Numerical Ship and Offshore Hydrodynamics

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Lecture - 50
Non Linear Time Domain Panel Method (Contd.)

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Hello, welcome to Numerical Ship and Offshore Hydrodynamics. Today is the lecture 50. Today again we are going to discuss about the Non-linear Time Domain Panel Method. Today discussion is if you remember that we today we are going to discuss the algorithm where we can pick the exact wetted surface.

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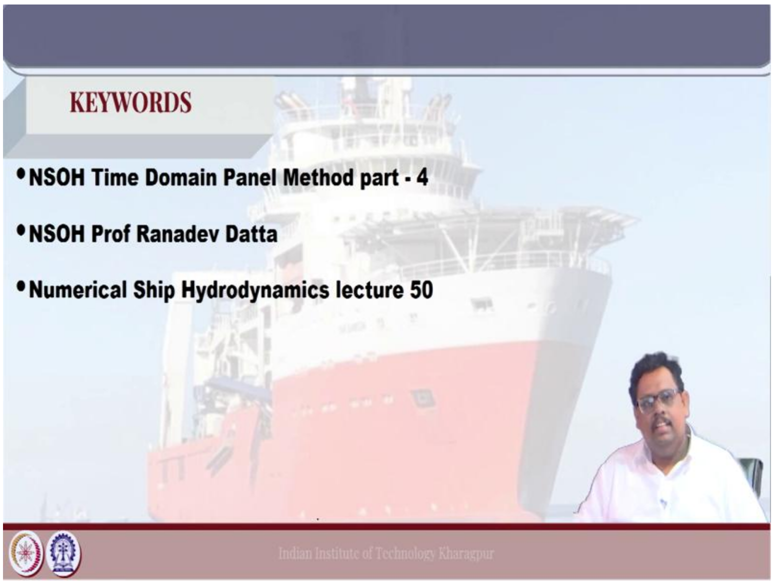

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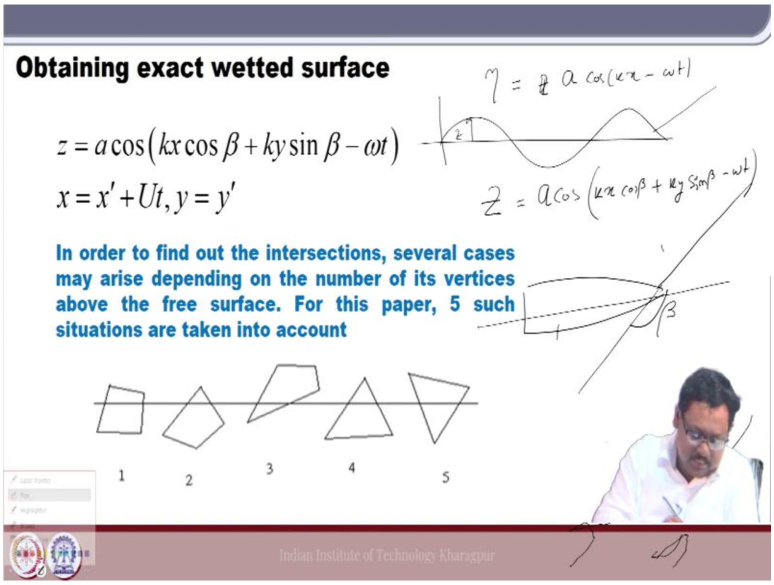

And this is the keyword that you have to use to get this lecture ok. So, let us start. Now, when I say that exact free surface, we discussed a lot where we mean that exact wave instant wave linear instant wave under the linear instant wave not the axially instant plus diffraction all other thing no it is only simply under the instant wave.

Now you know that η is or is we define this $a\cos(kx - \omega t)$ right this is how we define the η. Now if you look at the vector sense. Now, here that η is nothing but your wave elevation right. So, if I take a this the wave. So, this wave elevation or the z is defined by this formula right.

So, I just modify it as a z equal to now a is nothing but a wave amplitude a and in now the cos if I write in vectorial sense like if you have this suppose that that if there is a heading angle like this is the shape let us see that this is the shape and it is having some kind of a heading angle right this is the beta.

So, then you can know that this equation can be rewritten as it is $kx\cos\beta + ky\sin\beta - \omega t$. In fact, to be specific one should write ωt whatever. So, this is how we are going to write the expression for z right.

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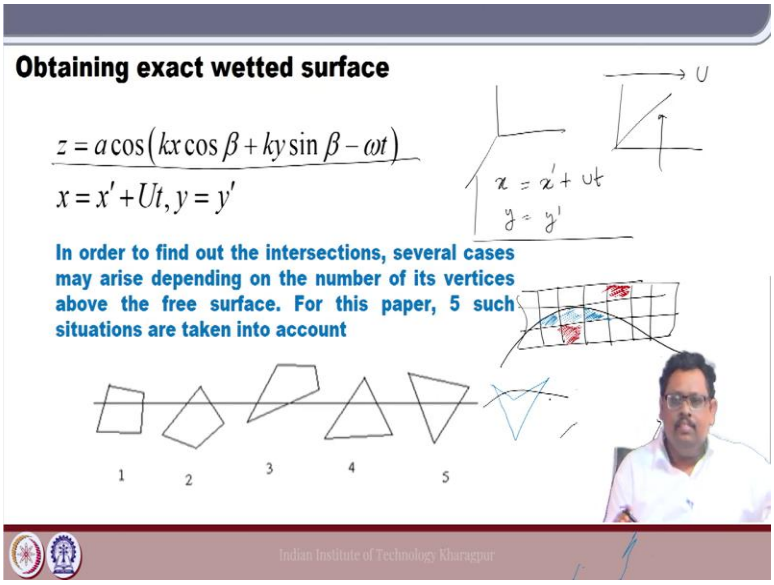

Now, since it is going advance. So, then the relationship between the fixed coordinated frame and the moving coordinate system. Now this coordinate system is moving with the velocity U. So, definitely that x which is the earth fix and if x' is the body fix both are related by this equation $x = x' + Ut$ fine. And since it is going there is no movement linear movement in the y direction.

So, $y = y'$. So, this is actually the whole picture ok. Now you see there is a 5 picture 1 2 3 4 5. Now what is this picture. So, you can read out here say the in order to find out the intersection several cases may be arises depend on the number of the vertices above the free surface or below the free surface. So, we are actually dealing with these 5 cases.

Now it this is not general like you can see that 1 2 3 4 5 you know these are the panels right and we have considered that this panel could be either triangular or quadrilateral right. However, in general there is not such restriction on the vertices it could be hexadecimal also. However, in our code in that panel method we use either it is a triangular or its a quadrilateral. Now you can see here that there are 5 possibilities. Now this black line is nothing but the let us say exact wetted surface.

Now, this is the exact wetted surface and you are here like this is your panel. Now this panel like further you can do in order to make it clearer we can further split into this way. Now you can see there are three types of panels right. Now if you look at here carefully then you can see that there is this panel is completely outside the water and also you can see there are this panel it is completely inside the water.

So, therefore, these sort of panel actually I am really not going to look at. Now for me the interesting panels are this panels this one that some part you can see that inside the water and some part is outside the water. Here also you can see some part is the inside the water some part is the outside the water. Here also some part is inside the water and some part is outside the water here also you can see the same.

So, when you do this algorithm that first thing you need to look at is basically what are the panel that you are getting that that some part is below the water of the panel some part is the above the free surface. So, we need to consider only this sort of panels. Now if you think of that what type of panel, I mean like arrangement could be like this. Now you see here there are lot of case can be arising. For example, you can see the picture number one it’s a quadrilateral panel.

Now, if now this black line is basically that the free surface is passing through and then you can see that it is this is still actually a quadrilateral panel. Now look at the second picture it’s a quadrilateral panel now; however, when it passes through it become a pentagon. Now here is a quadrilateral panel after this you can see it’s a triangular this is this one is a triangular panel, but after you know if you consider the free surface, it become a quadrilateral.

Now, here you can see it is a triangular panel after it split its again a triangle. Now here you know we consider this is the 5 cases that we can see when a free surface is passing through a panel there is not more you know other type of thing. However, you know if there is a bad panelling for example, you have this sort of panel ok and still it is possible that your actually the free surface can we go through like this way see is a very complicated a panelling.

So, we avoid such panels right we really do not want this sort of panel is a quadrilateral panel of course, but it's a very bad quadrilateral panel and this becomes extremely complicated situation. So, at the initial stage when you do the panelling or meshing you should avoid such kind of panels right ok.

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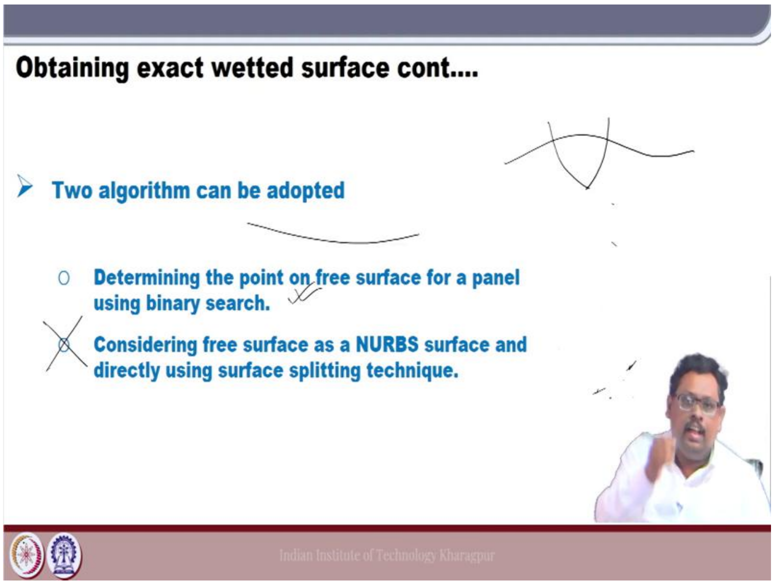

Now here there are two different approach one could take. Now, first one is the determine the point on the free surface for a panel using the binary search or constant. Considering the free surface NURBS surface and directly use the surface splitting techniques like there are you know if you use very commercial software's maybe directly you can find out such type of functions which actually the split the surface to NURBS surface.

For example, if you consider the ship now if I just if you do the body plan. Now, this one is a curve surface this one is curved surface and also you can see this is also a curved surface. Now maybe there are certain functions available in some commercial code where actually you can the split is a possible of splitting to NURBS surface and find out the intersections points this is possible.

So, but let us not discuss this part this one is much more realistic and one could able to write down this one.

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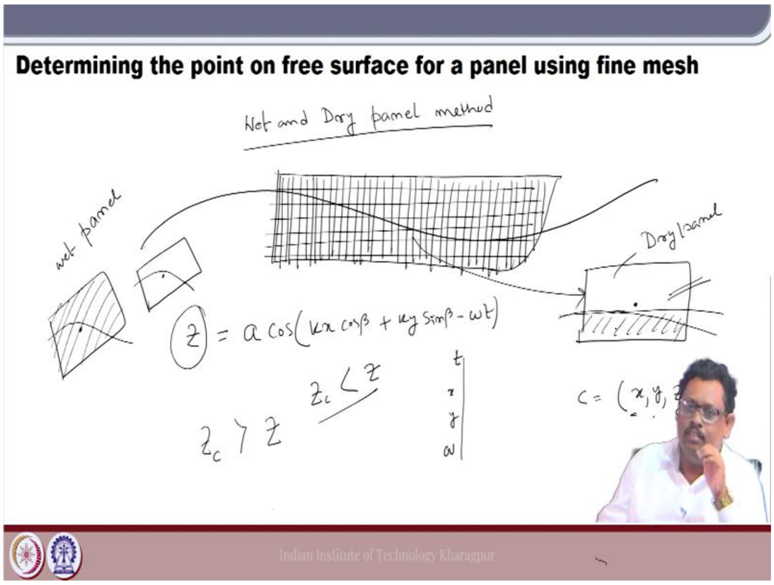

Now, before we go into this the binary search method let us try to find out there is another easy way to calculate or capture the free surface. It is not that accurate, but it is very effective and as I said very realistic, we can call it's a wet and dry panel method. Now, what is this? Now suppose you have a if now I just draw this one a free surface and let me draw a two-dimensional body over here ok.

Now let me do the panelling also. So, now, here I am doing very fine mesh I am making very fine panel not very big panels ok, it only works if you make this panel very fine. So, now, these panels are quite fine very small right. Now, you pick any panel let us pick any panel. So, I just zoom this one some panel like this you are picking up here.

Now what is happening here you have this is your panel and then you can calculate the CG of the panel or centroid of the panel. So, centroid of the panel definitely has a coordinate some x some y and some z, now at that point you try to calculate what is your wave elevation. Now wave elevation is nothing but your Z= η .

So, now this Z equal to at this point the wave elevation gives you $a\cos kx$ into let us say $\cos\beta + ky\sin\beta - \omega t$. So, at particular time t. So, and now you put this x and y over here and you know what is your omega, if you put all this parameter, you can get the eta or the Z. Now you if you if you check is the Z of centroid, I can call it Z c if it is more than the wave elevation Z then this panel I can call as a dry panel.

And if I think that Z c the centroid is less than the z that wave elevation, I can call that panel as wet panel. So, what is happening then in this case you know I do not care like if it is let us say maybe it is go like this way just below, I can say that there is no contribution from this panel. Now here let us say even if it is this like this the free surface going may be that area is more that area is less.

But still since the centroid is below the free surface, I can call the wet panel and then I take the contribution of the whole panel. So, here I am really not you know discretising the panel I am taking the panel as it is. So, I take contribution from some panel and I do not take contribution of some other panel based on the criteria that that if the z point of the wave elevation that is z the wave elevation is greater than the z point of the centroid.

So, it I can consider this as a wet panel; that means, I take the contribution of whole panel even if even if that that panel may not be like you know may be that marginally as I said over here like if this is the panel this is the centroid and this just passed like this still, I can take the contribution of the whole panel and maybe sometimes that may be like this is your centroid and it goes like this way.

So, it's a significant amount is actually inside the water, but since that z point is above the wave elevation address, but that particular x y location I simply discard this panel and I do not take the contribution of this panel. So, in a way this one is not I would say that very accurate, but if you do the very fine meshing then actually more or less it is it will it will give very good result.

Like if you want to avoid that complex mathematical analysis or algorithms writing the complex code splitting the panels if you want to avoid it you can simply you can you can do simplification of your code to capture the exact free surface one can go ahead with this ok.

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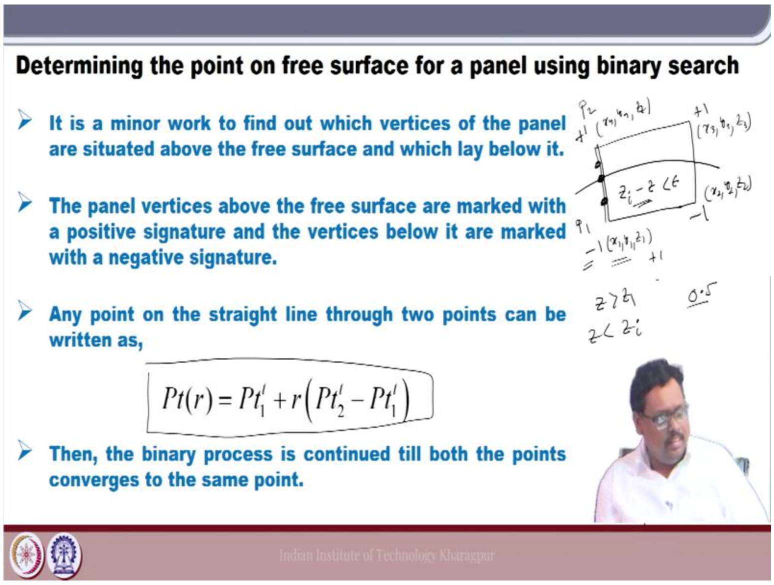

So, now that how we determine the point on the free surface using the binary search. Now, it is written is a minor work to find out which vertices of the panel are satisfied above the free surface and which lay below it. So, it is we call a minor work, but its yeah its minor, but you know you have to you have to do it very systematically to do that I will come to that.

Now the panel vertices above the free surface you can mark with a positive signature like the let us say plus and the vertices below the below it you can mark with a negative signature. Now, so, now, you know if you use let us say the $C++$ or $C\#$ then we have something called Boolean a true or false. So, that can be used as a signature if it is above the free surface, you can take it is true below the free surface you can take it is false.

So, in that way actually and if you use the Fortran in Fortran also you can use true false by it is possible, but normally you can go with the integer 0 or 1 ok or plus 1 or minus 1 whatever. Now, so, then the thing is that you have to go from the positive signature to the negative signature. Now let us demonstrate. Now suppose you have a panel like this now here I can say if this you know if all four are positive signature let us say.

So, it means that it is either above the free surface or below the free surface based on that what you define with respect to the positive sign. Let us take if it is plus 1 then it is above free surface if it is minus 1 it is below free surface. Now if you if you get 4 plus 1.

So, it means that that 4 point is above free surface. So, we are not yeah fine no problem and if the 4 point is below or negative.

So, it is entirely inside the what is called the free surface. So, here also we are not very much interested on these two types of things. So, we are interested if the positive signature is either for example, for quadrilateral panel if the positive signature is 2 or positive signature is 3 or positive signature is 1 it means that one point above free surface remaining below if it is positive signature is 1 you can get 1 it means that one point above free surface you get two 1 means two point above free surface in this case you can have 2 plus 1 and you have 2 minus 1 right.

So, next one is very easy next one is you have to approach from the negative signature to the positive signature and you have to find out at which location actually it intersects definitely your free surface is intersecting here. So, you see that algorithm is not that difficult I find out that 4 points right and then we see everybody has the three coordinates x_1 y_1 z_1.

So, you have x_2 y_2 z_2 you have x_3 y_3 z_3 and you have x_4 y_4 and z_4. So, now, as I said the first point is very easy why because if you know your x_1 and y_1 you can find out at this point what is your wave elevation. Now if the wave elevation is more than the z_1. So, then this point we have negative signature right and at it is this point if it is more than more than that wave elevation z_1 point.

So, z_1 should have the positive signature this is elementary I know I have all four points I have x coordinate y coordinate and then I know that at that point what is my wave elevation if this wave elevation z_1 is wave evaluation z is more than z_1. So, I know that this point having signature negative if the z is less than let us take z I some arbitrary right. So, then I know that this z i is basically having the positive signature. So, this is elementary.

Next point is that arrange find out in a way you can get from negative signature to positive signature I must go right. So, what I do? Now you have this negative signature minus one you have this positive signature plus 1. So, I can write a straight-line equation like this where r is the parameter. So, I am writing in a parametric form right now if r = 0 you have the you have this point let us take it is P_1 and let us take this point is let us say P_2 right.

So, then if r is equal to you know 0 you have the point P_1 if r equal to 1 you have the point P_2 P_2. So, this is very elementary now you start with r equal to 0.5 you will get some x y z. Now you check that x y z is above free surface or below free surface that is called binary search. Now if it is above free surface then in the next level. So, you start with r equal to 0.5 and you take that this point may be falls here.

So, above the surface. Now it is r = 0 and it is r equal to 0.5 then take r is equal to 0.25. Now then you can find this point is below. Then you divide this 0.25 to point. So, it is point I think it is 0.375. Now when you do the 0.375 then you can check that your z i minus z is less than epsilon may be possible at some point if you do this continuing this process.

So, at some point definitely you are going to get some z values or some z values which is very close to that particular point. So, this is how actually you can find out your point on the free surface and this is called the binary search ok. So, try it write an algorithm and try to get this binary search.

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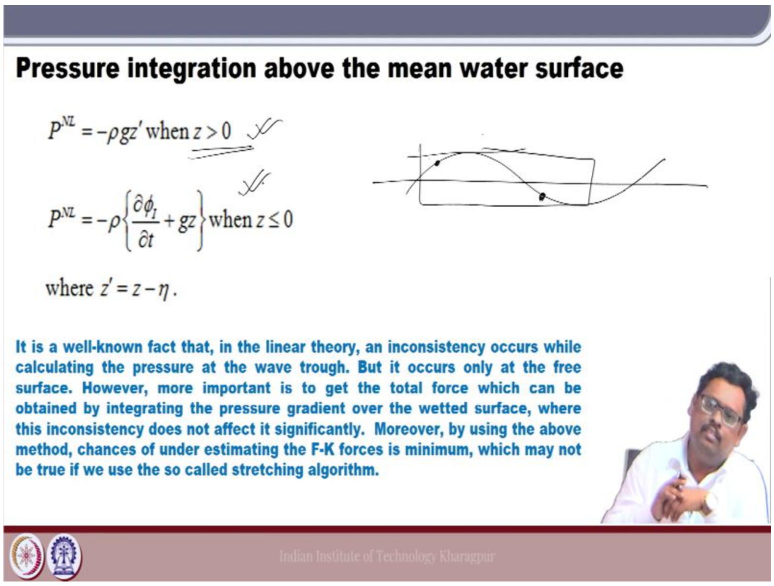

Now, once you get it then actually, we have to calculate the hydrostatic non-linear pressure. Now, we have already discussed the hydrostatic approach. Now, if it is if that point is that $z \succ 0$; that means, for example, that this is the wave elevation and suppose this is my ship and this is let us say free surface now if that z point is here that panel z point is here.

So, I am using the pressure at this point is this ok and if you think that this z point is coming over here when $z \prec 0$ then we are going to use this pressure as this ok. So, this is how actually we are trying to get the non-linear pressure non-linear Froude Krylov pressure. And now when you integrate this non-linear Froude Krylov pressure you will get the non-linear Froude Krylov force ok that is it that is what we are going this is the discussion point today.

So, let us stop today here and in another two session we are going to discuss some kind of coding algorithm it is very difficult to write a complete code of time domain panel method at this moment even in very elementary form also. But; however, we can discuss some trick part some critical coding aspect we discuss ok. So, that at least you could able to learn the basic functionality that is required to write the code ok.

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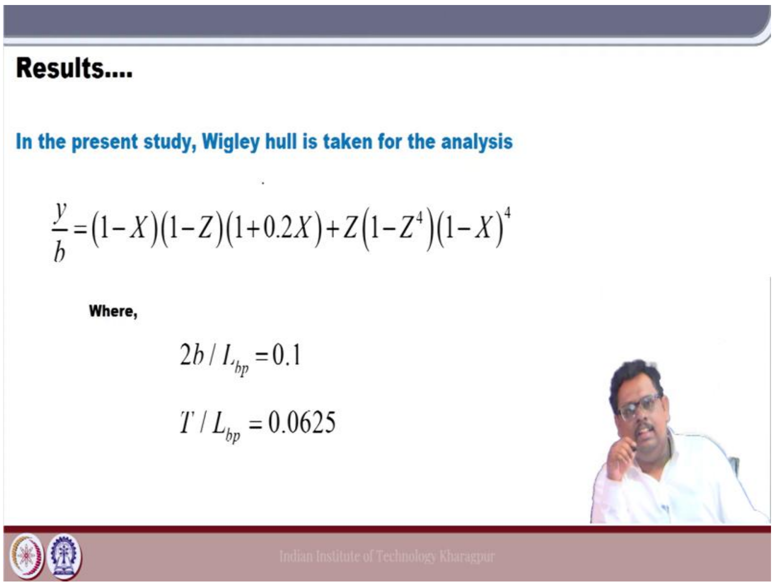

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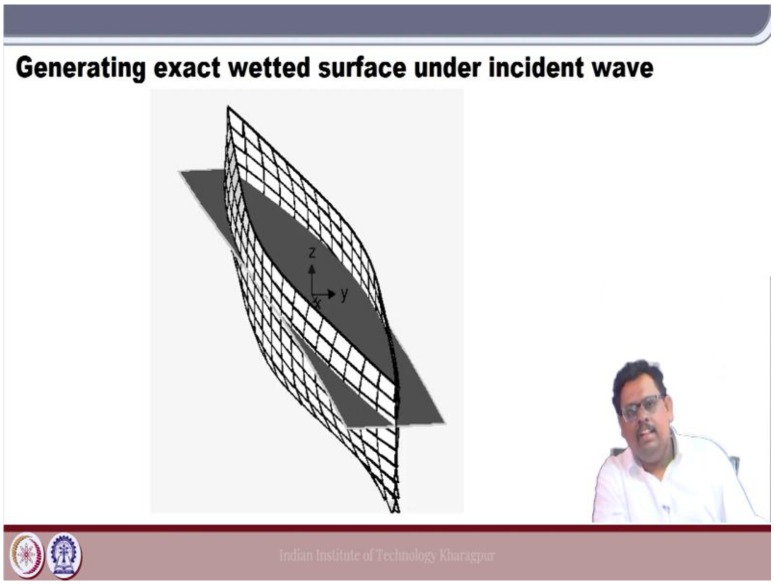

Now, before we stop let us see we have some kind of result with us let us see we are taking this wigley hull and then actually now this is how it look like. Now in wigley hull after z = 0 it is just gone straight ok and this black one is the free surface

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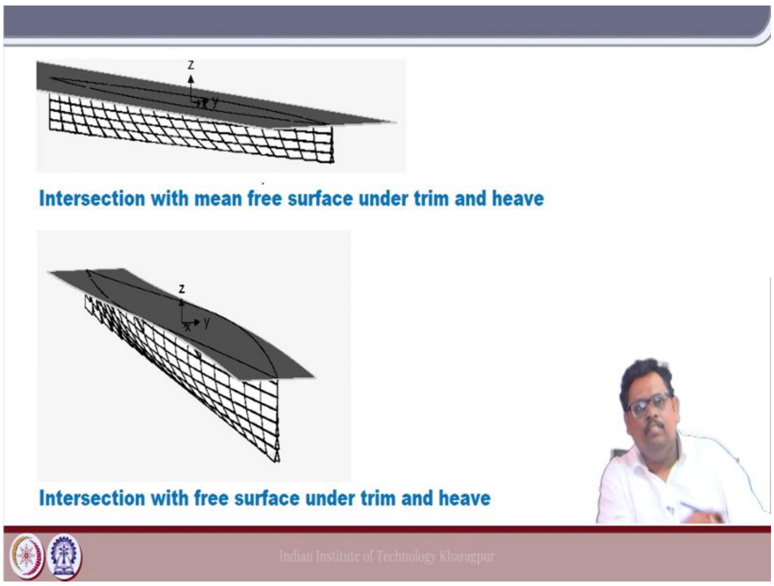

Now, we apply this algorithm now you can see that it is very nicely you know you can get the free surface right and once you get the free surface that getting the pressure is really very elementary right using the hydrostatic approach ok. So, let us stop today.

Thank you.