Numerical Ship and Offshore Hydrodynamics
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Lecture - 27
Frequency Domain Panel Method (Contd.)

Hello welcome to Numerical Ship and Offshore Hydrodynamics.

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Today is the lecture 27. Today we are going to discuss some basic idea about the free surface Green's function very rough idea we are not going to go into detail like we will just discuss that how I can get the free surface Green's or integration of the free surface Green's function. However, which is more interesting part later on the second phase I am going to show you that how actually you write a, I mean not write like use a commercial code which is one.

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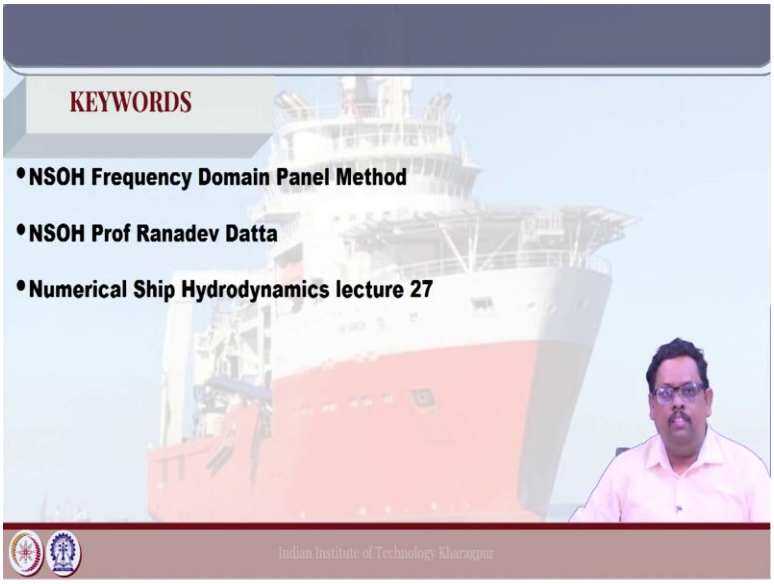

Now, this is the keyword that you have to use to get this lecture ok.

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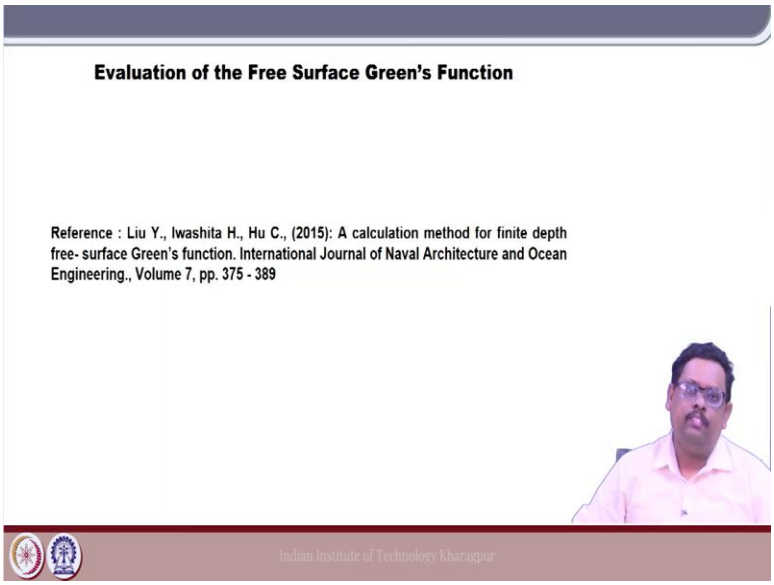

And this is the reference that the discussion I am going to give for this free surface Green's function that the thing you can get from this reference.

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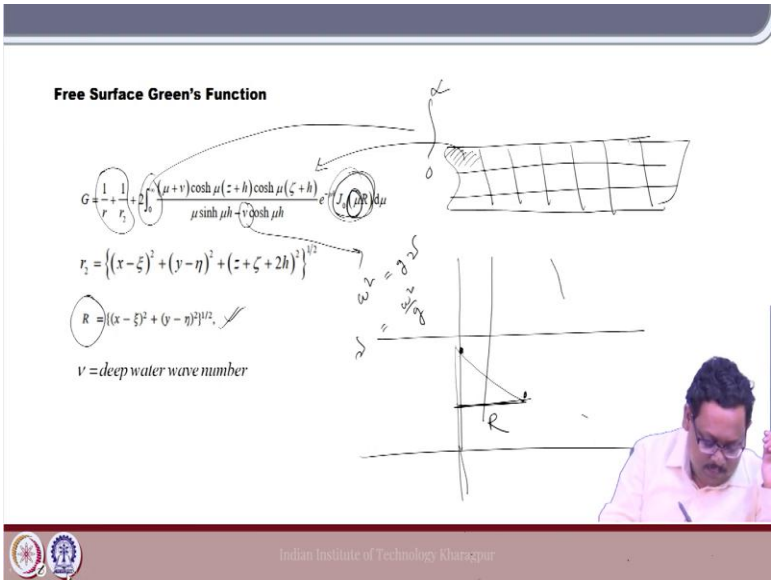

Now, as you know this is the expression for the free surfaces Green's function. We have discussed it is very complex there are many reason the first thing is that its a improper integral because you have this integration limit 0 to ∞ so, this is the 1 and also you can have a Bessel function here which itself is a infinite series.

So, therefore, we have a integral equation improper integral equation together with a Bessel function which is again a infinite function. So, it is the solution is not easy ok. Now also we have the Rankine source at the beginning; now we understand that how to deal with the Rankine source we discuss a lot about how we can deal with the Rankine source.

Now, let us today how to deal with this the free surface Green's function. So, there are many literature available mostly, there are many approaches one can take now somebody can do the direct integration technique what they do is as follows. Suppose I have a panel something like this and already we know that how to discretized it and you get this panels. Now over this panel they can use this is direct Gaussian quadrature rule they apply and they get the value for this integral ok.

So, it is called the direct numerical approach. So, you see that here the main issue is the convergent and as well as the Bessel functions you have to have some infinite series you have to deal with. So, this is one way of going into this; however, in fact, if you look at the work by several researchers people use this it's not that nobody uses this direct

numerical integration technique, but they are very popular to use some kind of asymptotic solution some kind of series solution to get this value integral value for this Green's function.

Now, what is asymptotic solution or what is the series solution those things are very core mathematical thing and then I really do not want to discuss here in this course, but; however, to give some kind of flavour let me explain that how to integrate using those functions ok.

Now, here actually if you look at this expression this Green's function, here before I go into solution I have to define so, many things. Now here this R this from this expression you can understand is it is nothing but the projection in the horizontal z equal to I mean horizontal z plane.

So, it means that if I have a. So, this is the thing if I have any source point here and then you have any field point over here. So, then see this distance is nothing but your R ok. Now if this is the sea bottom and this is the source point then this r_2 is basically the image about the about that you know depth which is the seabed ok and here this υ is nothing, but the solution for the deep water dispersion relation. Now what is the deep water dispersion relation? It is $\omega^2 = gk$.

So, just nu is nothing, but it is $\frac{\omega^2}{g}$ which is the deep water solution and then what is the mu? Now here you say like υ is the solution for the you know this dispersion relation now here there is a; there is a very deep mathematical things involved here to explain this what is υ.

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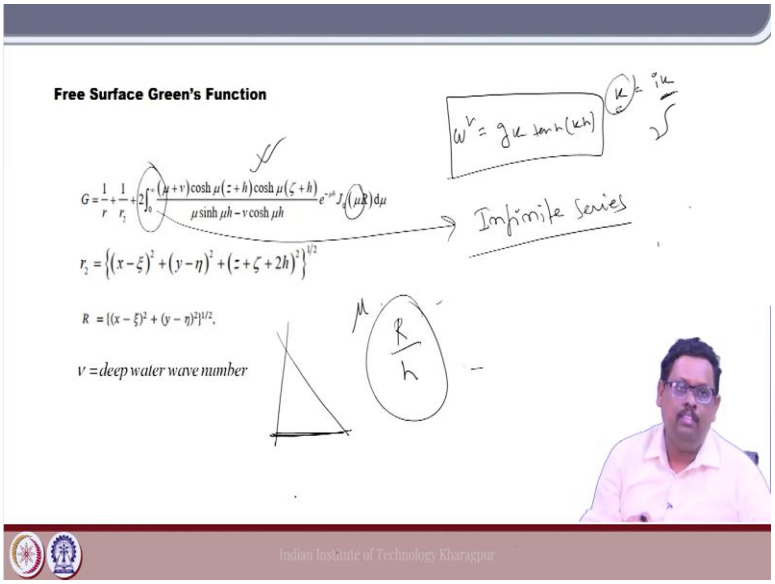

Now you know the dispersion relation is nothing, but $\frac{\omega^2}{g} = gk\tanh(kh)$ right. So, this is the and then from this you can get if you take ω tending to ∞ then you get the value for υ; however, suppose if you want to now here it is we have to looking into the solution and now it is an infinite you know improper integral the limiting values 0 to ∞ how to solve it? It only can be solved with the help of some infinite series now to get this infinite series I need infinite roots. So, how I get this infinite roots?

So, I just change this k = ik if I do that then actually I can have another set of integral equation I mean sorry another set of dispersion relation just changing k = i k and now you can have the infinite solution or infinite root for that particular dispersion relation. So, details you can you can take any standard book Water wave mechanics book, try to get what is called the evaluation mode and how to use this evaluation mode.

So, here we really do not want to go into that you know deep into mathematics, but at the end you need to know what is what. So, for that this mu is nothing, but the root of the dispersion relation if you replace k by ik then you can check it out what equation you will get. So, solution for that is nothing the root for that equation is nothing, but your mu ok and then now you understand that mu has you know the infinite number of solution ok.

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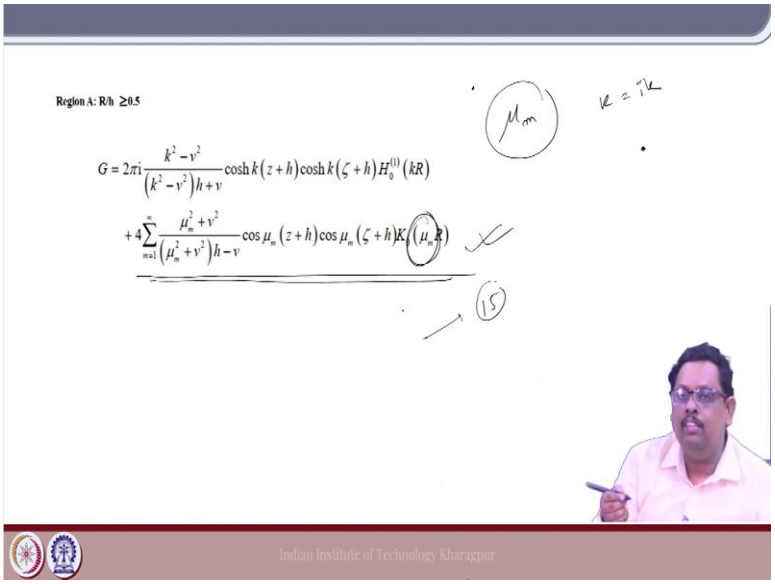

Now, here you can see that is the idea now what you can do is what we do basically we separate this integrand integration zone into several I mean several zone based on the ratio between this R/h. So, this is nothing, but the this ratio between R is basically what is the projective distance divided by the water depth based on that we actually write several solution ok and these are all available for last 30 years these all are available.

Now if this (R/h) > 0.5 ok. So, it means that when the source point and the sink point is really really have a very large distance right. So, and then if you h is the finite depth. So, h may not be that large. So, in that situation you can have this one right.

Now, here you can as I said you can solve this by infinite series. Now you can see in this infinite series you have this μ_m . Now you realize that why I discussed so, many in so, many things about this root of this dispersion relation.

So, now, you understand that you require those evaluation mode those solution of this dispersion relation and changing this k with ik right you then you have this infinite number of solutions and these are the root of those solutions you have to use this root to get the value for the g. So, this is the region 1.

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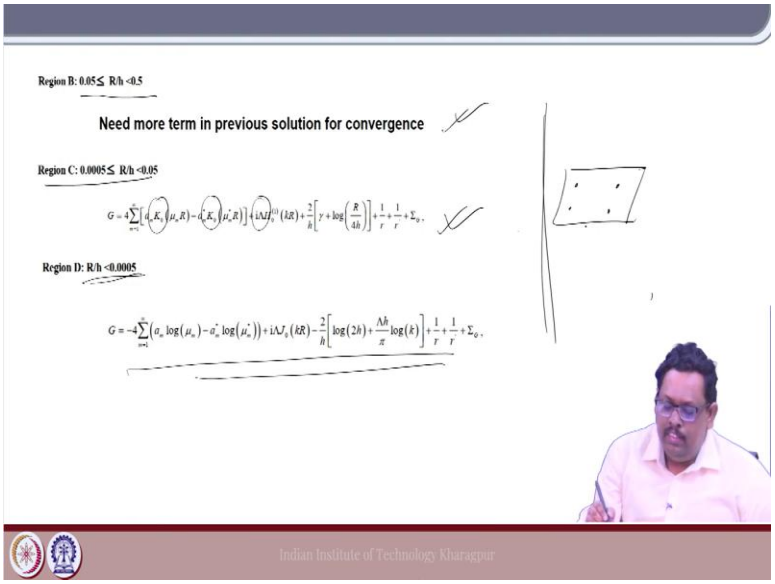

Now in the region 2 now I just very briefly I just write all these, all other region. So, in region 2 here it converges very quick if 0 point I mean this R/ h < 0.5, but in this region when this 0.05 < R/h < 0.5 so; that means, one is little bit closer; that means, that source point and the field point it is little bit closer right.

So, in that situation you need more number of terms for example, if you need to take here let us take let us say some 10 15 terms to get the convergence solution may be in this situation you need to take some 30 40 term to get the convergence solution right. Now if it is really close right then we are going to use some another type of series and here you can see there is a, there is a another type of Bessel function also comes into picture right.

And also if it is very very close then also you have some another type of series function. So, we have to use this sort of series to get the solution for the free surface Green's function ok. So, I think this is enough for now because this is not the idea about that how to write a numerical code for such complex thing we are ok with having some basic idea basic coding rule, basic coding structure ok we are working with this. So, this requires some more effort maybe later on we can go through some literature and we can find out how to get the solution for this one ok.

And always if you do not use all these things, you can simply use the direct numerical integration technique ok I mean that plain gauss quadrature will you have this panel. So, you take this gauss point and then you are using directly this function and you can do the

integration ok. So, this is the end now nowadays you have the MAT LAB we have the python in this MATLAB python actually integration of such free surface Green's function is really not that difficult ok.

So, you can use this these values directly into your MATLAB solver and you can get the value for the g ok. So, now, let us stop on this particular discussion now in this next phase let us try to see that how actually we can use a software and how I get the result using some commercially available software which is now we are discussing about one popular software is WAMIT ok.

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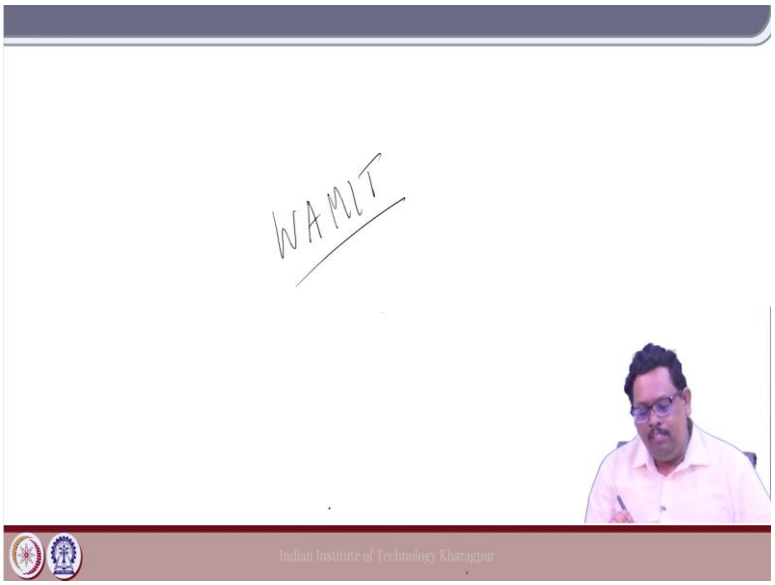

So, now let us see that how to use this WAMIT to get the motion of the body.

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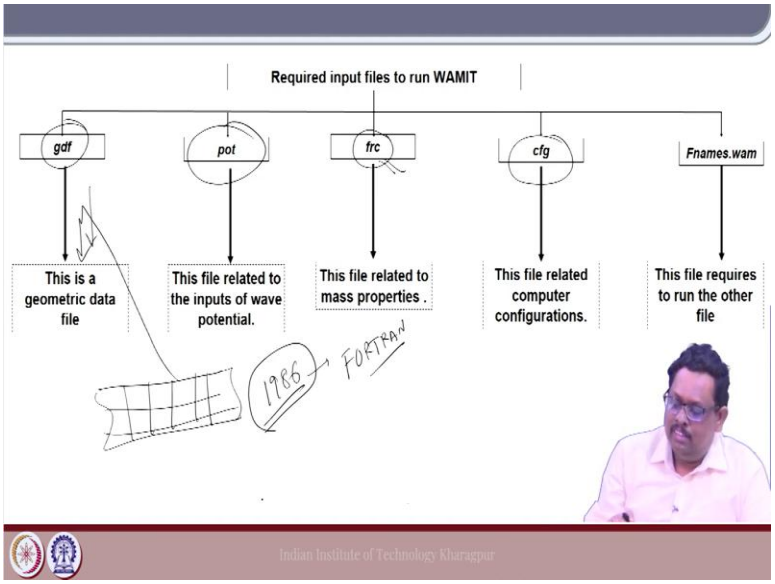

So, now, first actually to run any software you need two things like how to input and then how to understand the output. So, now, if you see the WAMIT it has there are some five file you have to deal with now first one is the geometry file. Now this is something is the panelling. So, it is nothing, but you have a geometry and then this file only take the machine. So, this file is for the machine purpose.

Now, if you have Rhinoceros software, then you can directly get the gdf file otherwise you have to make this gdf file manually. So, how to make this gdf file manually we are going to show you. Next one is called the pot file or we can say the potential file in this potential file we need to input all these wave parameters ok and then you have this frc file frc stands for the Force File ok. So, in this frc file we have to input all this parameter that is used to solve the equation of motion; that means, you need to put that radius of gyration the mass matrix etcetera.

And then also this cfg file that configure your CPU RAM etcetera ok and finally, now we have to understand that when this WAMIT is started in 1980 I think late 80 may be 1986 onwards that time people used to use the FORTRAN. So, in this FORTRAN they do not have that kind of fancy thing right nowadays that is available in your MATLAB not MATLAB sorry in any cfd based software like (Refer Time: 15:19) and other thing like you have a mouse you click you open the file you go to the file and you run it.

So, those things actually is not available in WAMIT. What actually here they require is they want a folder like they want a path where you keeping all these files. So, that is actually in a that Fnames dot wam file. Now you know if you are doing little bit of coding using FORTRAN or if you are experienced coding in c sharp or you are doing some console application if you do something called the console application if you do that then actually you have some file called exe folder right.

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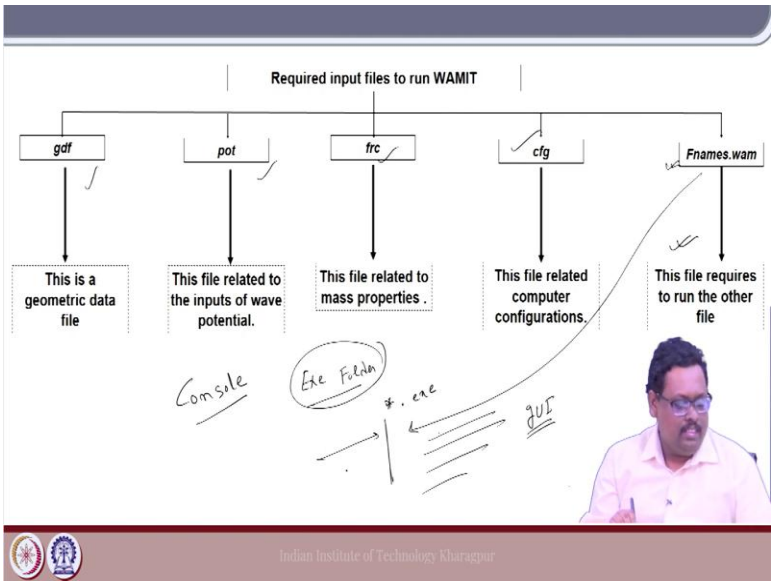

In this exe folder you have that compilation file and it is basically named as some start dot exe kind of thing is. Now in this folder when you click this code to run. So, first actually it go to this location where this exe folder is there and he reads everything inside this exe folder ok. So, now, here if you use so, if you put this file this Fname in this exe folder. So, under this folder he will know that what is the path of these files and what is the name of these files right.

Nowadays you know what actually what we are doing using this you know user that gUI like Graphical User Input right we use this graphical user input we call gUI. So, using gUI what we do? We actually specify the location of all these files right, but in that time it is not available. So, what is happening? This all the thing they kept into the exe folder right. So, this is very important if you do not put this then your WAMIT do not run ok.

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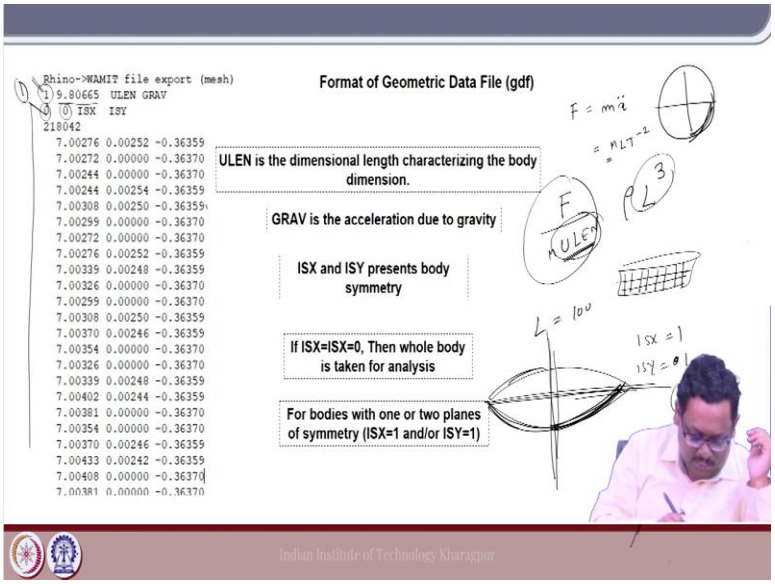

So, now let us see that how this all the file looks like. Now suppose you do not have the rhinoceros and you need to create the gdf file dot gdf then how you can create it? You can use a note pad to do that now what you need to do is that you need to remember this is the format of the gdf file. So, first thing is nothing, but that you know ULEN because WAMIT give all the result in non dimensional form ok.

So, therefore, some let us you know that as you know that the force is nothing, but the mass into acceleration. So, it is MLT^{-2} in this is it. So, then in order to get the force you need to divide it some mass into acceleration form right. So, when you non dimensionalize this force then at that time we are going to use this ULEN basically right.

Now, you see that this mass is nothing, but the dimension of L^3 right is the and multiply of course, multiply by the ρ right. So, therefore, normally if you look at the output all the forces that WAMIT provides in a non-dimensional form. So, that time we required this ULEN because normally they divided with the L^3 for the force I mean that like and the moment L^5 something like this.

So, here normally you know we can take it one sometimes people use the length of the Bessel. So, they take like 100 the length of the ship. So, then put ULEN equal to 100 its up to you second one is nothing, but the gravitation the g acceleration due to gravity ok and then this term is actually it is the geometric symmetricity.

Now, if your ship normally that is what is happening it has pore starboard symmetry right and suppose sometimes if your ship is symmetric in all directions for example, your ship is like this. So, this is symmetric about this axis, it is symmetric about that axis. So, if it is so, we put both are 1, but if it is not symmetric then we are going to put at 0. So, when I put it is 0 it means that I am not using any symmetricity property of the input file ok.

So, in that case what we need to do is if you put 0, 0 then you need to mesh the whole ship you cannot mesh the half ship ok. So, because we are not using the symmetricity right. So, 0 means, we are not using any symmetricity. So, we need to give the mesh of the whole body; however, if you use the symmetricity then you can use the one and you can use like you can put the half let us say if it is about this and not this.

So, this about this at axis you can put 1 and then other value you can put this value is 1 and you can keep the other value as 0 and if it is symmetric in all the end, then you only need to give the one-fourth of the geometry and then you can define both as 1. So, if you use the one symmetry then use one $I_{SX} = 1$ and then $I_{SY} = 0$ or otherwise and if you use the one for example, you try to find the hemisphere. So, is a circle is a complete symmetry all everywhere. So, you can just take one-fourth of the circle and then you can use both symmetricity 1 and 1.

So, this is the idea about the file and one more important thing like this is not the end you have to know how to give this value if you are getting it from rhinoceros fine otherwise how to give this. Here you can if you look at carefully this first four thing this first four actually define the first panel.

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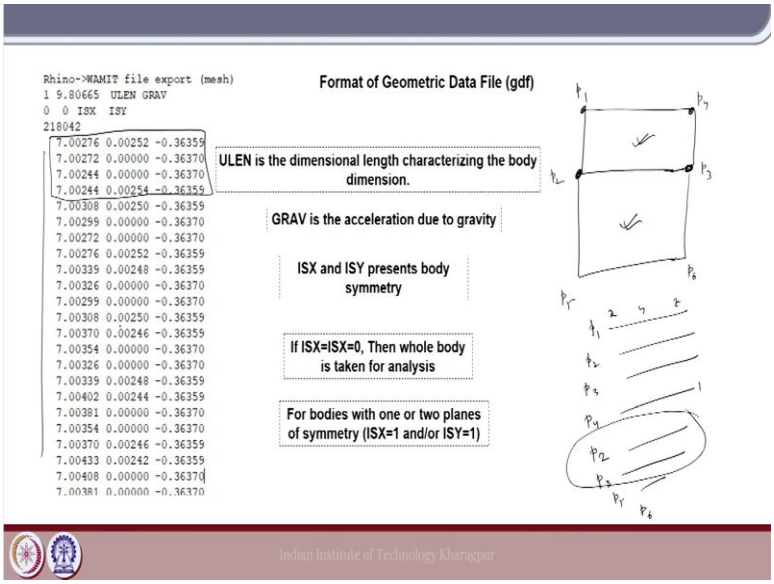

So, now if it is a quadrilateral panel. So, in that case we have to use the four corner. So, that is how you have to give the input. Now you can ask me then what is going to happen like if this is another panel. So, this is coming twice it is defined for this panel and the same point defined for this same panel also right. So, you have to mention in that case two times. So, let us make it point p_1, let us take p_2 it is p_3 and p_4 let us say it is p_5 and p_6 then your input file should be first the value for p_1 the first row.

So, p_1 x y z, then it is p_2 x y z then p_3 x y z and then p_4 x y z and again you have to say for the second panel p_2 x y z ok and then p_3 x y z and so, on right and then it is p_5 and then it is p_6. So, this is so; that means, that you need to repeat it is that many times it is coming that many times you have to repeat the whole thing that is how you need to create your gdf file ok.

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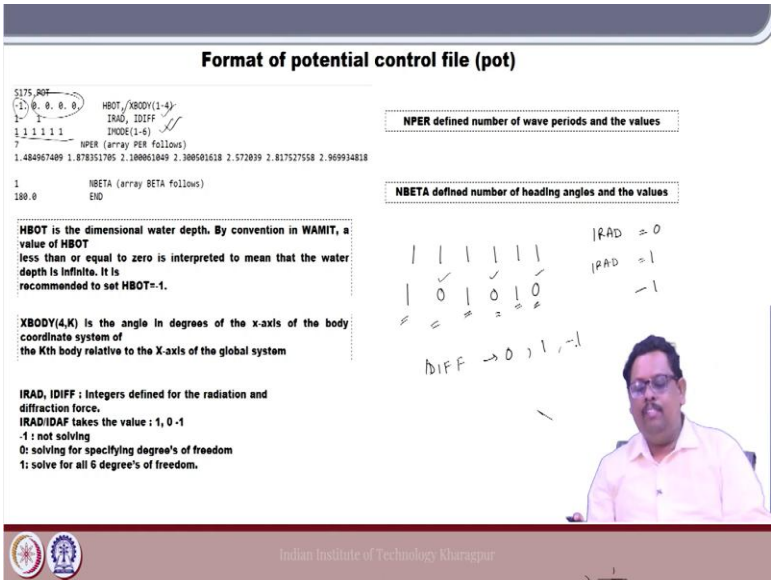

So, now this is the potential file if you look at it. So, it is the name of the potential file and here it is you have the. So, now, how we can write the pot file? Now you can see here I have HBOT and XBODY 1 to 4. Now the first define the water depth.

So, now, it is it is given just a dummy value it is given minus 1 and x body is nothing, but the angle of the body I mean if it has a trim or hill initial trim and hill then we need to mention this all these four values. So, normally we do not do that. So, we just keep it as 0 and then this IRAD and then IDIFF is basically it is asking for your radiational and diffraction potentials.

Sometimes suppose actually in that case actually I am making all the modes on let us see the IMODE. IMODE is nothing, but that the mode of motion. So, the first one for the surge, the second one is for the sway, third one for he then roll pitch and here. So, I am making everything on here just dummy case.

Now, sometimes I can make only let us say this way. So, I am doing that surge, then heap and pitch I just interest upon this 3 and then if I make this IRAD this equal to 0, then it only calculate this 3 mode and does not calculate these 3 mode and if I make IRAD equal to 1. So, even if I do not need these 3 mode, but still it can calculate the radiation diffraction force in all six modes.

And if I make it minus 1 they do not consider there is a radiation similarly for this diffraction force also. If I make I mean this term this IDIFF I diffraction if I make this equal to 0, then it can only consider this 1 3 and 5 mode. This 3 diffraction mode and if you make this equals to 1 then though I do not want the in second fourth and sixth mode still it will calculate all six mode right and if I make it minus 1 then it assume that there is no diffraction ok. So, this is the format of the pot file and this is the format of the frc file.

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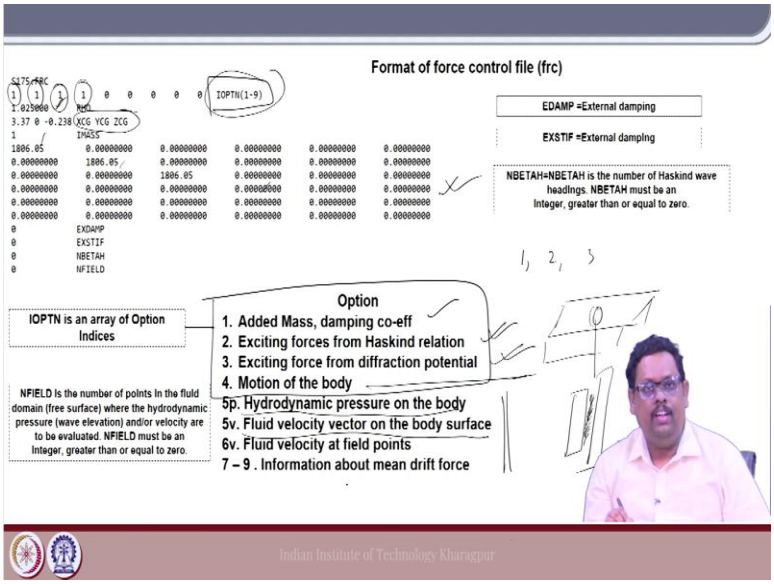

Now it is actually you can see that one important thing is basically here this IIOPTN this I option file you can see is called the option file ok and this is the you know this is the row you can define over here and you have to finding out that the location the CG location of the body and this is the mass matrix right. Here I can see I can only consider this linear I mean this 1 2 3 only that angular moment I just make it 0 side I am not interested right here I just interest as I say 1, 2 and 3 in that way.

So, I just give the mass matrix its a dummy file if you want you can give the other values also here you can take ix ixx and I zz value of cc input. Now the interesting thing is the options file. So, what is the option that it is actually used for your output what output you actually want from the WAMIT? Now if you want the added mass and damping. So, I just I want it. So, I make it 1. If I want the exciting force from the Haskind relation I make the option 1.

If I know one from the you know this panel method code diffraction potential exciting force from diffraction potential I make this option 3 1 and if I know this motion also.

So, normally we want this four only right I am interested on to get the added mass I am interested to get the exciting force I am interested to get the motion of the body; however, for the detailed analysis sometimes it is important there are different altogether there are you know what I said that scenario like when you look at the second order forces sometimes we are interested sometimes actually suppose I have a body with a moon pool let us say.

So, at that time actually I am interested to finding out that what is the pressure field around the body. So, sometimes let us say there are two body side by side. So, if you want to find out what is that in between fluid what is the resonating situation. So, at that time you need the hydraulic pressure on the body, you want to know the hydraulic pressure on the surface all.

So, those are the special situation when you need all this information also otherwise normally, we are going to use this four standard thing right.

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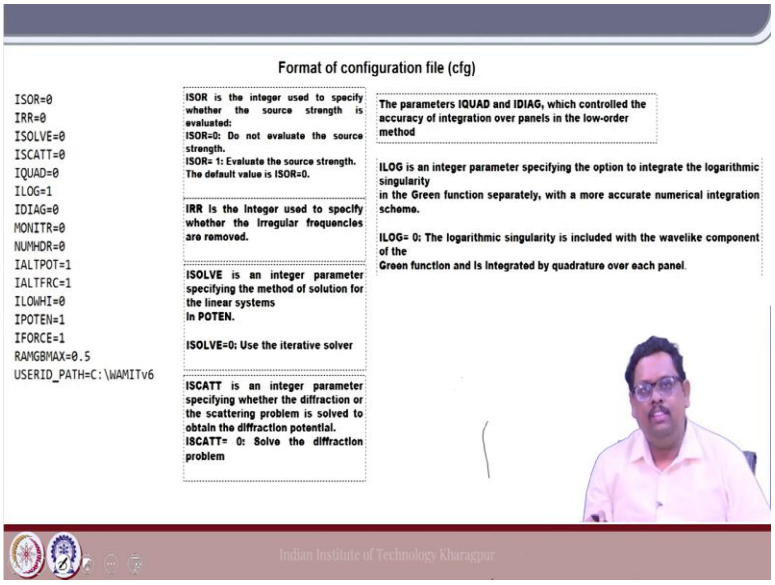

So, this is about this frc file and this is how we configure the computer ok. So, so just you can follow the WAMIT manual it is written over here how to set your RAM, how to set your all other things. So, this is over here you can control that to the this cfg file.

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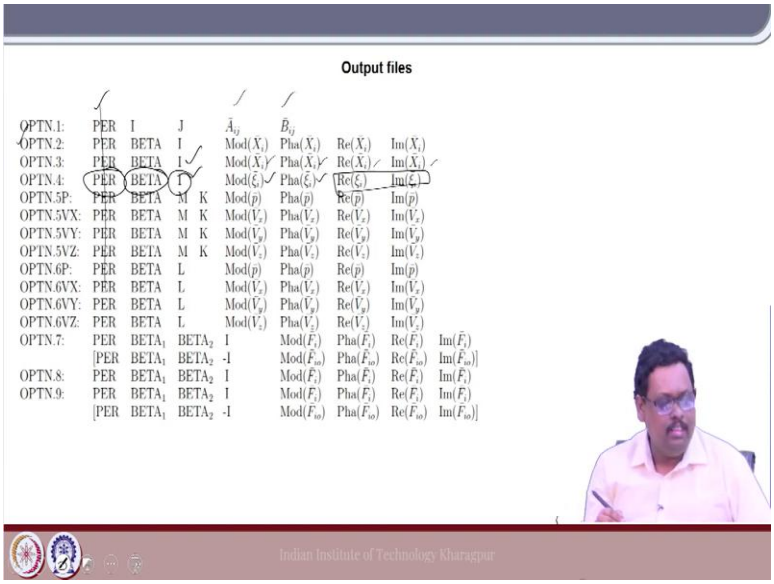

Now, finally, let us see that how I can get the output file.

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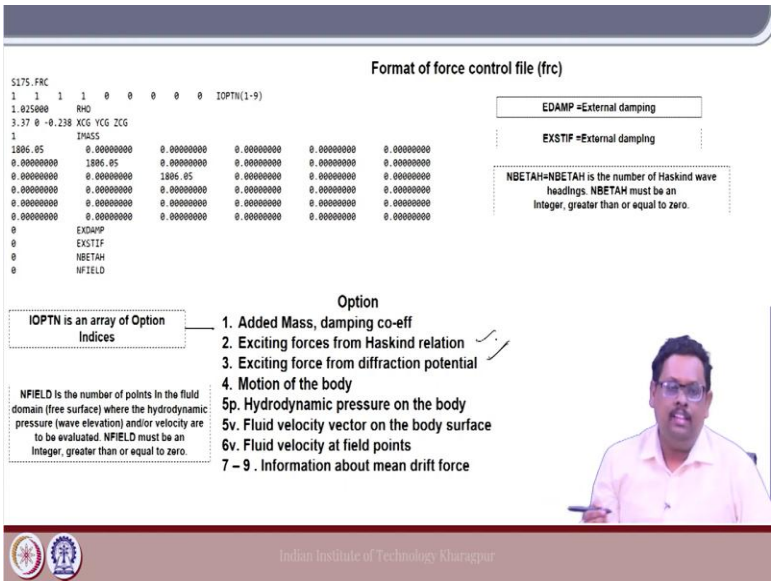

If you remember that here I talked about the option file. Now here if you click option 1 now then this is how actually you can get your this. So, you can get your add inverse and damping. Now you see like the first you know this file should be written in this way the first one is period then the modes and then the term A_{ij} and B_{ij} in that way.

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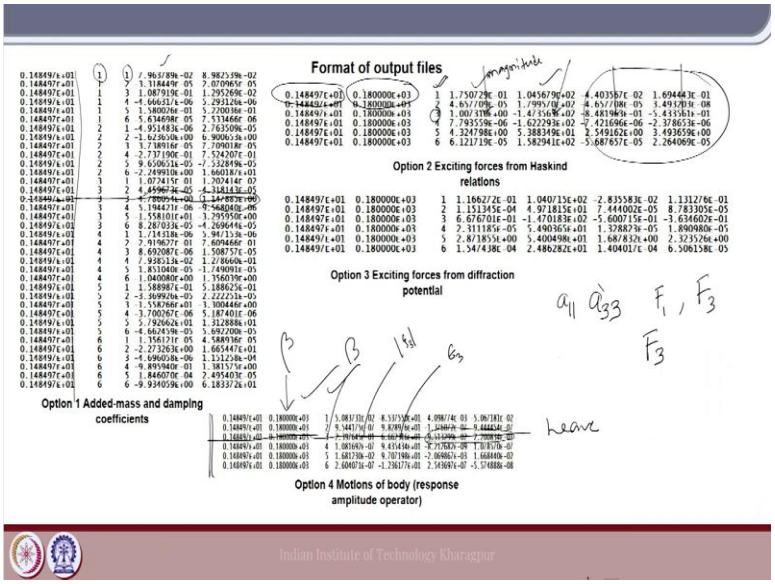

Now, let us see that this is basically your added mass file now if you look at here these are the time periods. So, these are the time periods right now the second one is the mode so; that means, this is the added mass for a 11. So, mode 1, mode 1 for example, now this one if I just mark this values this one is the added mass for 33. So, this is the added mass for 3 and this is the damping coefficient right.

So, this is how actually I can read the option 1 file if you make it on then you get this result. Now let us see that if you want the option 2 then what you get? Now if you just look at here the option 2 is the exciting force option 2 and 3 both are the exciting force one is from Haskind relation one for the diffraction both are almost the same.

Now, here how it actually it can see now it is I is nothing, but the mode that I am interested in, then the next column is the modulus of the amplitude and next the phase and then the real part and the imaginary part. Now if you look at this format now you see here this is the time right and then the next one is the heading angle the beta now you can see the heading angle is 180 degree.

Now, here it is the mode so; that means, I am talking about the exciting force F_1. Now if I look at here it is the exciting force for F_3 ok F_3. Now the first one is nothing, but the modulus of the force this is the magnitude. Now this one is the phase and this is the real part and this is the imaginary part. So, actually you really do not need the last two right.

Now, from this last can you can verify whether this one is correct or not from the imaginary real part if you take this square root of I mean a^2+b^2 then you get this the magnitude and if you take $\tan^{-1}$ (b/a) you can get the phase ok now this is the motion.

Now if you look at that how this the motion gives here option four similarly first is the period, then the heading angle, then the mode you are interested and again the magnitude and the phase and also since its a you find out in the complex potential normally you get the complex number. So, it will give you the real and imaginary part.

You see here now this is the mode 3, I am just striking this - this is the mode 3. So, this is the for the heap right. So, first one is the frequency time period, second one is the heading angle. So, it is β and this is the mode now I choosing the mode 3 and this is the magnitude.

So, $|\xi_3|$ and this one is the phase. So, it is ε_3 and this one actually you do not need is the real and imaginary part ok. So, you can see. So, now, in WAMIT you can see that you can have all kind of information you can have the added mass damping value, you can have the diffraction force, you can have the exciting force also you can have the motions right.

So, this is how actually you can get the put the input to the WAMIT and also you get the output from the WAMIT. Now you know that how important this is because based on that actually we are going to have the solution for the impulse response function based method that we are going to discuss from the next class ok.

Thank you.