Numerical Ship and Offshore Hydrodynamics
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Lecture - 52
Ship Hydroelasticity

Hello, welcome to Numerical Ship and Offshore Hydrodynamics. Today is the lecture 52. Today we are going to discuss the Ship Hydroelasticity.

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Now till today I mean previous class everything we discussed about assuming the ship is basically a rigid body. This is ok with the small-scale ship with 50 meters to 100 meter or 150 meter maybe, but nowadays there is a trend to go some kind of vessel which is having 400 meter long or something like this. In that case we really cannot consider the ship as a rigid body.

So, therefore, it is interesting to know that if we do not consider the ship as a rigid body if you consider ship as a flexible body then how the mathematics got changed and how we can do this fluid structure coupling ok.

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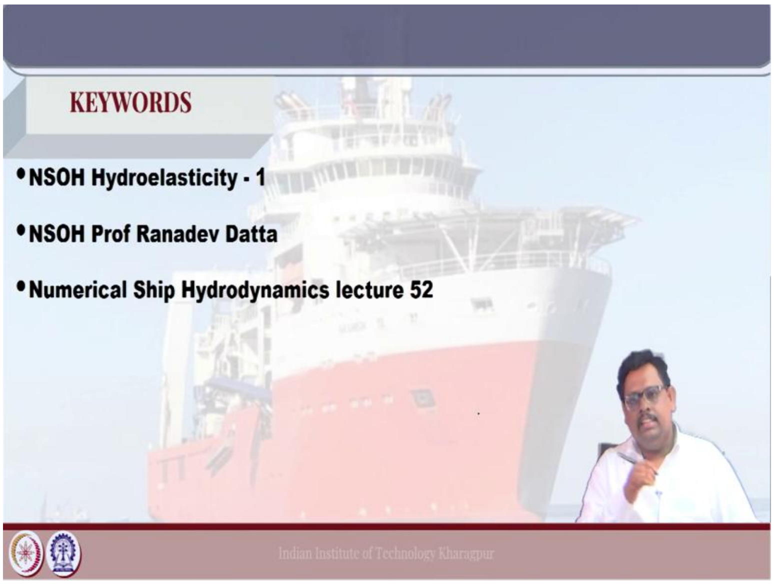

So, this is I going to cover in today's some introductory class of course, and this is the keyword that you have to use to get this lecture.

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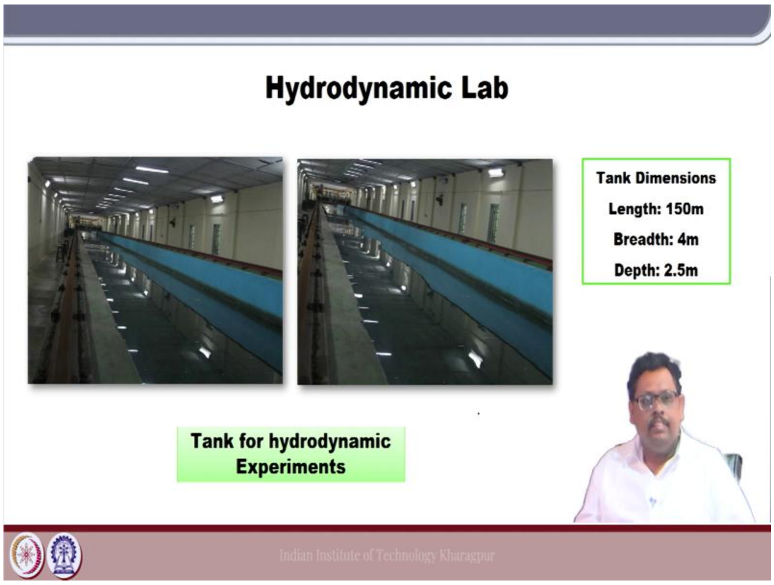

Before we start let us start with a small demonstration. Do I write is experiment it is really not an experiment. So, to do this demonstration I am using our departmental lab which is the Ocean Engineering and Naval Architectural Lab. So, this is the tank dimension is the length is 150-meter breadth is 4 meter and depth 2.5 meter.

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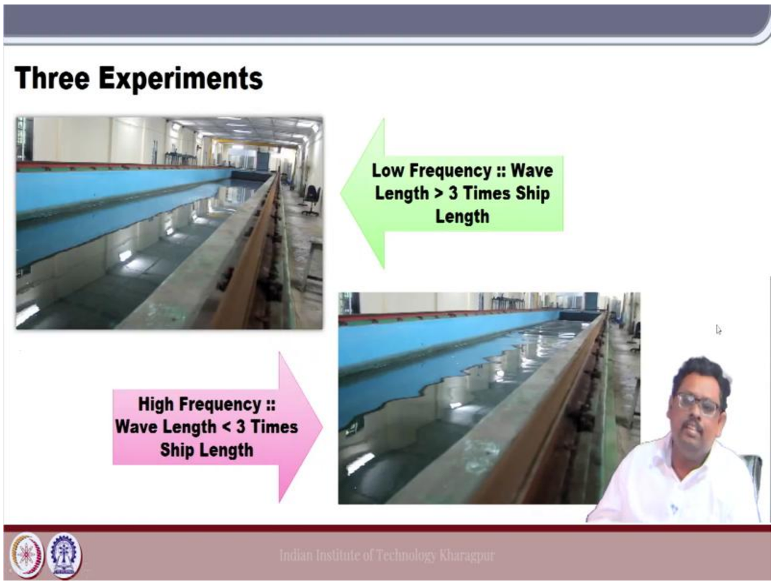

Now let us see that what did I do? Now actually I consider three different types of waves now one is that when the wave length is 3 times than the ship length. So, we can see that it is we can consider as a low frequency region right because the lambda is 3 times larger than the ship length.

Second one is we can say the higher frequency because here the wavelength is the 3 times smaller than the ship length ok. So, let us see that in these two situations when actually the lambda is very big the wavelength is much higher than the ship length then what is happening? Ok. So, let us play this. Now you can see here that wave is approaching is very low frequency waves.

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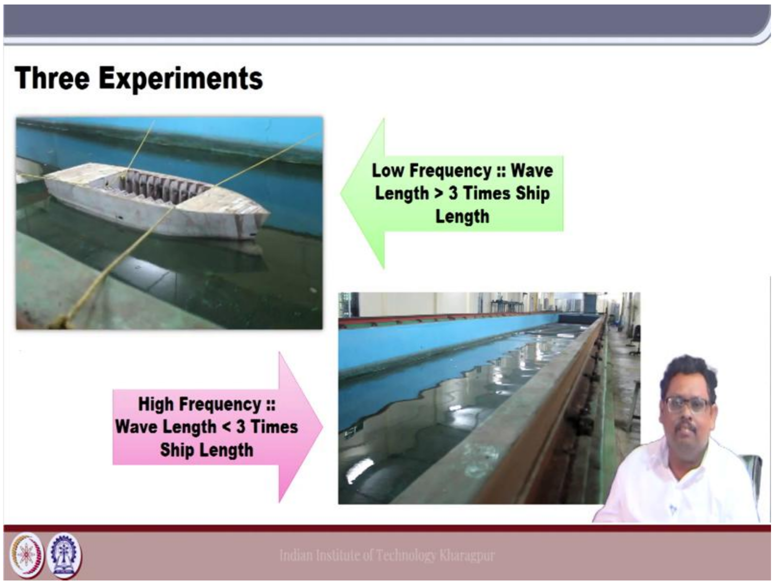

Now you can see there is the ship does not response is very minimum. Because this is the similar situation when actually you go into the sea and you take a bath you simply just go up with the waves and you can come down with the waves. So, also you can see the phases also zero. So, let us see that another situation when that that high frequency phenomena.

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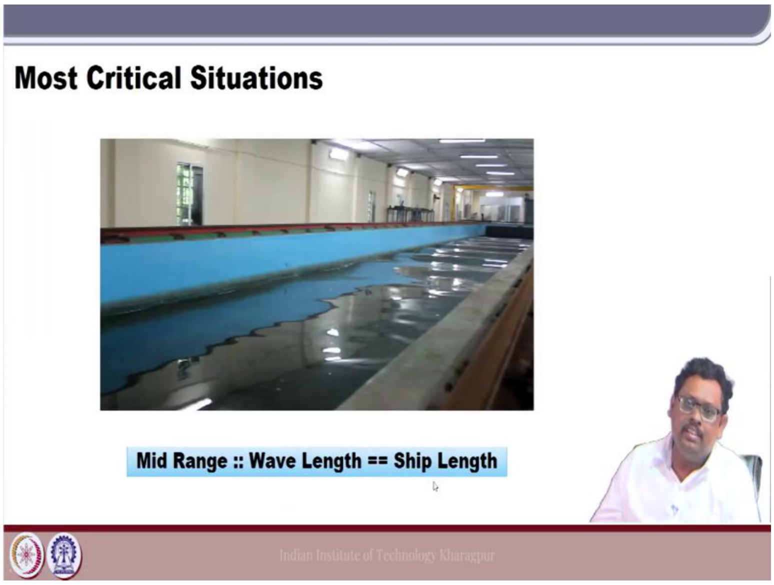

Here also you can see yeah let us play it now here you can also see that still that response of the vessel is not much because you know its frequency very larger. So, it does not dissipate much energy and you can see here that almost like a ripple.

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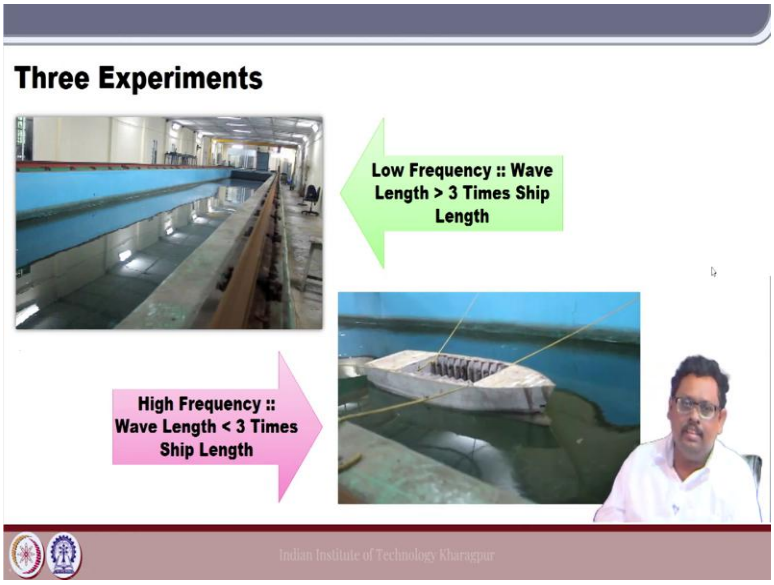

So, ship does not move much right, it is not moving. So, now let us see when actually the ship length is equal to the you know wavelength. Now in this situation let us see what is going to happen. So, it is not an experiment because I did not measure anything just to demonstrate you.

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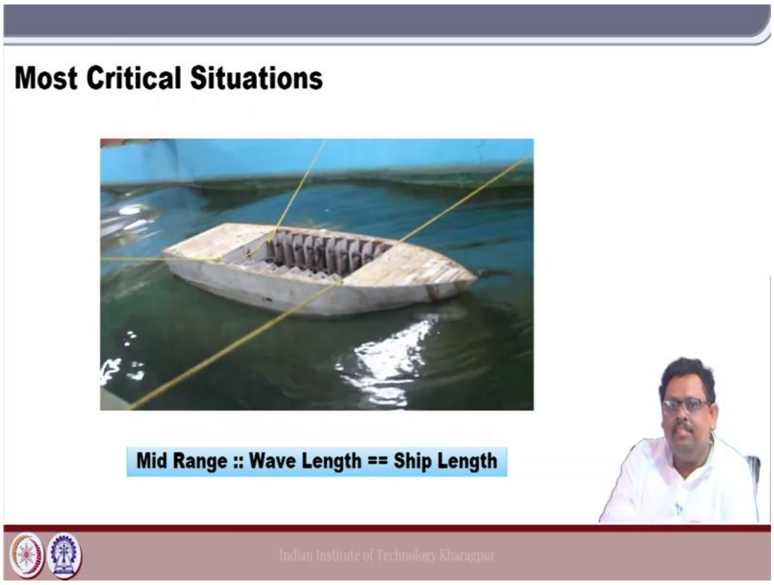

Now, you can see here that now you can see now the response is very larger and also you can see there is a phase between the waves as well as the ship now here everything is very critical like still it is not slam or there is not much green water not much there is not green water at all here, but at least it is the verge of that situation.

So, you can see that how it is that rope also have a lot of stresses on the ropes. So, let us see once again like just to check that how now here everything is under the rigid body. Now if the ship is smaller then I understand this one is ok it is a rigid body mechanics is happening.

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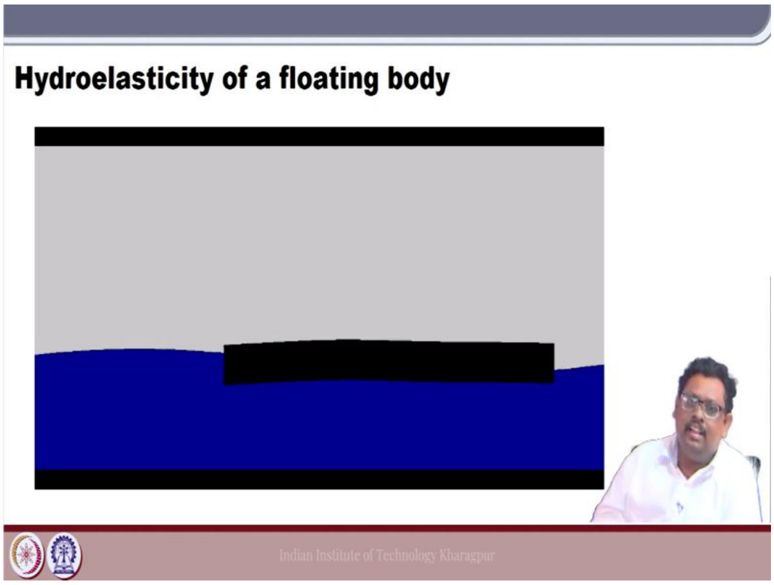

Now if the same thing is happened with the longer ship, then let us see what is going to happen. Now, it is a numerical simulation of our own code this hydro elasticity code that we are we are discussing right now. Now if you see here that now I considering that it is a flexible body. So, you can see it is not only having this phase lag and that abrupt motion, but at the same time it behaves like a flexible structure.

So, because of this you can have some bending moment or may be sometimes I mean more serious thing is sometimes springing or weeping many things can happen. And therefore, it is very important to understand the hydro elasticity of a body; that means, that wave structure interaction considering the structure is flexible.

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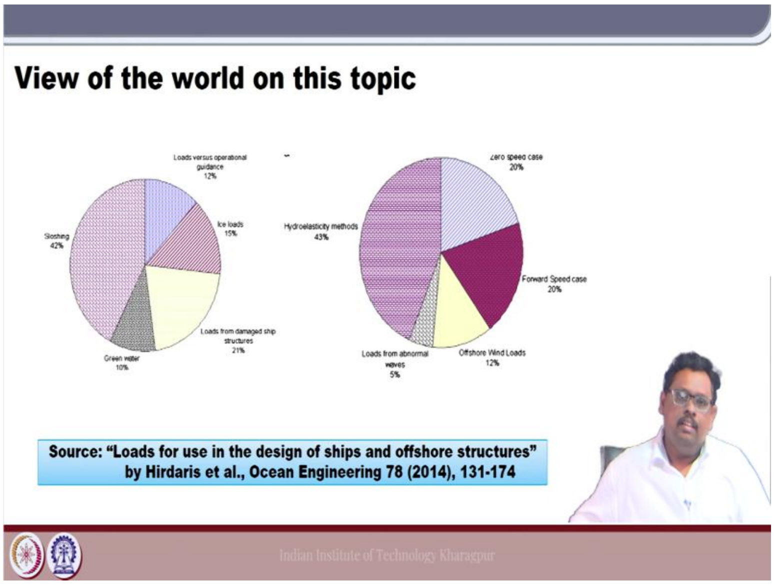

So, since the introductory class I would like to mention that that it is. So, important in last couple of last couple of the last one or two decades where people actually started building longer ship now there is one you can say that very useful work by Hirdaris et al they research it and find out that there is a 43 percent of the people actually they are working on this hydroelasticity problem.

So, one can understand that how important this for today now it is the paper is in 2014. So, we have almost 10 years, but still, it does not lose the importance ok.

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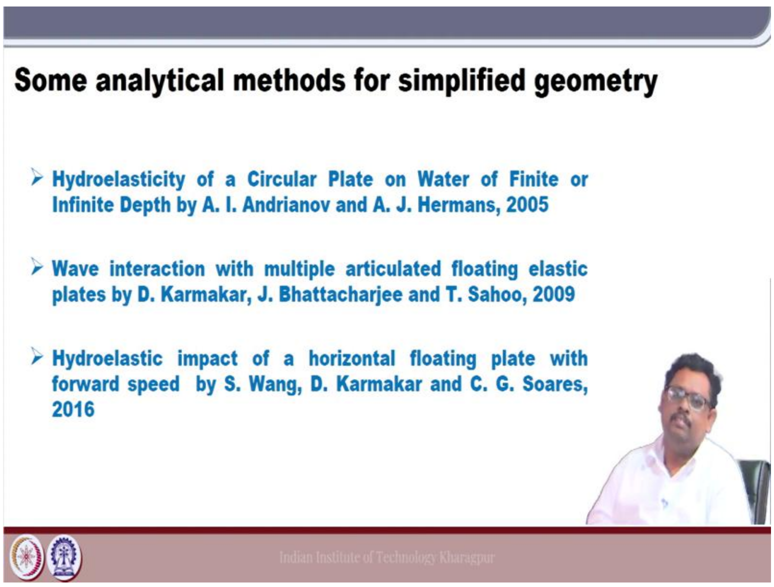

And there are some works that one should read before do anything in this particular domain and I would like to some very useful work that one can you know see like, now some work here everywhere some work actually is a analytical work. This one is very helpful for us because for the benchmarking.

So, you can see that this work if you look at it that they are using some two-dimensional body the body is very regularly circular disc or may be a plate and for and they apply the high velocity on it ok. So, these are very good for benchmarking.

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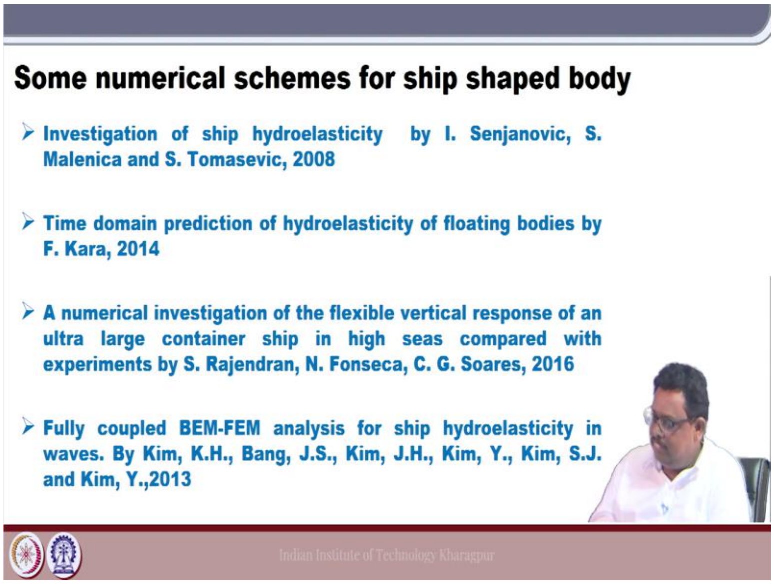

However, if you want to do some kind of some practical work, we are trying to figure out that high elasticity of ships. So, in that one that one has to go with some rigorous numerical coding. Now these are some very pioneer works by Senjanovic or Food Kara or the group by Gets Soares and also the Koreans group the Kim. So, they have solved this problem using some kind of numerical technique.

And here what we are going to discuss is that we have already developed I mean in last couple of lectures previous lectures we have developed a in I mean not develop we have discussed a numerical technique based on time domain panel method. Now, here what we are going to discuss is suppose you have the rigid body code how to advance it for the hydro elasticity that actually the objective of this lectures.

Now, once you have the rigid body, then you can actually think of incorporating this hydro elasticity or flexibility into the structure for that you need to have some knowledge of finite element also necessary. Here we really not into the finite element; however, which is necessary for to understand this particular methodology that much definitely we are going to discuss here.

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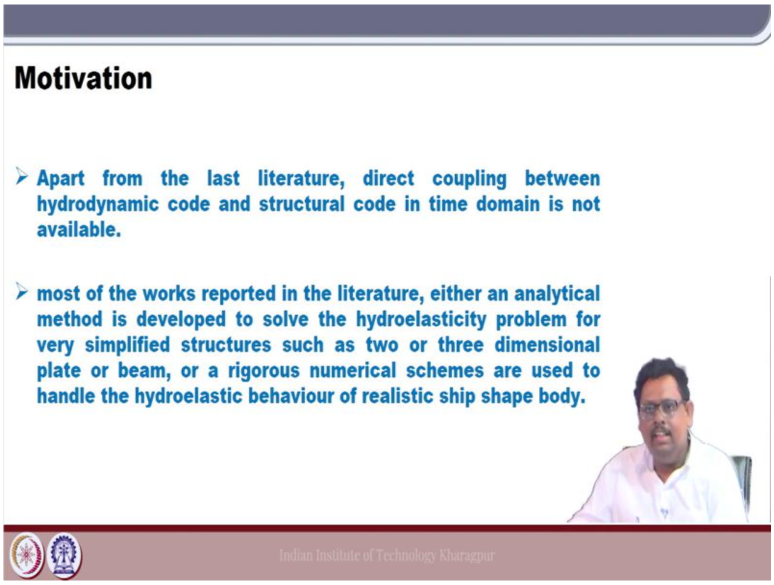

So, the motivation actually here is that that we have a rigid body code with us. So, now, if we look at the all the literature mostly either they are using some kind of frequency domain method I mean it is absolutely under the linearity and of course, even if the linear situation also very complicated ok. But here the advantage is this we are going to do this in the time domain.

Now what is the difference between the frequency domain and time domain at least at this point everybody knows very well that in time domain that we can add some kind of non-linear force in the equation of motion. However, if we use the frequency domain code it is very; it is very you know complicated work to you know incorporate some kind of non-linearity.

For example, the last you know in this course the we stop with incorporating the slamming and green water into the hydro elasticity solution. Now this green water or slamming those are not you know periodic in nature. It is a impulsive load. Now once this is a impulsive load the handling that thing in frequency domain is really difficult.

So, therefore, that would be the further motivation to understand the hydro elasticity in time domain ok. So, actually here in this course I actually frame two methods or you can see that the two approach actually.

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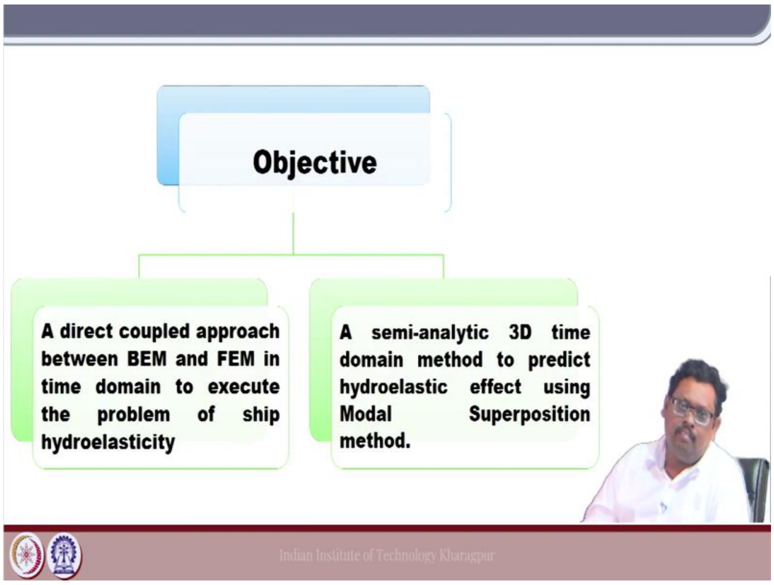

The first one is which is the direct coupled between the BEM and FEM that is what I am going to discuss initially that I have my rigid body code. So, how I can use this rigid body code to address the hydro elasticity. This is the fundamental one. And you know once we develop the rigid body code then you can see that it is not that complicated to incorporate the flexibility into the solution.

Of course, there are many levels of complexities there, but at least you can capture the initial level which is even a fairly complicated. Now in another level what I am thinking of like we can discuss let us say I have a ship and I really do not want some rigorous analysis at the basic level I mean at the initial level.

So, I got the design. So, I need to estimate I because I need to calculate the strength of the ship. So, what would be the thickness of the plate and many more things like. So, design load is very important for me. But at this point all this code is available here for example, this sophisticated time domain codes or frequency domain codes or hydro elastic codes. These are not you know very cheap in terms of cost availability etcetera etcetera.

So, we really may be in the initial level we really do not want to use such complicated or sophisticated software. Rather let us the focus may be that I can get some kind of idea about what would be the range of the bending moment, what is the range of the shear force like and the stresses etcetera etcetera. So, if your motivation to get those things in initial level.

So, we really do not need to use this complicated or sophisticated panel method or this numerical code. So, for that actually we are going to discuss that we can we can actually without making much compromise on the quality of the result. I mean when you say the compromise means like if you use the sophisticated method definitely you can rely more on it.

My point is even if you do not use it you use this semi analytic three dimensional time domain method still you can get some you know very much realistic result and the difference between this and that may not be that larger. So, that you can think that ok this is not gives a realistic value from. So, I should go for the complex sophisticate time domain solution and that you know it is not that bad as I said.

So, both are may be different, but they agree I will show you they are they are more or less within 10 15 percent or 20 percent at maximum ok. Now let us start with the first one and then after that well we will discuss the semi analytic one.

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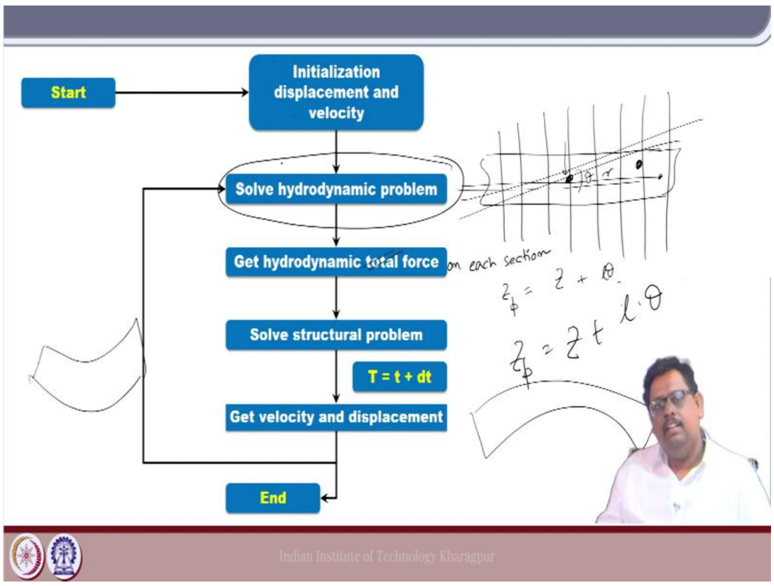

So, now, how we can do this fluid structure interaction problem this as follows. So, initially we have to make that the velocity the displacement the acceleration that is our input. So, everything has to be initialized. So, we make it 0 everything and then we solve the hydrodynamic problem.

So, why I solve the hydrodynamic problem? Because by solving this I know the hydrodynamic pressure distribution over the hull right now this hydrodynamic pressure distribution is important because that is actually going to solve your structural problem. So, that would be the input.

So, here you can see that here this solving this hydrodynamic problem and this get the hydrodynamic not actually total force mean total sectional force. Now, see now it is I am not considering the rigid body I am considering the body flexible.

So, I understand that here at each sections the velocity and the displacement it is actually changing right. Otherwise, normally if you consider rigid body, I am happy to know what is the force acted acting on here at the same rate and then I multiply with the moment term r and I can get the moment as well right.

And also, if I know the here at this point what is the vertical displacement z and if also if I know that the angular displacement theta. So, at any point I can find out my total displacement $Z\phi = Z$ plus some l the distance from here to the point I try to calculate what is let us say this is the point and if this length is l. So, it is l into theta something like this right.

So, let me write in bigger way you just get it something like this l is this distance between from the CG to that particular point. So, you can get the displacement of any point. This is fine when we consider the rigid body. However, for case of a hydro elasticity that ship might bent in this way also or maybe bent on this way also. So, in that case at each section it has different displacement velocity are and also therefore, to get it I must have the hydrodynamic force on each section the total hydrodynamic force.

So, get hydraulic total force on each section on each section. So, this is the input for me to solve the structural problems. So, then I start doing either you can do the modal superposition technique or we can use the advanced finite element method. So, we can get the. So, with this we can solve it we can find out the structural displacement velocity and this again we are going to use here for the solution of the problem right. So, this is the overall flow chart of this of the hydro elasticity code right.

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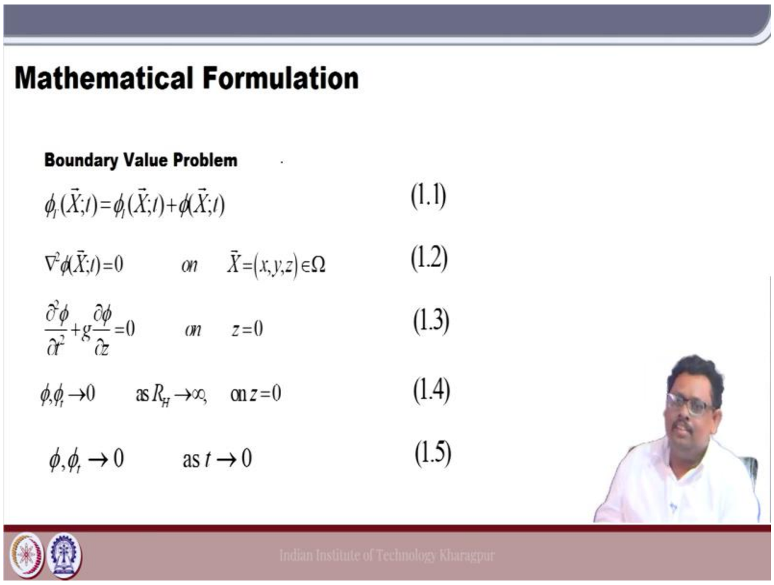

Now, here let us see that you know today it is again like we just review of the previous thing now here you can see the that boundary value problem is the same you can see that all other here we are taking the same thing like we are using the total potential and then we are using the disturb potential then 1.3 is nothing but your kinematic free surface I mean the total free surface boundary condition and then you have the constant infinity and you can have the condition at initial (Refer Time: 20:40).

So, this is fine, where is the difference? Now the difference here is actually when you write the body boundary condition.

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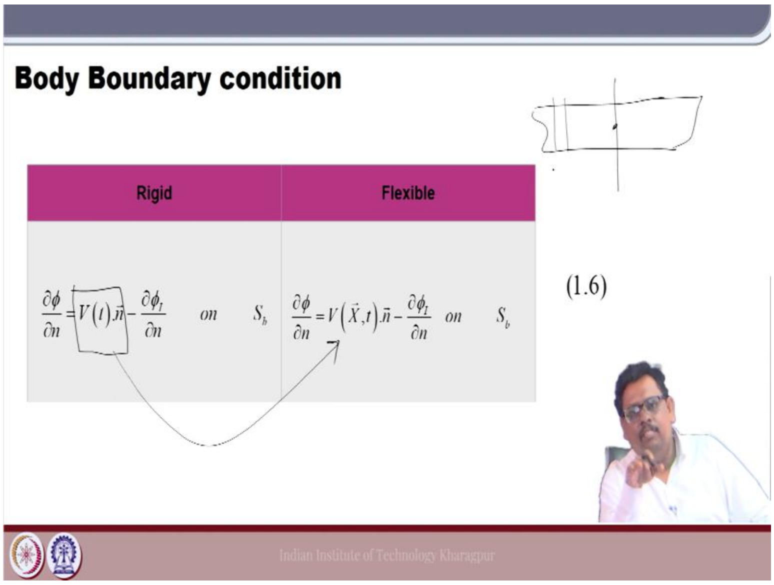

Now, when you are writing the body boundary condition in case of a rigid body you can see that we are writing it is V into n now this V is applied at the CG of the body here. So, V is not the function of x. So, what is happening here in case of a flexible body I have to apply this boundary condition at each X. So, this is the first changing from the rigid body problem.

In case of a rigid body, we are having it is only a single point which is CG just one velocity of the rigid body which is applied the CG and then we can use the boundary and del phi del n equal to this now here. So, $\frac{\partial\phi}{\partial n}$ now $\frac{\partial\phi}{\partial n}$ is not the function of course, the space not the function of the time only it is also the function of the space. So, this is a huge change like and one has to address this.

So, this is the first thing that is different from the rigid body situation right. However, otherwise if you understand this change then remaining part more or less same right.

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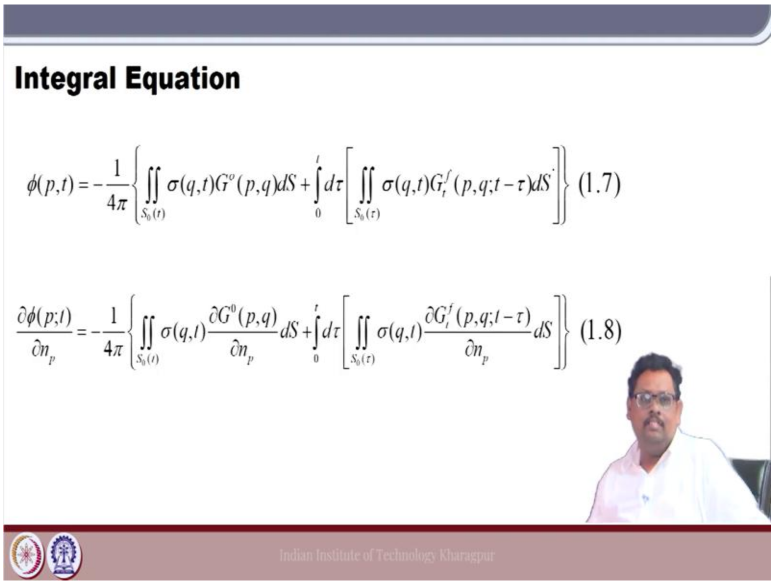

So, that we are using the same integral equation over here you can see that 1.7 and 1.8 we are using the same integral equation for solving the ϕ right.

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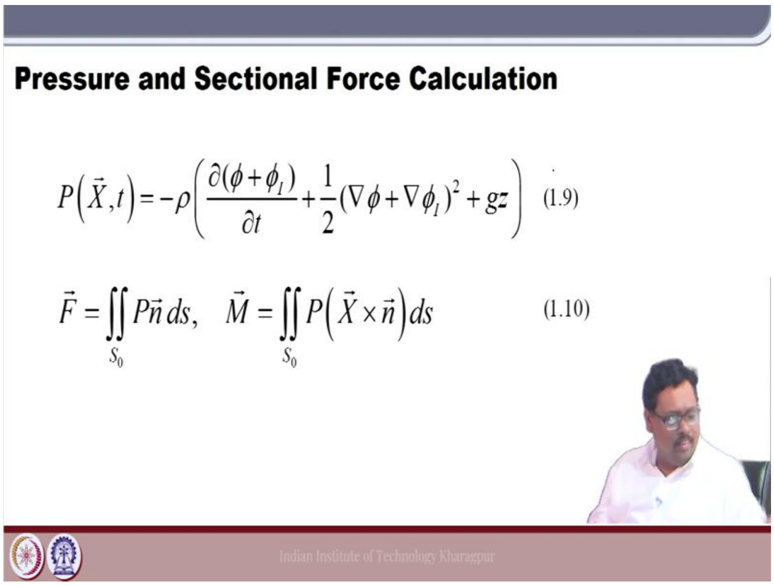

And also, we are using the same equations to get the pressure as well as the force and movement right. So, here in fact, 1.1 10 also we need to change here because this 1.10 gives you the force over the body; however, we are interested on the sectional force right. We are not now when you solve the hydro elasticity, we are really not interested on the total force which is only for the rigid body.

Now this 1.10 also we need to change a little bit. So, now, we understand that it is almost the same code the only thing that this body boundary condition we should be very careful where to put this 1.6 and then this 1.10 how to incorporate 1.10 to get the sectional force those things definitely we are going to discuss in details in later class ok.

So, today we stop here and we continue with this time domain panel method for hydro elasticity in the next class ok.

Thank you.