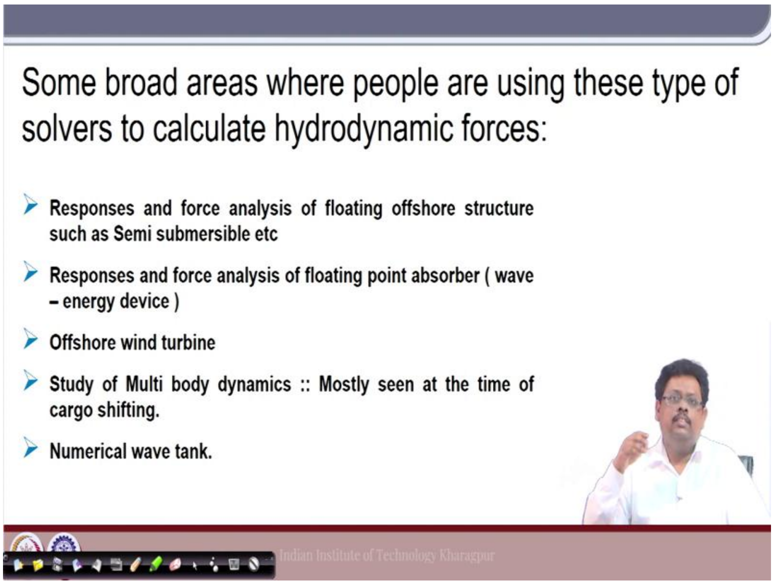

So, there are some areas as I mentioned before that people are working. So, like for example, response of a force analysis of floating offshore structure like for example, a semi submersible right. We use this and also as I said the floating point absorber not only this floating absorber, sometimes actually people are trying to do the numerical wave tank that I am writing at the end.

So, people try to couple this you know boundary element based panel method with the CFD based, I mean this is also some can argue that panel method or some kind of a CFD analysis. What I meant when I say that it is the RANS based solver, we normally called as a CFD base solver.

Now, what is happening here, that if you try to calculate the radiation force or exciting force, or try to find out the global motion of the point absorber or some semi submersible structure; then it is this is very useful, of course, to use this. And it is also very time efficient as well.

However, there are many times like this is not all. We have to deal with some kind of the local force also. For example, the green water; some waves coming and splashing on the deck. We can have slamming sometimes, these are not the very simple harmonic motion and then this frequency domain cannot capture all this phenomena very efficiently.

Also, like now in case of a point absorber or anything like then, you need to extract the energy right. Now, when you do the machinery which extract the energy from this wave energy devices and that particular time that thing also cannot be considered as very much oscillatory or panel method cannot handle that also. So, we need some blend like this panel method is efficient in terms of memory, efficient times of in terms of cost.

And also it is quick and it is reasonably good to predict the global loads, global harmonic load which is radiation diffraction etcetera. However, it is not that well to capture the other local phenomena. So, now, if I write some code, which is the blending of these 2 things right; the some part actually where this panel method is efficient. I calculate with respect to I mean with the boundary element method and some part I can which is not very useful like panel is not useful to predict those things.

And if we capture those phenomena with some so called pop CFD based or the RANS based solver and then, if you a way to couple these two then actually the thing is coming out is the numerical wave tank ok. And one more interesting point that actually mentioned here is the study of multi body dynamics right. It is kind of like if I series of point absorbers; so, then if I oscillate the one then there is a there is a effect in some other body also.

So, suppose like for as I mentioned that I have a here also I have a big platform and then I have a small shape and then there is a multi body dynamics, because two body is oscillating in closed by. So, we can ignore the effect of one body into the other. So, in that case also this panel method is very useful.

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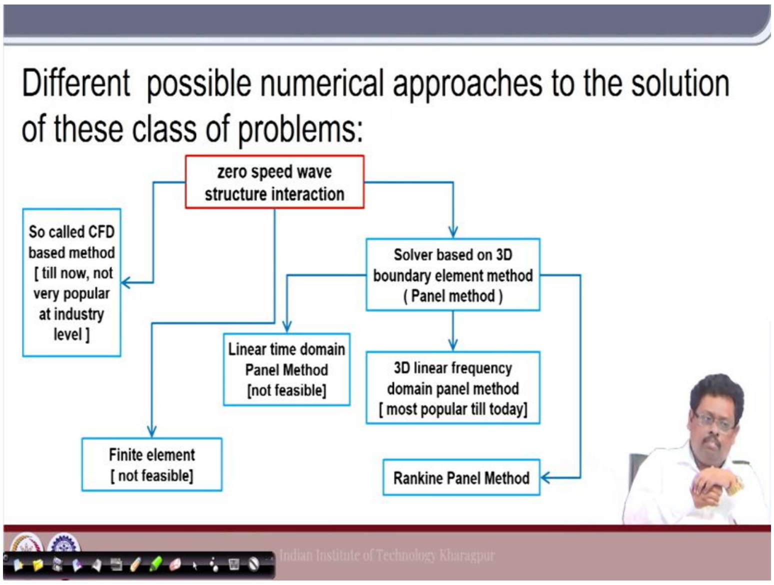

Now, you know when we start something let us try to figure out that what are the other possibilities exist nowadays. So, now, we have tried to find out the zero speed wave structure interaction. Sometimes popular it is called the zero speed radiation diffraction problem also ok. So, now, as I said that now it is in 2020 the we can say that CFD, we cannot ignore the CFD methods right.

But still, even if today's computing speed it will take much much more computational expensive; in terms of time and in terms of cost ok. So, therefore, it is not still that popular. It is not that people are not using it, but still if I you know this frequency domain panel method that what we are going to discuss is much way popular compared to the CFD, but definitely we do not know still what happen after 10 years.

Now, this is one way when we are; when we are computing with RANS based solver, now, just remember when I said CFD. So, I meant that either the RANS based solver or maybe smooth particle hydrodynamics right, something like this. Otherwise I mentioned the panel boundary element method ok. Now, solver based on 3D boundary element method or panel method there are also lot of variations are available right.

So, the first variant is we can say the linear time domain panel method, but as I mentioned that it is not feasible; that reason is very simple right. Reason is if I use panel method why not use a CFD, because may not be it is that expensive in terms of times like

CFD, but linear time given parallel method also expensive with respect to time. Because, we have to deal with the green’s function later on we are going to discuss about that.

So, this green’s function is actually is a convolution integral. So, therefore, we need to integrate every time from starting point to that particular time. So, evaluation in this green’s function is very time consuming. Now, in case of a zero speed problem, the that the linear time domain and then frequency domain it is only a matter of Fourier transformation. So, therefore, why should I go for the linear time domain.

Because, I can solve it in frequency domain and I just do the FFT to get the corresponding time domain solution. So, that is why it is really not that feasible. So, next part is the 3D time domain panel method that is the most popular till today, I will still I am saying compared to the CFD still today 3D linear frequency time domain method is popular, when you try to calculate the radiation diffraction force of a floating structure ok.

So, just you know we have to be very careful when I say that is popular not popular which problem actually I am trying to deal with. Our problem is that we try to figure out the radiation diffraction force or global motion or wave load for a offshore structure which is floating on a ocean. So, if you restrict our thing into this particular objective, then definitely the 3D time domain panel method is till now the most popular one ok.

This is another one. So, still it is may not be I mean that is also not Rankine panel method is equally popular right. And Rankine panel method definitely offered lot of let us say that advantage over this 3D linear frequency domain method, because Rankine method can be in time domain, it could be in the frequency domain. And in Rankine panel method, we already discussed that it has it has only the Rankine part of the green’s function which is 1/r.

So, evaluation of the green’s function it is much more easier right, in compared to the 3D frequency domain panel method. We are going to see that, why I am saying it later stage. And also in rankine panel method, you can incorporate some kind of non-linearity; let us say Froude Krylov law or even the radiation diffraction force nonlinearity. It is much much more easier in Rankine panel method in comparison to the 3 dimensional linear frequency and panel method right.

It is everybody you know accept that fact. So, it is again as I said is so you know complicated to take any statement like which one is popular or which one you should go, because it is you know depends on the people perceptions like for me I think that 3 dimension frequency panel method is should be, we should take it; because, it is well established and very popular in 90s definitely in the 90s or early 2000 these are the this is.

I mean that time undoubtedly these are the most popular one, but now that CFD also comes into picture this Rankine panels are day by day become more and more popular. So, still since it is a very classical method and this is the very popular in 90s and of course, in 2000 till first decade of the 2000. So, we are this course we are mostly focus on this 3D linear frequency domain panel method ok.

And now, another one is finite element. Finite element is popular everywhere, in structure analysis it is one of the best method, and finite element is much more versatile than 3 dimensional panel method, I mean the boundary element method of course. But if you try to apply here then there is a problem. The problem is that in finite element you need to discretize the whole domain, computational domain.

Now, look at this ocean. It is a huge right, and then there is a structure on it. Then how can you know discretize the surface. So, it is not that feasible to do that. Now, here also this panel method is little bit beneficial, because you really do not have to discretize the whole computational domain. So, what actually we do here, let us see then let us try to figure out that what are the advantages.

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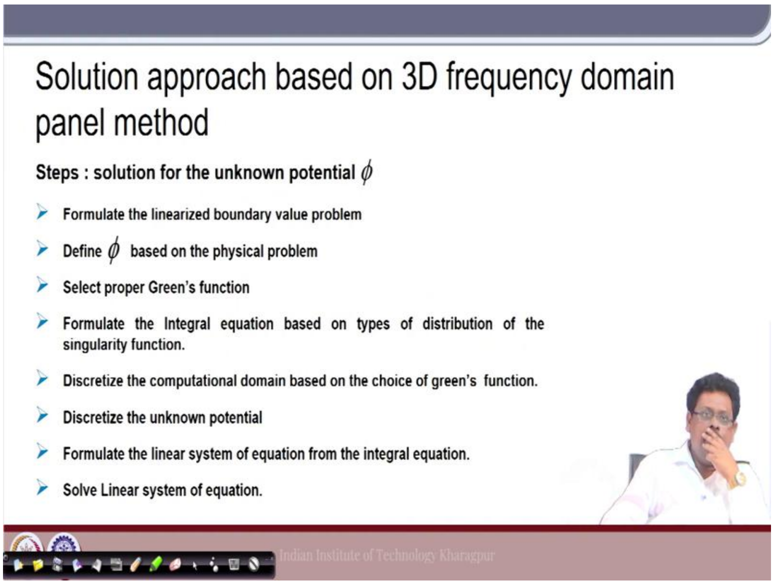

Now, here this is the solution approach for the frequency domain panel method. Now, here all these things right now maybe you can think of little bit complicated, but we have already done the previously how to you know do this one by one. Now, here also the idea remains same. So, we have to formulate the line linear linearized boundary value problem in frequency domain right. And then we need to define the ϕ based on the physical problem.

And then, we have to select the proper green's function; then we have to formulate the integral equation based on the type of distribution. Now, if you remember in our previous class we have only discussed about the source dipole distribution, but here we are going to learn there are there exists some other kind of distribution also. So, that we are going to discuss in the later classes. Then, the similarly discretized the computational domain based on the choice of the green's function.

If you remember, the I said that machine a 1, a 2 etcetera like if you want to discretize the whole domain, I mean like the body and the free surface or only body based on the green's function that you have taken. And also then we have to discretize the velocity potential phi also. Now, we have already discussed that if you take the - you know this linear lower order panel method, then ϕ would be the constant of a single panel and different from the different panel right.

So, this is this all we have discussed and then the final part that from the integral equation, we have to convert the linear system of the algebraic equation and we are going to solve it. So, all these things, how we are doing it for this 3 dimensional frequency domain panel method; that definitely we are going to discuss in the next class from the next classes.

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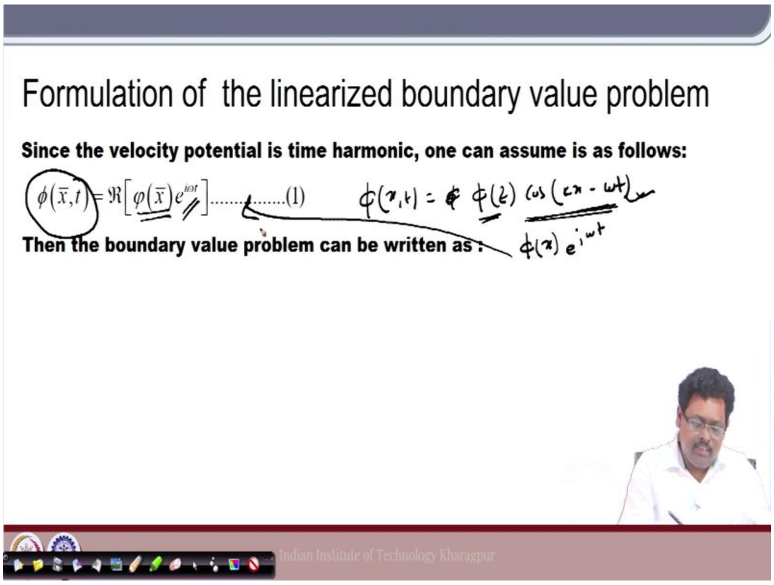

So, now, if I start like here what we did is that we describe the phi in terms of harmonic way, like see if you look at this equation 1, then we can we understand that here this $\phi(x.t)$ that actually we divide into 2 part. One is the space coordinate and then, we multiply $e^{i\omega t}$, which is the time coordinate.

Now, here you know here we are really, if you remember that we normally define this ϕ as some we have done that. That let us say $\phi(x.t) = \phi(z)\cos(\mathrm{kx} - \omega \mathrm{t})$ and then $\cos(kx - \omega t)$ that was my trial solution right; because we know that it is not harmonic in direction of z, it only harmonic in the direction of x. So, therefore, we have find out this that way. Now, even if now this, $\cos(kx - \omega t)$ also now, I can further modify. We can say that it could be I can write that $\phi(x)e^{i\omega t}$. So, that is what we have done and then finally, we get this expression right ok.

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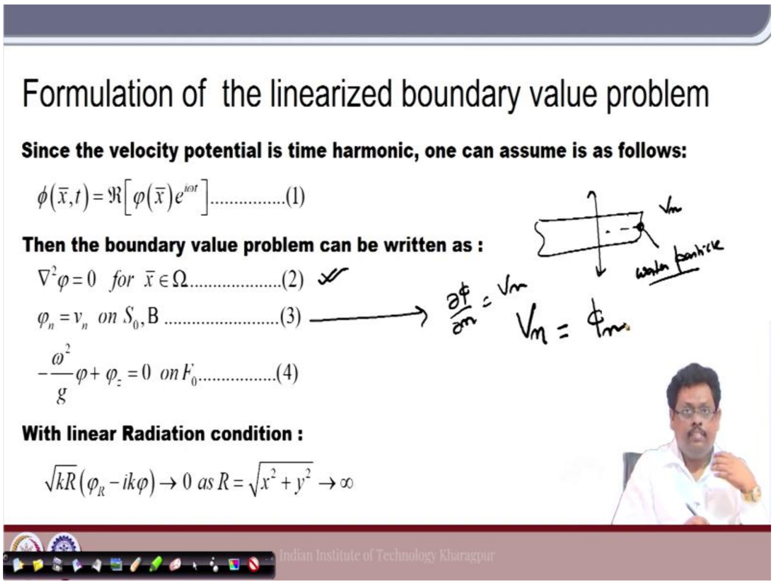

Now, if I set this as my the ϕ, then definitely we are going to solve for this set of equation. Now, this set of equation you know that del square $\nabla^2\varphi = 0$, it is the laplace equation. So, now, actually if you look at this expression, I am not solving for this ϕ. So, I am not solving for this ϕ, rather I am solving for this one, the space coordinate right.

Now, this space coordinate actually satisfy the Laplace equation, which is $\nabla^2\varphi = 0$ and together with this is the body boundary condition, which is del $\frac{\partial\phi}{\partial n} = Vn$. So, we have already discussed it means is a kinematic condition. It means that suppose ok I am writing a ship again right. So, if it start oscillating. So, this water particle associate with this it should be stick on that body only. So, how when then why it is how it is possible.

Now, if you remember that in our previous lecture, what is the boundary value what is the boundary surface. So, in that case that if you assume that ship to be the boundary surface. So, if this is the boundary surface then this water particle, this water particle, this water particle should stick here right. So, it means that the normal velocity of the ship. So, that is the normal velocity of the ship should be equal to the normal velocity of the water particle.

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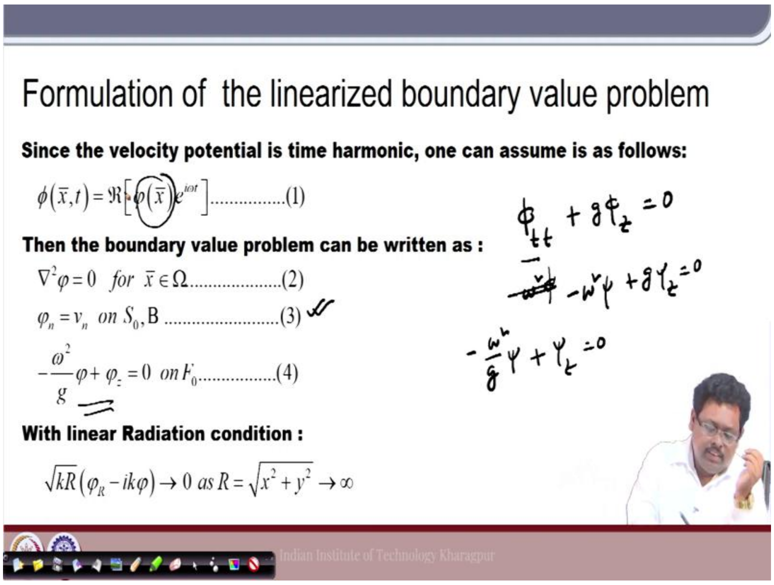

So, this is what actually writing in the equation 3. And this is nothing but the linearized free surface boundary condition. Now, you know that our boundary condition combined is $\phi_{tt} + g\phi_z = 0$. If you remember this is our free surface boundary kind it is the combined free surface boundary condition. Now, if you take this ξ as $\varphi(x)e^{i\omega t}$. So, ϕ_{tt} becomes $-\omega^2$ into now, here it is ξ of course ok.

And then, ok let me write it is $-\omega^2\varphi$ and it is $g\varphi_z = 0$. Now, if you divide the g over here then it becomes $-\omega^2\psi + g\psi_z = 0$ right. So, I am solving for this ok. So, then now I understand that how this free surface boundary condition comes and this of course, the radiation condition. So, it means that at infinity you do not have any wave right. So, therefore, therefore, we have to we now this is the - we have to solve this set of equation 2, 3 and 4.

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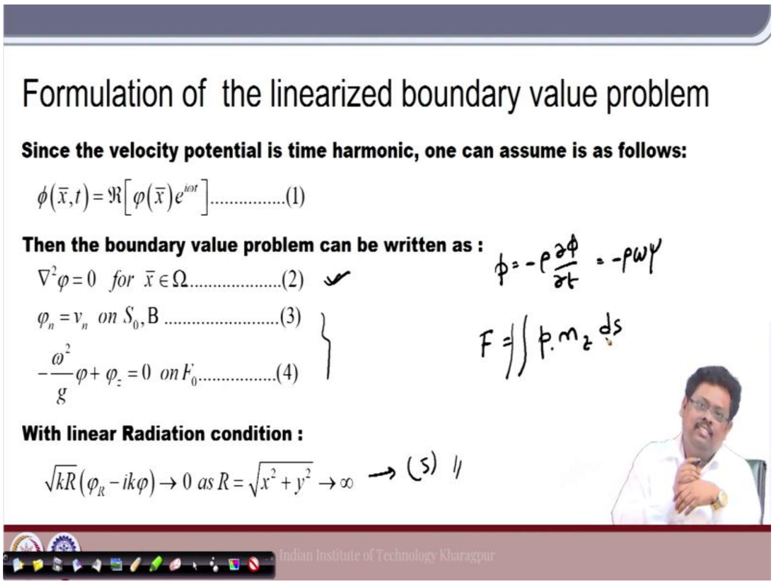

And of course, the linear radiation condition we can call this 5. So, we have to solve equation 2 with this boundary condition 2, 3 and 3, 4 and 5 to get the solution for ξ, and once I get the solution for ξ; I can integrate the you can get the force by integrating the pressure of pressure I get by $\frac{\partial \phi}{\partial t}$ now. $\frac{\partial \phi}{\partial t}$ is now, in that case you can see that $\phi = -\rho \frac{\partial \phi}{\partial t}$.

So, now since the ϕ is the harmonic, so, definitely it becomes $-\rho\omega\psi$. Now, once I get this pressure p and then if I integrate. So, I just force is nothing but I integration this pressure and multiply by the normal. And now, in this any mode so, I just make this z because most of the time we are dealing with the heave anyway. So, this is how we can get the force also.

So, this is the primary idea. So, now let us try to find out now here, as you know that lot of forces are occurring over here.

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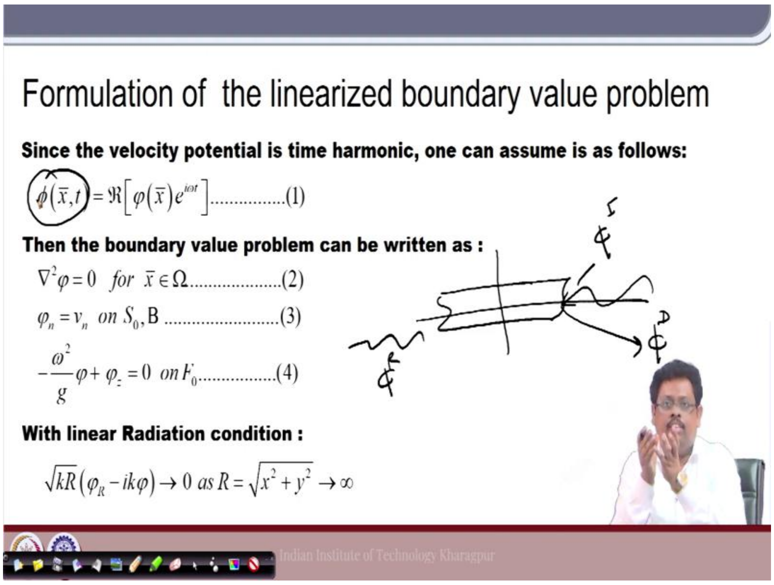

Some is the radiation force, like if you look at this complete phenomena, which is nothing but you have a shape, you have a shape. And then this wave is hitting and because wave is hitting this body start oscillating. And when this body is oscillating, then we can have another set of waves which is called the radiated wave.

So, this we can call that incident wave we can call this ϕ_I it is hitting, and then we can have the radiation wave ϕ_r, and then some wave got diffract also you can call this ϕ_d. Now, if you look at this ϕ, this ϕ should you know consider everything. Now, this becomes very problematic, because you know how do I define a single phi which takes care everything. This ϕ_I, this ϕ_d, this ϕ radiation how do I do that.

So, actually frankly speaking it is extremely difficult to solve this problem with a single phi. So, definitely we should have some kind of approximation to get the solution. Now, let us see that what is the solution.

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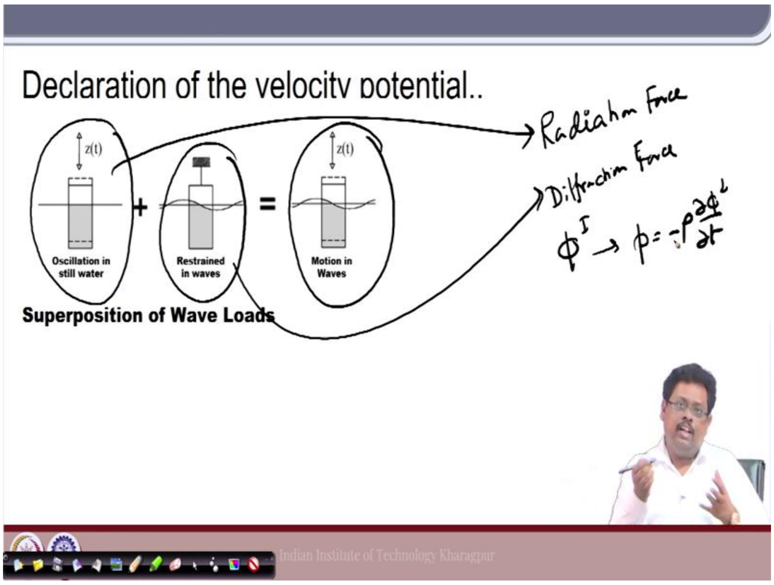

Now, what we do over here very nice thing. We do the super positions of the wave loads. Now, if you look at here, the same picture actually, I this is the picture that actually you are going to solve, the motion is waves. Now, this picture actually split into 2 things. One is oscillatory in still water and this gives me the component of the radiation force. And then I restrain in the waves. So, here this body is not moving the wave is hitting and this will gives you the diffraction force.

And also, you know that how to calculate the how to calculate the you know that Froude Krylov force, because it is we have already done that right. Froude Krylov force it is we know the expression for ϕ_I. So, definitely we can find out what is the pressure; it is nothing but minus rho del $-\rho\frac{\partial\phi_I}{\partial t}$ and from that we can get the force. So, I know right. So, here because if you remember this picture.

So, you see how actually I can approximate something and I super superpose the 2 different wave load to get the; to get the feel of the actual problem and that is the beauty of the linearization. In case of a non-linear we really cannot do that.

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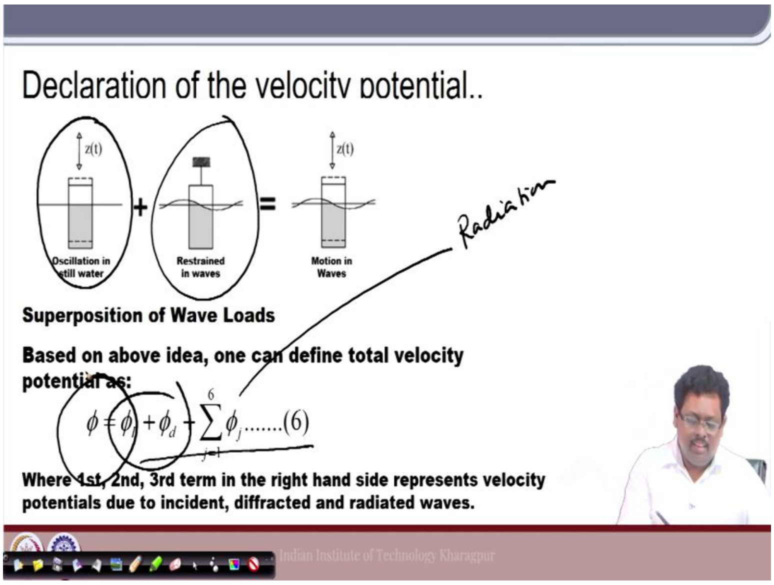

So, now based on this above idea, the we can define the total velocity potential as $\phi_i + \phi_d + \sum_{j=1}^{6} \phi_z$. Now, this ϕ_j is nothing but, it is my this is nothing but my radiation force right.

Now, here what I am doing, I am in still water I can oscillate the body in 6 different mode right. I can oscillate in this way, in this way, you know in this pitch, in this way in this way. So, I have 6 different way, I can oscillate the body I can get the radiation force right. So, this is the - this picture. And these 2 will give me this picture, which is I am not oscillating the body, but I am allowing the wave is hitting the body and then got diffracted and then this is called the scattering problem.

So, therefore, this if you superpose all these things, then actually I can get this ϕ, which is the solution for this you know the wave structure interaction problem right. So, this is really a nice way help, I mean getting the help from the linearization and try to figure out how we can solve this problem without much compromising on the physics of it of course, right.

So, today we have only discussed the formulation of the problem, that is how I can get the phi from the superposition of the radiation force and the diffraction force right. And in the next class we are trying to figure out how we can get the solution for ϕ considering all this force ok.

Thank you.