Numerical Ship and Offshore Hydrodynamics
Prof. Ranadev Datta
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture - 04
Seakeeping - 3

Welcome to the Numerical Ship and Offshore Hydrodynamics in this lecture 4.

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Now, in this lecture we are going to continue from our previous lecture like some concept of the basic hydrostatics still we are going to discuss along with that we are going to discuss the how I calculate the numerical, numerically the restoring coefficient which is we have three restoring coefficients that we need to calculate.

And also we are going to discuss the brief outline that how are how we are going to solve the equation of motion like you know what whatever we do the finally, our main aim to calculate the, under the waves how I mean what is the displacement of the vessel right.

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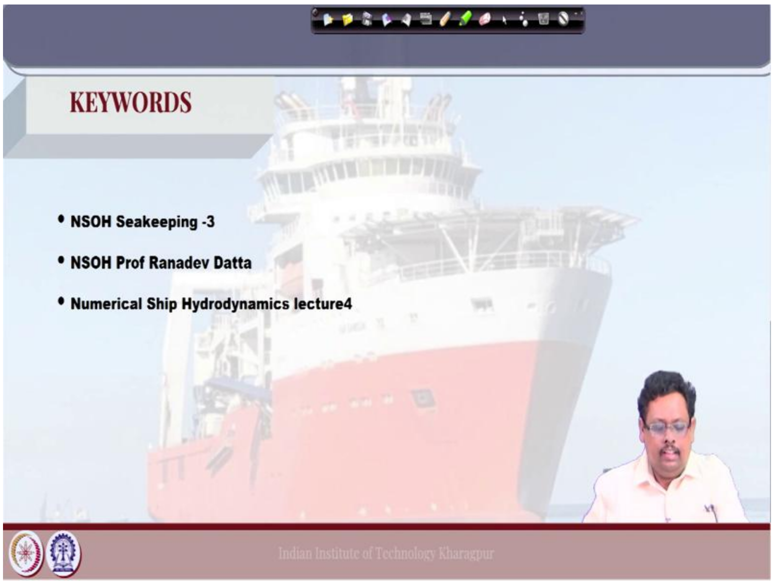

So, at the end we are going to solve the equation of motion only right. So, how we do that that we are going to discuss at the end. And this is the keyword that you are you can use to find out this lecture.

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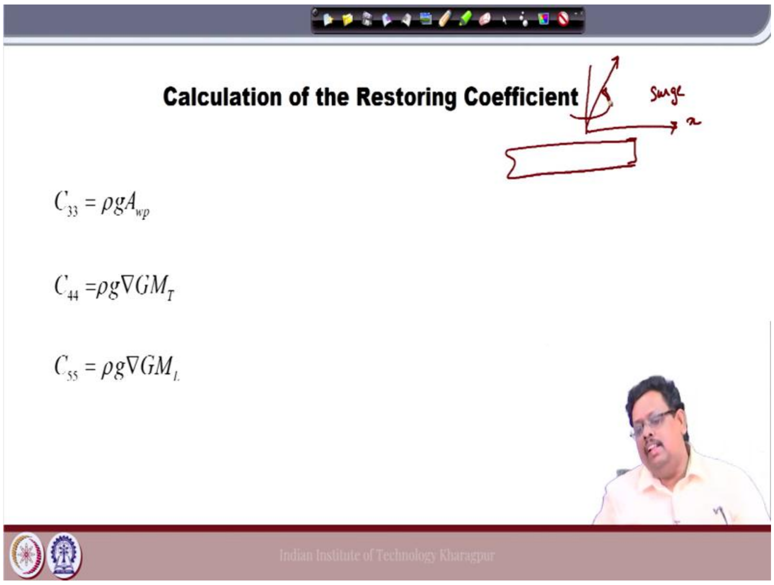

So, now we have actually need to calculate the three different restoring coefficient C_{33}, C_{44} and C_{55}. Now, yet not discussed about the use of this j and k. So, let us you can ignore here also, but physically try to understand what is the C_{33} means, so, what is the C_{44} means and what is the C_{55} means.

Now, if you look at the 6 modes of motion which is surge which is along the horizontal axis, right? we have the surge which is now let us draw the ship just for clarity. Now if you consider the surge which is along the horizontal axis, the x direction. Now this motion or the surge you know it is, it does not experience any kind of restoration right? because there is nothing to pull him back, nothing.

Similarly, if it moves along the direction of y, slowly, slowly drifting along this axis so, there is nothing no force which is actually pull him back, eventually if you rotate along this you know vertical you know about the z axis; that means, you just rotate like this way. So, really you know there is nothing to stop the ship, right.

So, now, you understand that out of this 6 modes of motion there are 3 modes of motion where there is no restoration. However, if you consider that ship is actually heaving; that means, it is going downwards then there is of course, there is a buoyancy force that is actually pulls him up, right? So, it experiences kind of forces.

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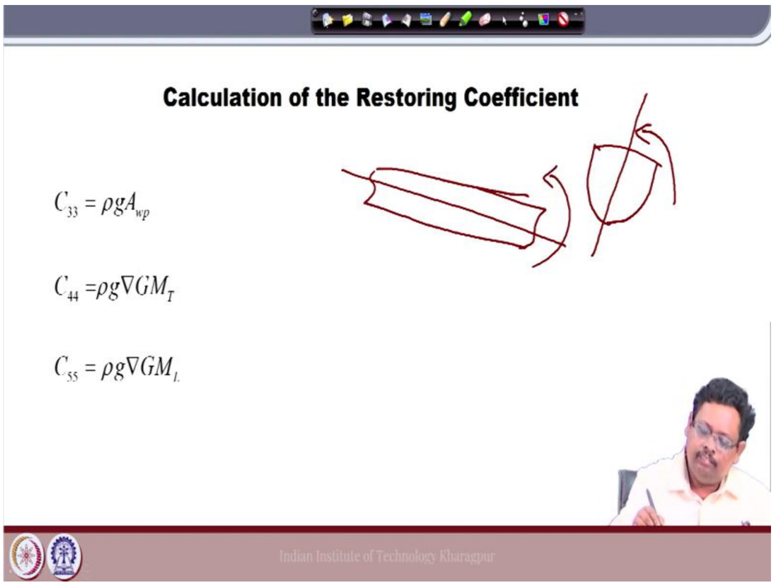

Now even in case of a roll, now if the ship again if the ship rolls like it is rolls let us say, let us draw a mid ship section somehow and it actually it rolls. So, then they experience that a moment that pulls him back and also if we consider this in direction of, very badly anyways. Here also so again it experiences a moment. So, therefore, I understand that there are at least 3 modes of motion where we can have a restoration. Now, in case of a heave we are using C_{33} and this is the nomenclature and in case of a roll we use the C_{44} and in case of a pitch we are going to use the C_{55}. okay?

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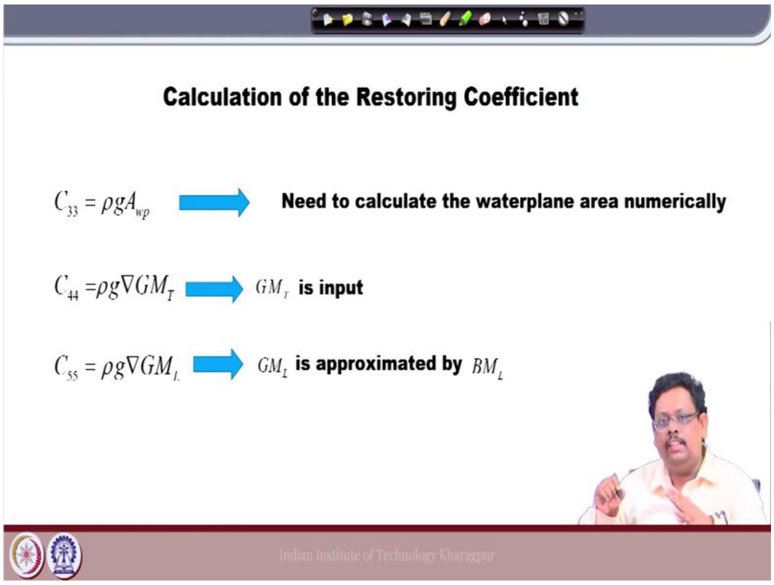

So, now in C_{33} now ρ is a constant, g is constant. So, only thing we need to do is how we are going to calculate the water plane area right. Now, in case of a C_{44} you can see that, now ρ g is you know that how to calculate I mean here is a ∇, ∇ is displacement right. Remember this is a typical ship nomenclature or the notation we use this for the volume, ok. So, then here everything is you know known to me and also the GM_T is basically the input.

So, we have nothing to do with that. I mean we cannot geometrically calculate the GM_T that is what I mean. Now in case of a you know C_{55} also, now, now it is again that first three term actually you know and then GM_L also can be a input, but; however, the GM_L can be approximated by BM_L and this BM_L you can calculate numerically ok. But now we have to understand, but this is all the hydrostatic things and definitely, we more detail will be there, but here again we are discussing it because for the sake of completeness, Ok, fine, fair enough.

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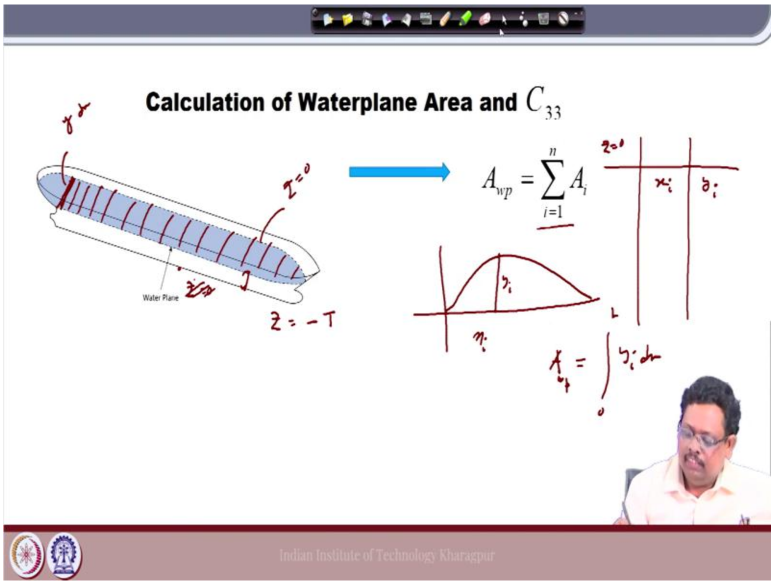

Now, how we are going to calculate the C_{33}, now you know that it is that ρ g into water plane area. Now, here I have a nice picture and you can see that, that what is the what is actually the water plane area, right? So, as I discussed last class like it if you take a if you take a small strip along this axis right, if you take a small strip here and this is basically your y right?

So, therefore, you know and if you multiply by the dx so, you can get the area right. Now then you just this area if you successively add for each section right, then actually you can get the water plane area right. Now from the offset table how you get it, now offset table also very easy, because in offset table because here it is you remember that this is basically the design waterline we can call this as z = 0. Remember that when you calculate hydrostatic normally the, this last point here this point is noted I mean this point is denoted by z = 0 right.

But in case of hydrodynamics that what we are doing here we define this z = - T where the T is the basically the vertical distance from the water line to the kill point, kill point is means the bottom most point. So, we define this as 0 to - T right. So, there is a some something that actually you have to understand like if you are using some software like WAMIT you have to use this convention.

However, there are many software's like even they are using that this orientation that a normally that whatever understood from the hydrostatic they define the z = 0 and this =

+T ok. And then they change everything internally. But anyways remember that here the z is fixed, you call it z = 0, you call it z = T, does not matter, idea is this is the top most point above there is nothing but the air. So, you take this point and then you calculate so at so now, in this table now I know that the vertical z = 0 let us take z = 0 and then we have a table for you know x and y.

So that means, each x location x_i location we have the y_i right, then if you plot it then you can have a graph. So, this graph might be look like this I mean let us say and then this basically at some point x_i, this is y_i. So, therefore, if you integrate it along this axis so, let us say 0 to L then y_i dx that is your that can be given that would be your water plane area or A_{wp} right.

So, this is how actually we are going to get my water plane area, fine ok.

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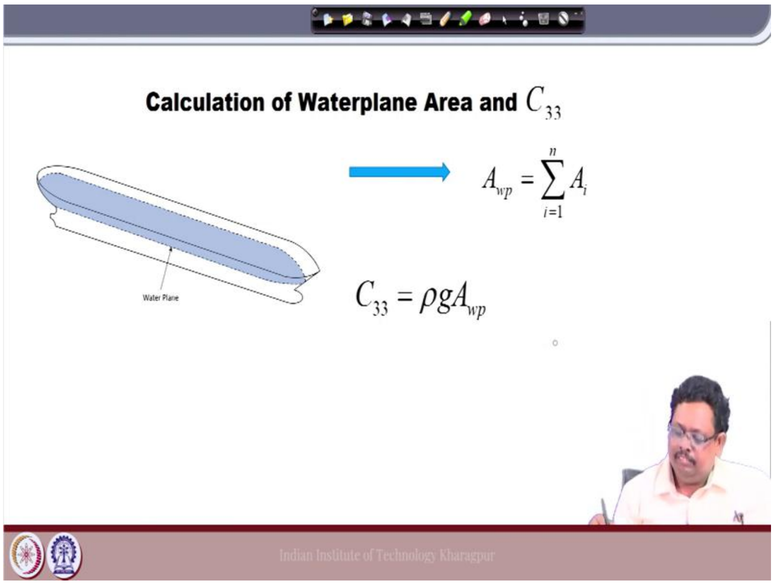

And then of course, once we get the water plane area, your restoring coefficient is pretty easy it is C_{33} nothing but $\rho \times g \times A_{wp}$ fine ok.

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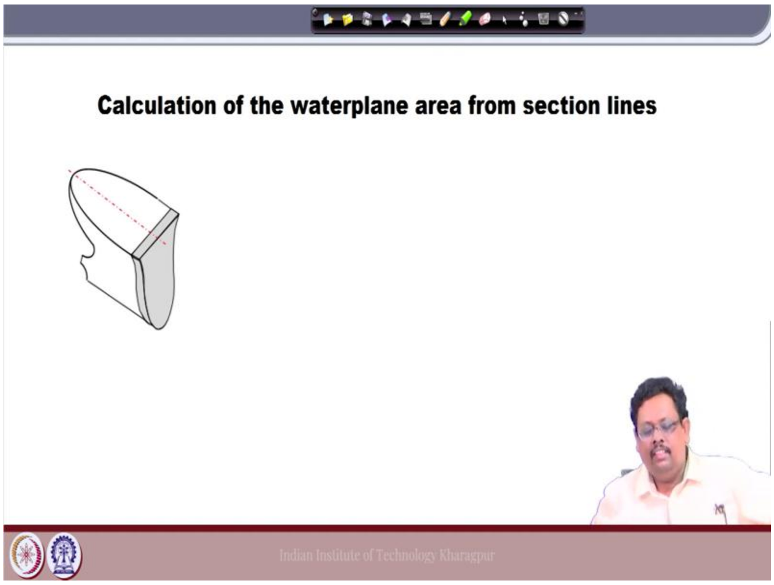

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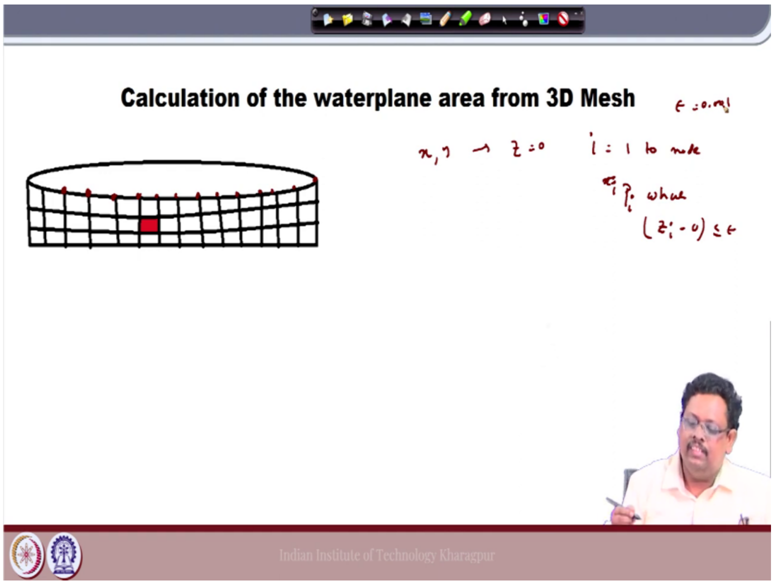

Now, ok that is what we had discussed. So, let us go to the next. So, how we calculate the water-plane area from the three dimensional mesh right. Now, again as I said it is very interesting right now we have to calculate the water plane area with respect to the three dimensional mesh. So, now, the section lines or offset table is not given to you.

So, you do not have the data, you know you do not have the data for these points right? Of-course, you have the data, but you need to do lot of calculation lot of ifs and but right? That also you can, we can do of course, like from the mesh you try to find out the z that x coordinate and y coordinate where z = 0.

So, you can write a computer program with list of now this is called the nodes. So, we can run like just numerically I am just say come just let us say i is equal to 1 to number of node and then you can make a check that, that x_i I mean or you can say the point p_i where t you know z_i-0 you know less than epsilon you can check the take the fellow ε=0.001.

You can do that, but this is not the way people the smart people will do, we have better methods of course, we are going to discuss this. Well, now suppose you have this mesh with you. Now, what you need to do is now let us say this is the red thing that your select this mesh here right.

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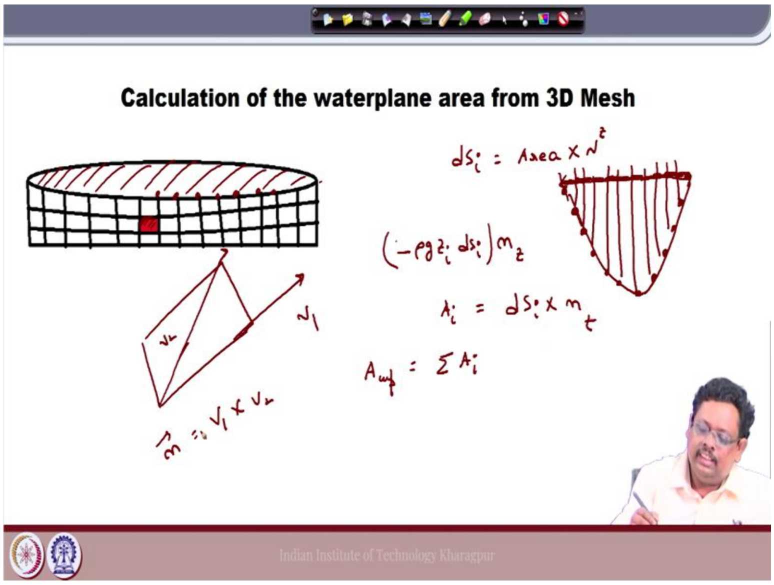

So, then what you can do is so, you can find out the area. Let us say ds i basically the area. Ok, right and if you remember that this area, if you multiply, I mean by the normal n_z. So, essentially what you are going to do basically you are taking the projection along this plane right.

Now, you see what is actually happening if I show you in 2D it will be very clear to you; now suppose this is your section line ok let us do it for 2D. So, what is your interest basically your interest is find out this length and but you have the information or nodal information of this line ok, you have the nodal information of this particular line. Now what you are doing is you take a length and you project in this vertical plane.

So, what you get? See if you take a vertical plane, you are getting this much of length. Again if you take these two point and you take a vertical projection then you get this much of point length. Now, again if you take these three point and if you take a vertical projection you get this you keep repeating it taking the projection in vertical plane you multiply this length multiply by the normal to the z direction.

So, you get it, you get it, you get it, you get it, you get it. So, I miss the first one if you do this what we get. So, we can say that just doing it. So, what essentially that since already you have mesh right you have the area and you also know what is the normal of this I mean the all different sort of normal.

So, why to waste time to calculate all the points actually, which is lying on the z equal to 0 with some very you know badly written you know not badly very, very nicely written also, but it will again computationally expensive and we really do not want, suppose normally if you do the meshing in let us say, I mean it let us say you can have some thousands of nodes.

So, now, in thousands of nodes you are going to find out like there is some 10 or a 100 of nodes which have this which occupying this in the free surface here, z = 0. And then from that you will going to do it is not very smart way of doing it; however, this one is much straight forward right?

Because you have all the data, when you calculate the hydrostatic force what did you do at the hydrostatic force, you are calculating the - ρ z into the centroid $z_i \times ds_i$ and then you take the projection n_z right, but now what you need to do is you have the ds_i and you take the projection. So, that will give you some piece of the water plane area.

So, therefore, now if you add this A_i then you get your water plane area right? Now you know that how to find out the normal vector right? Now again just repeating I know that you all know all these things. So, I have this thing. So, you have defined the vector, let us say V_1 and just take this another vector V_2 and then if you make $V_1 \times V_2$ then definitely you are going to give the normal vector right.

So, just you get the normal vector multiply by the z component of this vector you will get the water plane area right. So, this is how actually we can get the water plane area if the mesh is given to you right? Okay?

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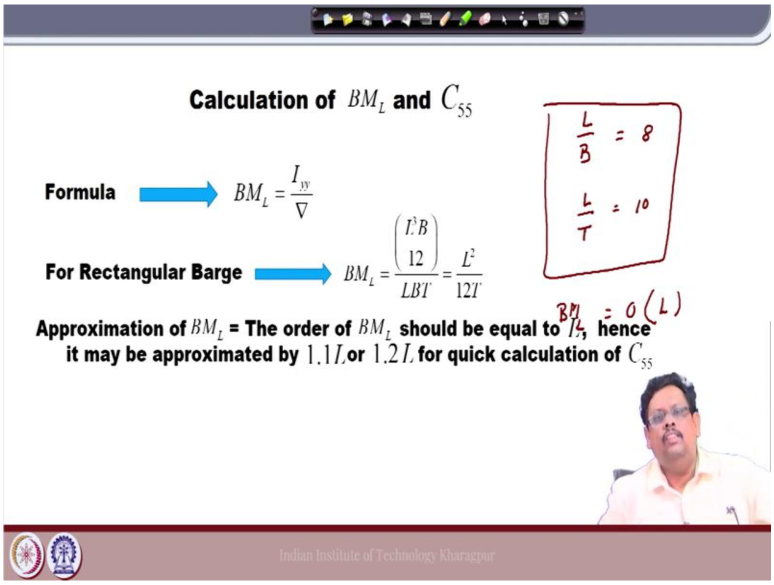

Now, let us coming back to that calculation of the C_{55}, I am I am not going to discuss C_{44} because you know the GM_T is always you know is a input unless you have this I get the GM_T, we can approximate by some numbers of course, but normally it is the input. Okay. Now, let us find out that how I calculate the C_{55}, now formula for calculation of the C_{55}, BM_L it is given $\frac{I_{yy}}{\nabla}$.

So, you know that I_{yy} how to calculate, I_{yy} for a different thing. So, I am not going to discuss about this. So, this is the straight forward formula that are going to use and then the moment you get this you know actually I have for simplified case let us take a you know rectangular barge.

So, this I_{yy} you know that it is known for you it is LB cube by 12 everybody knows it. So, that gives you the idea of BM_L is basically L square by 12T. Now why I am using writing this, there is a purpose. So, the main purpose basically to give you some kind of rough approximation or estimation that what would be the range of the BM_L.

Now normally now this sort of you know idea is very essential for an engineer, like for example, like what should be the ratio between the length of the vessel to draft of the vessel or the beam of the vessel right. Normally, we can I mean there is a there is a vary, but like L/B, you can, you can, you can make it like 6 or 8 or something like this or L/T is approximate by 10 or something like this, like you know this is the thumbnail like that you can use it ok.

Now, actually having said this if you use, if you take this ok, then if you see this $\frac{L^2}{12T}$ term then you can, you can understand very well that, that BM_L, BM_L is kind of order of the length because L by T you can replace by you know 10 right. So, or 12 or something like this so, then you can understand that the range of BM_L is, is very close to the L, right? So, this is the, this is our take basically like. So, we can say that, that approximation of the BM_L that we can make like we are not going to let us say we are not even do the calculation to calculate the BM_L. We do not do that ok. So, but we need some values ok to get the restoring force C_{55}, we need a very quick calculations somehow we sometimes we need we do not have much time. So, we have to calculate the motions we just need to put some number. So, it is essential to get some idea about the numbers right.

So, now this BM_L we can see that we can approximate it by let us say 1.1 L or 1.2 L for the, the quick calculation for C_{55} ok. So, let us see that how realistic it is ok. Remember this formula for BM_L is L square by 12 T right. So, now, let us do one thing. Let us really now try to calculate the, that how this approximation is valid or not let us try to find out.

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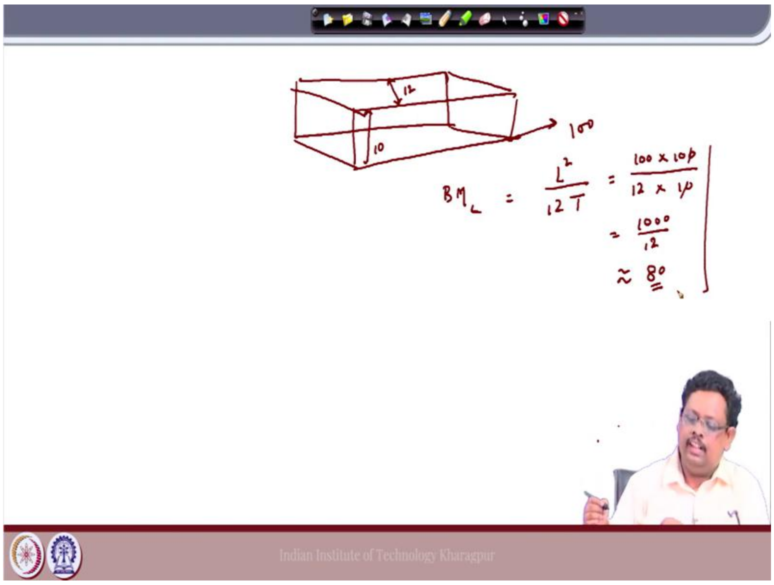

So, let us take one rectangular barge and let us take this length as it is I just take it is 100 and let us take it is, some let us take 12 and then let us take this side, it is 10 right? Now find out what is the BM_L? So, I know that it is $\frac{L^2}{12T}$ right? So, $\frac{L^2}{12T} = \frac{100 \times 100}{12 \times 10}$. Now it is around 70 or 80 something like this right.

So, we can see that the length is L. So, 100 is basically the length and then it is coming out 80 you can say there is a 20% or something like it is the deviation, but I will tell you that there is a difference between the ship thing and the microsurgery right. Here this 20% is allowed because the moment is very high and there is still some 10%

So, because if you consider the numbers it is very large. So, so, therefore, and it is not that sensitive towards these values also, very, I do not say it is not sensitive it is not too much sensitive. So, therefore, this fast and approximation actually works nicely. At least for this at least for the for calculation of this C_{55} and so on ok.

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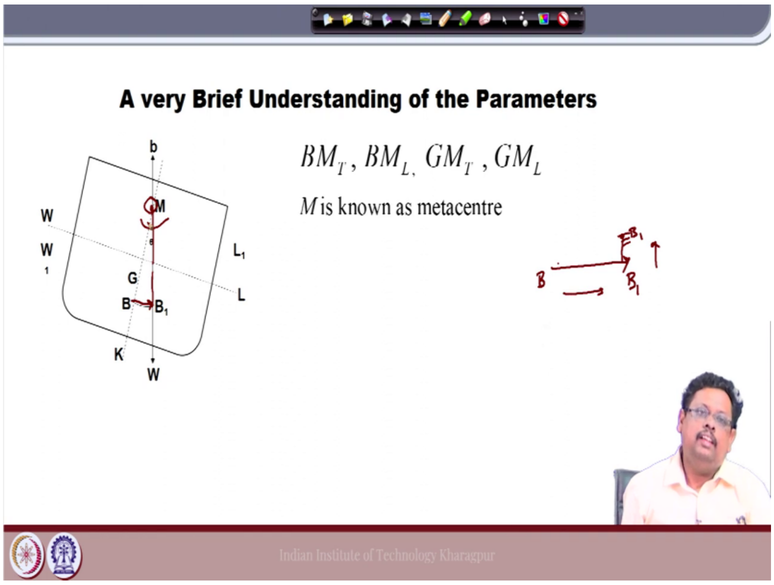

So, let us move on to our next topic okay? Before that like we talked about the BM_L, BM_T, GM_L, GM_T. So, let us try to find out what is the actually M here right, also again referring to the hydrostatics everything is given nicely over there. So, I am just sake of completeness I am giving some basic standard definition. Now, here, M is known as metacentre.

Now what is metacentre, if you look at this picture in here. So, this is the initial position of the ship was W1L1 and then it tilted right. It tilted in direction of let us say it is you know I am taking a cross section that midship section I just tilt that midship section, we are we are now talking about the GM_T and the BM_T ok, fine. So, now, I just if I tilt here, now you can see that we have new water line W-L right and also we can see that the buoyancy actually shifted from B to B1.

Now, here to calculate you know there is a something like to calculate this metacentre we have an approximation. The approximate about that that tilting this angle θ this angle θ is small and then how small? Now, when I say the how small it is, we are what I am talking about if you if you like I will tell if you tilt more than it shifts more. So, therefore, M will come down somewhere like. So, we can see that M should be the function of θ, but we say no. M is not function of θ, because this M when at the limiting point when the θ is very small that time I can calculate the metacentre. Now, let us first see how we do how we calculate M. Now, here from the B, we assume there is a assumption is that the shift of B is only in the horizontal direction.

So, if it is B then it shifts only at the, so, normally what happened it you know it shift B can be in general it, it shifts horizontally also vertically, but; however, we ignore this. Now, if I shift it horizontally and then if you draw a normal to the new water line and the point it meet at the, at the initial normal to the initial water line that point we call as a θ.

Remember that here the shifting takes place only in the horizontal direction. So, this is this is somehow you know in, in, in case of the large moment then definitely this M is function of θ, but here, but that time we do not call it metacentre, we call metacentre when the θ is small, right?

And then once we understand the, that M then definitely we understand that that what is BM which is nothing but the distance from B to M and then GM is the distance from G to M, G is the centre of gravity of the ship right? So, that means, when the mass distribution is given you know the value of G and therefore, you know the all the value of BM, GM etcetera right.

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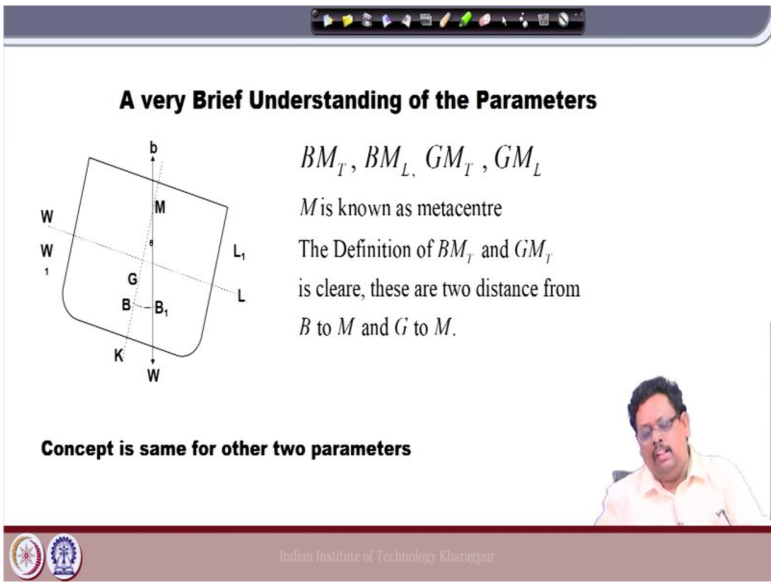

So, here similar thing actually, similar thing basically in case of a GM_L and BM_L also right? The concept is same that only thing is that instead of tilting in this location we tilting in this direction to find out that metacentre for that GM_L and BM_L ok.

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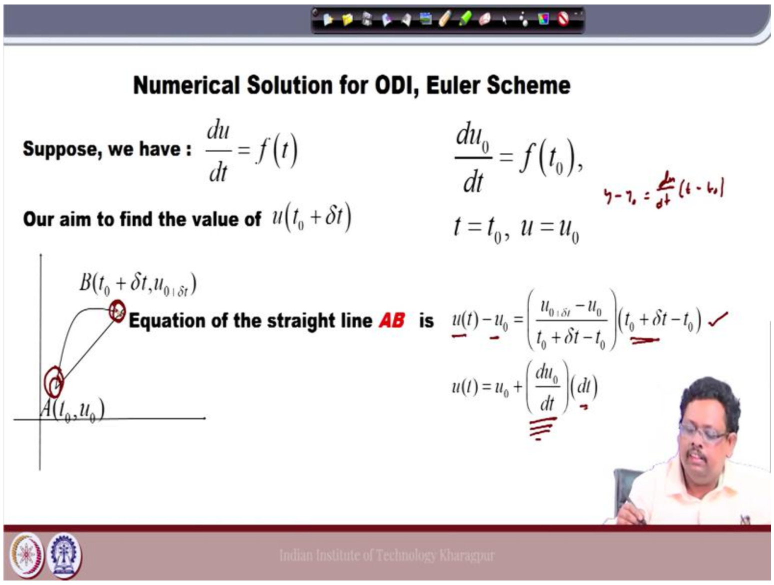

Now, let us come to the final part of it. Let us now you know that we have the equation of motion how to solve it right. Now, let us let us discuss a very easy scheme that is Euler Scheme, let us see what is this Euler Scheme. Now, we are going to solve this differential equation $\frac{du}{dt} = f(t)$ and what is given is the $\frac{du}{dt}$ at, at initial time t_0 value of $\frac{du}{dt}$ and then value of the u at the initial time right?

Now, what we are going to do here like everybody you know it is basically we are doing the straight line approximation. So, you can see from this graph it is at t_0 it is here and then at $t_0 + \delta t$ it is here right, and then we just join this as a straight line. Now you can see here I am writing that that equation of the straight line right? Which is $u(t) - u_0$.

So, we know that the equation of straight line $y - y_0 = \frac{du}{dt}$ or let us say $\frac{du}{dt} \times (t - t_0)$, I am just doing it right instead of t, I am writing $t_0 + \delta t$ that is the only thing I did right. So, it is $u(t) - u_0 = \frac{du}{dt}$ x dt because here t_0 cancelled out. Now here you know I just would like to discuss one small thing in 1 or 2 minute not.

So, this is the slope defines if your method it implicit or explicit, if you are doing $\frac{du_0}{dt}$; that means, you have to consider a slope at this point it is the explicit method where instead if you consider slope at the point B, then it is the implicit method. Then what is explicit method, what is implicit method, definitely you have several courses for this. So, I am not going to discuss elaborately I am just discussing, here as much is required by me for this particular course ok.

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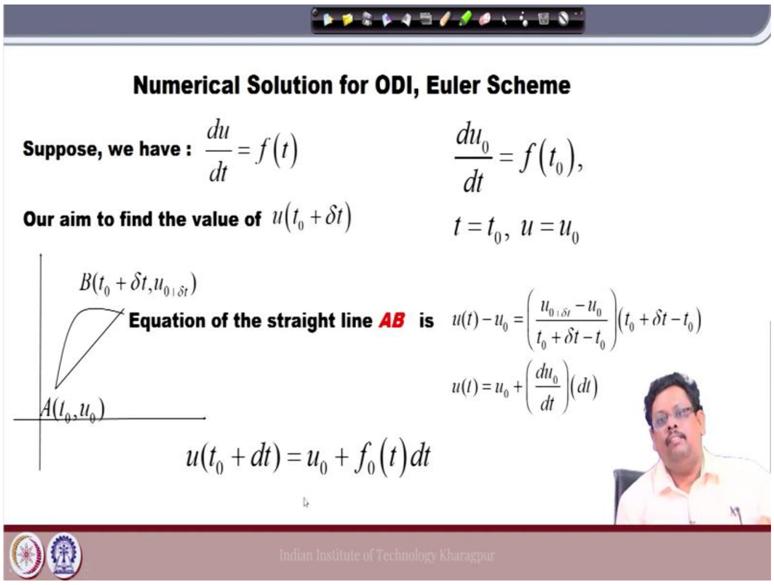

So, now here this is my final equation numerical equation. So, I try to find out the value of u in future time step dt if I know my value at the present time as well as the $\frac{du}{dt}$ at the present time. So, how I am going to use this for my particular case?

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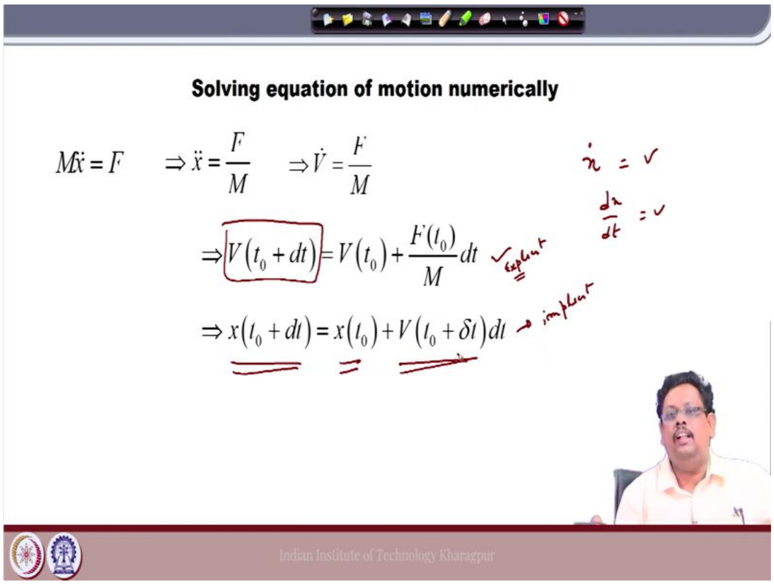

Now, here we are going to solve $M\ddot{x} = F$. So, now, I convert this into the first order equation which is $\dot{V} = \frac{F}{M}$. So, $\ddot{x}$ is nothing but the $\dot{V}$ right. Now I am using this Euler approximation scheme so, I can find out the velocity at the next time steps equal to velocity at the present time state plus the functional value.

So, the moment I get the velocity again I can use because I am going to use basically again that $\dot{x} = V$. So, that means, that $\frac{dx}{dt} = V$. So, if I use this. We can find out the displacement at the, at the next time step if I know the displacement at the present time step, also now here I can make an improvement. Since I have already found out the velocity at the next time step. So, I am using the velocity of the next time step.

Now, you see that this scheme we can called as the explicit and here we can call is implicit, because here I am using to calculate the velocity, the slope at that present time here to calculate the displacement time using the slope at the present time steps ok.

So, actually this is all about today. So, from the next class onwards we are going to discuss about the modes the j and k and actually how we are going to apply this method in numerical ship hydrodynamics definitely we are going to discuss from the next class ok. So, till then.

Thank you.