Numerical Ship and Offshore Hydrodynamics
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Lecture - 45
Time Domain Panel Method (Contd)

Hello, welcome to Numerical Ship and Offshore Hydrodynamics. Today, is the lecture 45. Today, we are going to continue ours discussion on the previous talk.

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So, previous class we have discussed that some basic mathematical formulation. Now, today again we are going to discuss only the numerical part of it like its big and it requires some time to do. But, today also in surface level, we are going to discuss that how what is the approach to solve this Time Domain Panel Method ok.

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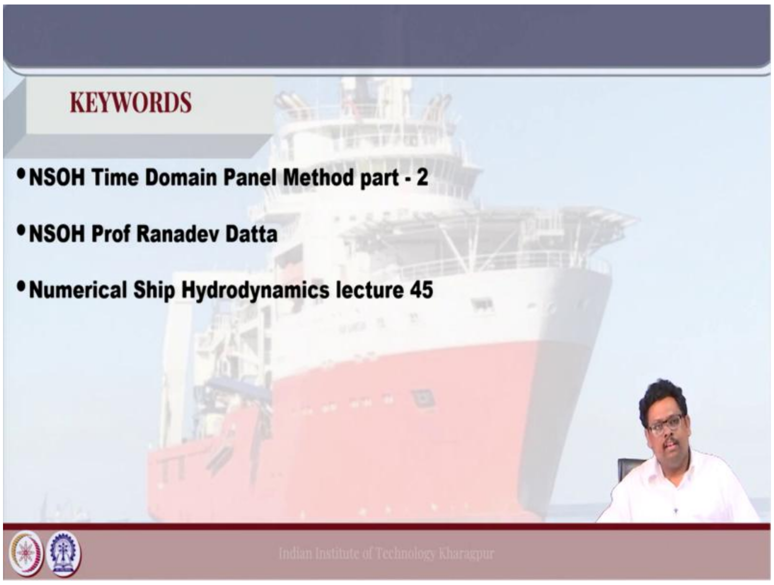

Now, and also these are the keyword that we are going to use to get this lecture. Now, let us try to figure out how we can solve the time domain panel method numerically ok.

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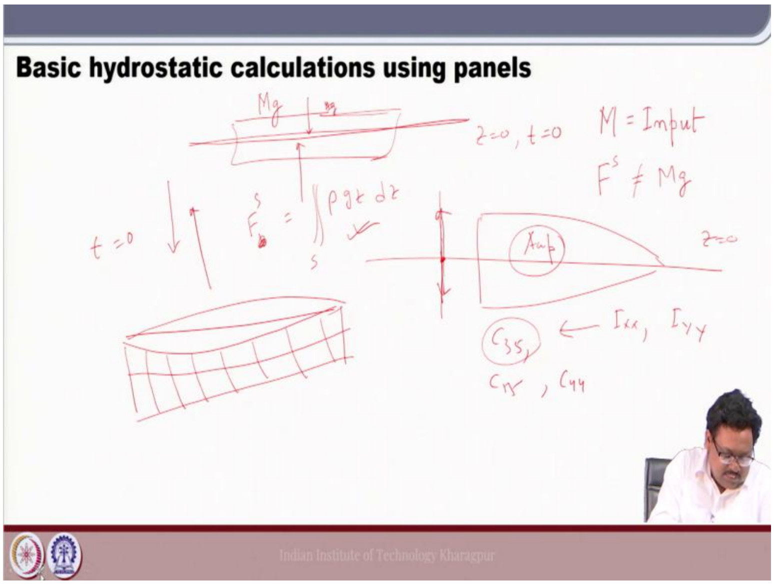

Now, remembering that we are not going to discuss the theory, theory is already discussed many times and in last class also some of the theory we have covered. But, today we try to address numerically or we try to attack this problem numerically and try to find out the solution. I mean not trying to find out, but the like the surface level discuss as I said like what would be the approach to get to the solution ok.

Now, you can see that first we have started with the hydrostatic calculation. Now, this hydrostatic calculations are very important because, you know it is in time domain why this hydrostatic calculations and correctness of the hydrostatic calculations are very important; let us briefly discuss first. Now, suppose this is your some mean line, let z = 0, there is no waves and then you have a ship the top of it. So, this is the pure hydrostatic condition like at z = 0 with the mean sea level and at t = 0.

We assume that there is no waves and then it is exactly it is in static position. Now, this is the physical phenomena and that you need to confirm through your numerical coding; that means, in numerical coding under these circumstances that your weight Mg should be ok; let me write it bigger way, that weight Mg right should be you know. And, then this is the upward force which is ρgz and if you integrate this over the surface dz is the buoyancy force.

So, you can call the F^B, both should be the same or we can say F static. So, static force and the weight should be balanced each other. Now, this is very important, suppose if it is not then what is going to happen? Let us say in some way your code is not performing fine, like you are taking that M as the input. You can take this mass as the input right and it calculated somewhere that input right. And, then when you do the hydrostatic calculation like this thing, then you get some the buoyancy force F static and both are not equal, F static is not equal to Mg.

So, if it is not equal to Mg, then what happened at t = 0 either your ship as a initial some downward force, because of the weight or it could be some upward force. So, what is happening if you try to plot the graph at t = 0; so, at initially it has an impulse, static impulse either this side or that side which is not desired right. So, you know that is how actually one should be very careful when even they started coding, he has to confirm that at static position everything is fine right.

So, this is actually I just explain why it is so, important to get your basic hydrostatic calculations done. Now, there are many ways you can do this hydrostatic calculation, like you can take our so, called you know what I say like in hydrostatic that so, called conventional method. For example, you can you can have let us say this top at z = 0, you get this water plane right; you can find out and then actually you can integrate this.

So, you can get that water plane area right. And, then then again you can try to figure out that what is the value for you know I_{xx}, area moment of inertia and I_{yy}. And, then then actually through this actually you can find out what is the coefficient, then C_{35} or C_{55} etcetera or C_{44}, this coefficient. So, there is a way to do this right. However, when you using this panel method code from the beginning what you have is the panels right.

So, beginning what you have if you use this panel method code ok; let me draw very simplistic three-dimensional geometry. You can basically this is called the Wigley hull ok. So, from the Wigley hull also so, whatever the thing anything that if you started with a panel. Now, see it is a very it is not very smart way to figure out that what is the value of water plane area, what is the value for C_{35} or C_{55} etcetera etcetera using this the panels right or the weighted area right; how we calculate the weighted area normally.

Now, when you calculate the weighted area what actually that the normally we are going to do from the hydrostatic table or the offset table suppose is given to you. So, then normally what you people do as follows.

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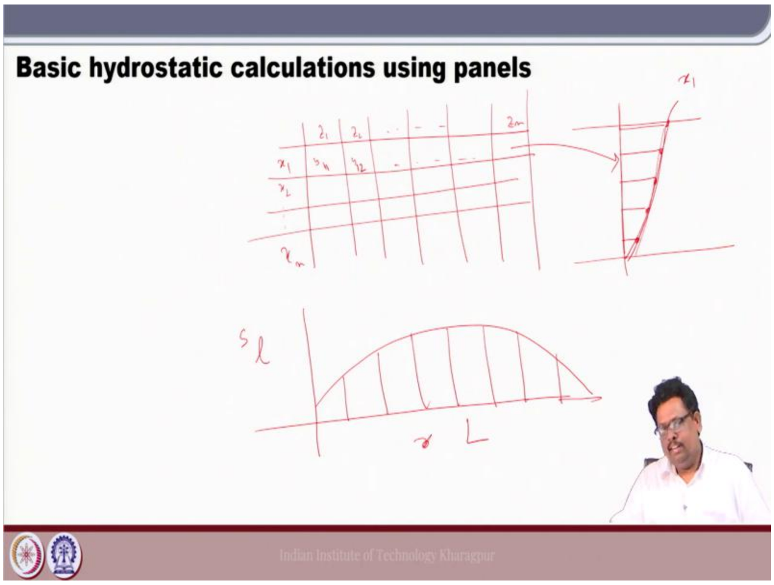

So, they are having as I said offset table. So, they are having with some with respect to here we can call x_1 x_2 and x_n and then you have here z_1 z_2 and then different draft level. So, in different draft level what we are having is the y. So, if you fix your some station x $_1$ and if you vary your draft level. So, this may be the corresponding to x_1 and this y_1, let us say y_{11}, y_{12} etcetera is basically nothing, but the this distance along the z.

So, this is the distance, this is your y point and this is the graphical representation of this rho right. Now, what is happening normally what we how to find out that weighted surface is nothing, but you find out the length of this ok. Now, if you find out the length of this so, then what is happening from you know along the length. So, along the length and if you find out the that length of this, if you this l that the length in the sectional length you can call this sectional length, then again you might have some kind of a graph like this right.

Now, if you have this graph with you and you can simply do the trapezoidal or Simpson, whatever you can get the surface; I mean the area right, the length. Now, if you do this continuously along this the line then definitely we will get the surface area. So, what is happening?

In this particular x you have this length, this particular length you have this length, that particular length you have then this length and then you are integrating along this. But, this is all it is fine when you do not have the you know panels. Now, fortunately we are having panel so, therefore, the whole exercise become very easy. How? Let us see.

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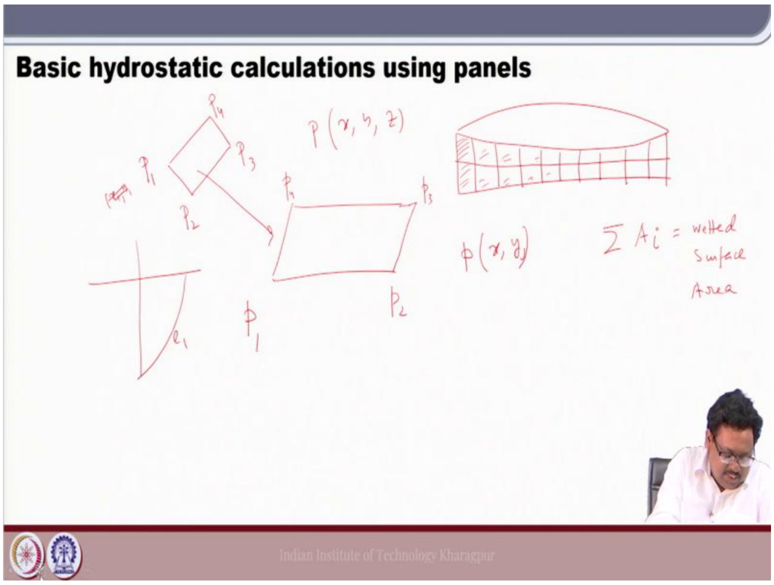

Now, again I am drawing the same simple ship for clarity. I could use this some graphs also, but I thought it is this is fine. So, suppose this is you have the panel right. Now, if you remember we have already discussed how to get the area of a three-dimensional surface, planar surface. So, now, if you have this x_1, y_1 or let us say let us give it a point P_1, P_2, P_3 and P_4 and all these point are let us say a three-dimensional surface P(x, y, z).

Then, we have already discussed from this three-dimensional thing, how to transfer back to the some two-dimensional arbitrary plane. So, it is you can call a p_1, p_2, p_3 and p_4 right and then this all this small p are is only the function of x, y right. So, then and also remember that what we have done is now we have very simply we know the how to find out the area of a quadrilateral. So, if you do this area of a quadrilateral so, we know the area of each panel.

So, now, if you sum of this area of the panel, if then actually we can get the weighted surface area. If you see I really do not need, I really do not need to do all these 6 sides, I am just calculating this from this offset table, what is the length of each section I mean the sectional length in fact, just again this is a sectional length if just l 1.

So, I just look at l1, l2, l3, l4 and so on and then I just integrating its really time consuming. However, once you have the panel, it is a simple just I try to find out the panel area. So, I then I do this integration or the summation I will get the surface value, I mean the weighted surface. Now, this is one how I get the panel area. Now, second is that how I get the water plane, water plane area?

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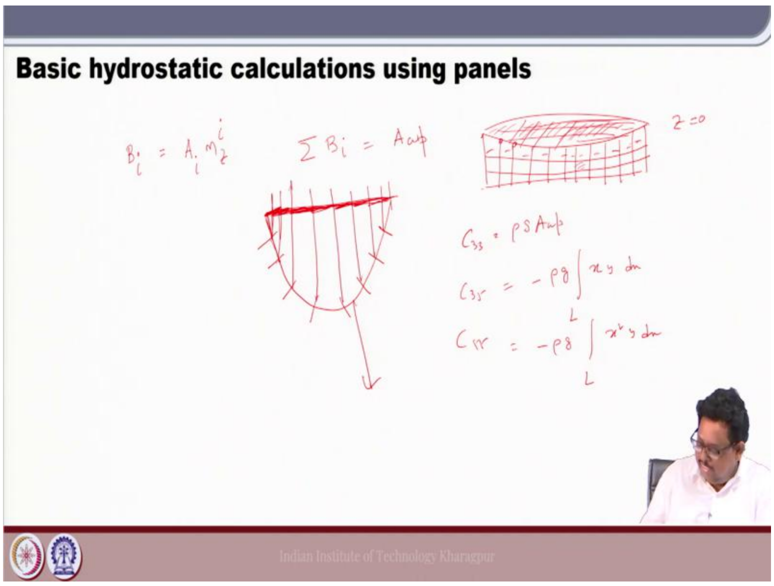

So, what is the water plane area? Now, if this is my ship again, I am doing the panelling ok. I can have one more here that is better, just trying to keep the aspect ratio is good yeah. Now, let us say this is again a this thing. So, what I try to figure out that what is the water plane area. So, this how to get this water plane area right? Now, it is also very simple, frankly speaking now you try to find out that panel area, it is I can call this area panel area multiple by n_z.

And, this will get some number and you can call this is your let us say B. So, it is $B_i = A_i n_z^i$. So, what I am getting that I am getting that area of the i^{th} panel and I multiply with the n_z, that vertical component of that area. Now if you; that means, the vertical projection of the area. Now, if we add this B_i, if we add this B_i, then this gives me the value for the water plane area right. You check that you check that it is very easy to see in case of a two-dimensional body.

Now, suppose this is your line and then this is the shape of the curve and then you are distributing it number of panel in two-dimensional case. Now, what you are doing is you take this and then you take the vertical projection of this length. Now, if you take this vertical projection of the length, then it gives you this much of length. Then, again you take this and again you take the vertical projection of this. So, you will get this much.

Again, if you get this and you take a vertical projection like this, then you get this much of area. Again, you take a take this, then it will get this and similarly if you keep continuing doing this, taking the projection and if you sum everything, you sum everything will get this line, that is how it works. Now, you see that when you do the panelling, then we already know how to get the area. We already know how to get the normal to this to that panel.

So, you so, I can take only the vertical component which is n_z and multiply with the area that gives me the water plane area. These are the very important and also it has to be correct. I mean it should match with our formulation because our entire code later on based on this geometry, based on this normal. So, even if something wrong to getting this water plane area, it is consistent with the coding. Because, I am using my own panel, I am using my own normal right which the entire code is written in that particular normal I mean.

So, if something wrong there it may be wrong, but it at least it is consistent with each other. Only thing we need to figure out that when you do the basic thing, the panelling the normal should be correct or it is the outer down normal, it do not work. Suppose, it at somewhere you will get this downward the normal, normal should be uniform right ok. So, that we have to be careful when we define the normal, that is why I keep telling you make your all the normal unified ok.

Now, this is to something is very trivial and then this coefficient C_{33}, C_{35} and C_{53} also. In fact, in that case I would suggest you, you can use the that what I have solved for you know that in the C_{33} is fine, C_{33} is equal to rho A_{wp} right. Now, in case of a C_{35} or C_{35} specially, C_{35} it is the moment about the water plane area. So, it is better now from this panel try again you just figure out at the that points at z = 0.

So, I just select only these panels because I only select this panel and then from that I can select these points. And, then I can do this C_{35} stuff that what we have done for the stiff theory code and similarly I can get C_{55} also. So, C_{35} is minus rho g integration over the length which is (x . y) or you can say (b. dx) and it is $= -\rho g \int_L x^2 y dx$. So, that is how we can get the value C_{33} C_{35} and water plane area ok.

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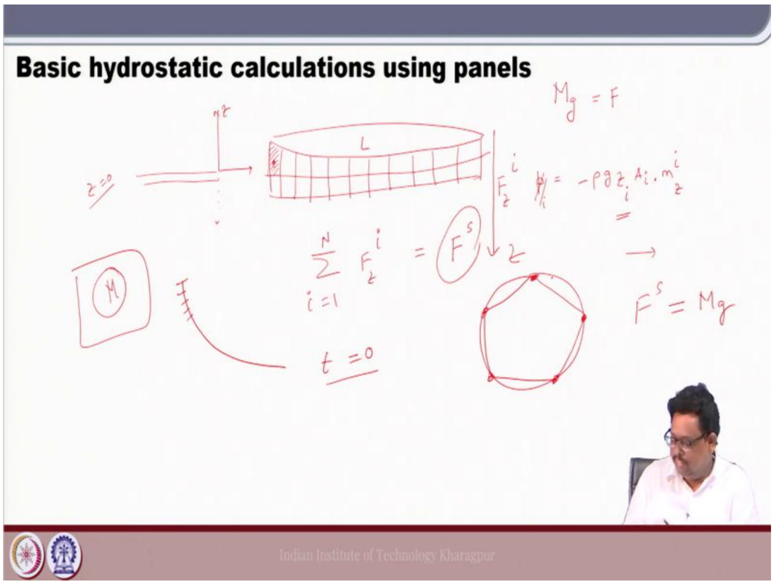

Now, in next level, next level what is important that to match your mass it is very important right. So, to match your mass what you need to do is you have to have a hydrostatic force a priori and then you need to check that your M.g = F. So, how to do that with respect to the panel method, that is also very easy. Now, again I am drawing this.

So, now, I have a panel right. So, now once we have this panel, then I take this point let us say called the centroid of this panel. So, then I calculate what is the hydrostatic pressure. So, $p = -\rho g z$. Remember, that z the this is if it is z is positive upward right and z is negative downward right. So, and then this is the value at this level is z = 0. So, you should remember this right, because at the end this minus and z also minus become plus ok.

Now, thing is that so, this is the hydrostatic pressure at panel p_i and then you need to multiply this with the area right. So, this is the area and then if I try to figure out that if the weight should be equal to the buoyancy. So, it should be multiplied that the z component of the panel. So, this gives you that my the z component of the i^{th} panel right. So, what I do? So, I just use $-\rho g z_i$ of this particular panel, then multiply by the area of this particular panel and then I multiply the normal component.

So that means, the projection again and then if I add so, let us say it is i = 1 to N. So, if I do this F^i_z, that gives me the total static force ok. So, now, we need to check that M g = F, if it is not suppose, suppose sometimes what you are going to do is you are going to take this input M from the code or some input. So, like when you do the design part, you would you do the design.

So, that time this all the specifications is given right, like there is a shape and in then in that shape then you know that what is the displacement that means, the weight? And, you know all this length, the breadth, everything is given to you. And, suppose you know you are not that you know what you say that like little bit go with the convention, like I should take this mass ok. I will say little bit conservative on this hydrostatic part.

So, and then you are taking ok this is my ship, this is the design. So, I must take this M which is given to me from the hydrostatic table or the design office right or this hydrostatic particular when they calculate they give you this mass. And, you say that no I am going with this mass. Now however, when you do the panelling, panelling might not be the great okay? Why I say that great, because at the end that a curvilinear surface you are modelling with the you know planar panel. Right?

So, when you do this, when you do this curvilinear surface modelling with the planar panel and then you have to make the panel is sufficiently small. So, that you can have the minimum curvature over there right. So that means, even if like the high curvature like this. So, you if I ask you to draw this curve through some straight line approximation. So, then you need to make it smaller, smaller, smaller, smaller. So, at least you make sure that each individual section can be approximated by the straight line.

Now, suppose you are having some 200 meter or 250 meter long ship and then there is a curvature is always there, like at least not if even if not along the length definitely they have a curvature along the draft. So that means, in direction of z definitely. So, then then suppose if you want to make sure that this curvature can be approximated by the planar element. So, definitely you need to discretize the ship with ample number of panel like some 2000, 3000, 4000 right.

Now, once you do that, now we discuss we are again going to discuss later on and already we have discussed in the last class also; we have a convolution term involved in the dynamic calculation. So, it means that at each time, at each moment you need to calculate the force from the t equal to 0 to t equal to that particular time period. So, let us say; let us say about the 100 second what is going to happen? You have to calculate all these 4000 panel thing, that dynamic force or whatever from $t = 0$ to $t = 99$.

See that gives you the time it is so, time consuming that you really cannot afford it right. So, normally what we do is we make little bit compromise on the panelling.

So, we grossly because see here the point is that we are at the end we are replacing this geometry by the number of sources right, that is the; that is the essence of the boundary element. So, in a way we really do not want you know that rigorous panelling because, this panelling or this things only important for the geometric calculation like areas, like this source is associated with area right.

So, it is really that not sensitive towards the correctness of the panelling right. So, therefore, often we really do not replicate exactly the same geometry by improving lot of lot of mesh, lot of panels around the body and make a perfect body. We do not really that is not our focus; so, we compromise on that. So, what we do is we use some 800 panels to 1000 panel mostly, normally we do that for modelling of the geometry.

Now, when you do that what actually, we are lacking that geometric, some definitely when you do that modification, the first effect is that if you try to calculate the area or volume under that body, it cannot be same right. Now, it does not affect on the hydrodynamic side, but it has effect on the your at least from the hydrostatic point of view. Because, if you try to calculate the volume of a circle and if you take only very less number of points and if you try to approximate this by a this by a straight line, a polygon.

Then, definitely the area is not matched right, if you know just in other side like this is how people going do this polygon to find out the area value of ϕ or so, that little understood; let us not go into that. But, the idea is idea is you need multiple point to closer and closer to the circle, that is the idea. So, here where we compromise here on this volume. So, now essentially if it is compromised that the volume is not equal. So, definitely the hydrostatic force or static force is depending on the geometry.

So, geometry cannot give that static force not necessarily matches with your displacement, that is given by the design office or the design. So, if you do not make this happen then what is happening, I discussed at the beginning at t = 0 you have definitely, you are going to have a unbalanced force and that cause your numerical instability.

So, therefore, idea is you do this static calculation it is very easy right, only ($\rho - \rho g z_i$) into area of the panel multiplier normal component this gives the static, force at that particular panel. Add thing, you get the total static force and you match with the your input mass. If it is not equal, then do not go with the input value that is given by the design office, then you should go with this hydrostatic component as your weight.

So, this is the; this is the whole point of discussion of spending much time because, it is always very important at the static level t = 0, you have to have a static balance. Like mass should be equal to buoyancy that water plan area, the all the component that you are measuring, you are measuring from with respect to your own definition ok. So, with this we stop over here ok and in the next class we will try to discuss something on the dynamic part ok.

Thank you.