Numerical Ship and Offshore Hydrodynamics
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Lecture - 47
Time Domain Panel Method (Contd.)

Hello welcome to Numerical Ship and Offshore Hydrodynamics. Today we have the lecture 47.

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Today we are going to discuss on time Domain Panel Method of course, but for the non-linear case. So, today we are really I mean in previous class we discussed till previous class we have to discuss the linear part and as I mentioned that if you use the time domain formulation earth fixed system. It is it may not be that difficult to include some sort of nonlinearity into the solution. So, let us see that what sort of non-linear thing actually we can include in the linear time domain solution ok.

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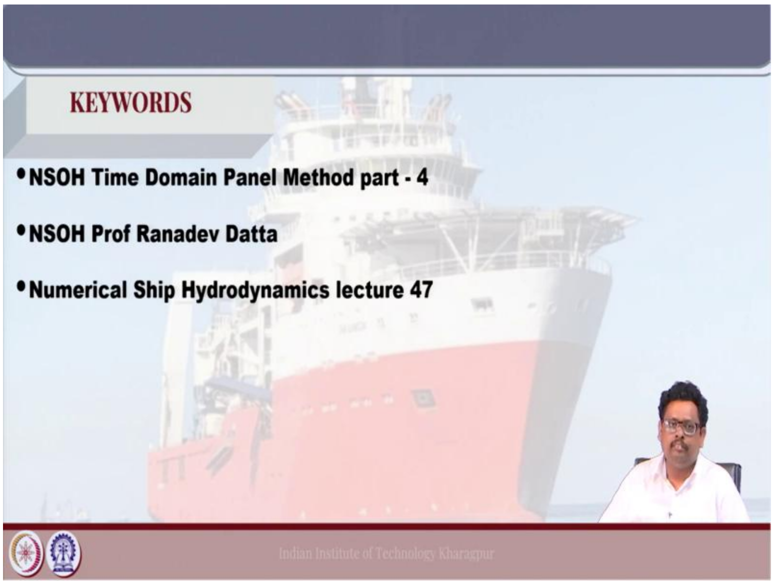

And this is the keyword that you are going to use to get this lecture.

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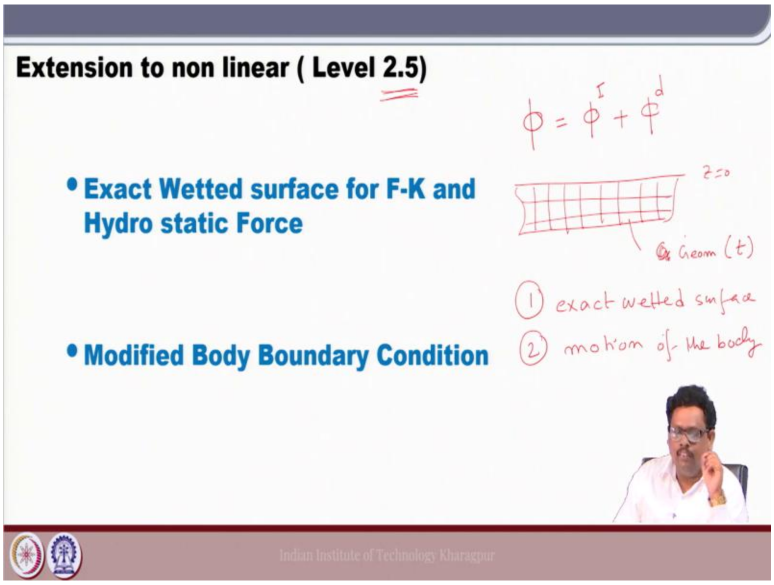

So, let us start the thing. Now here you can see that I wrote this is level 2.5. Because before I explain what is level 2.5. Definitely we are going to discuss what is level 2, level 3 and level 4 and level 1 right. Now in level 2.5 it is you know it is between the level 2 and level 3.

So, we will discuss that, what is the other levels. Now what here the focus is that what non-linear we can include. Now if you remember that in our case we are taking this total

ϕ is equal to that ϕ incident right and then plus ϕ disturbed. Now when we do the linear thing what we do is we use the linear Z = 0 that free surface right and then this is actually that our body up to Z = 0 and then I discretized the body up to Z=0. So, over the time that in boundary conditions so when we apply the boundary condition all the boundary conditions about Z = 0.

So, therefore, this geometry if I called this geometry G ok. Now G is the greens function. So, I can called geometry is geom, see geom is not the function of t. Because this geometry is invariant under time because we are doing the linear analysis and then, but when you do the non-linear analysis at that particular time we do consider following things.

What are these? First we consider the exact free surface exact or exact wetted surface and then at second we incorporate the motion or body motion. So, these two things actually we consider right. So, when we use these two things then the geometry is no longer remain the invariant why? Because very simple reason.

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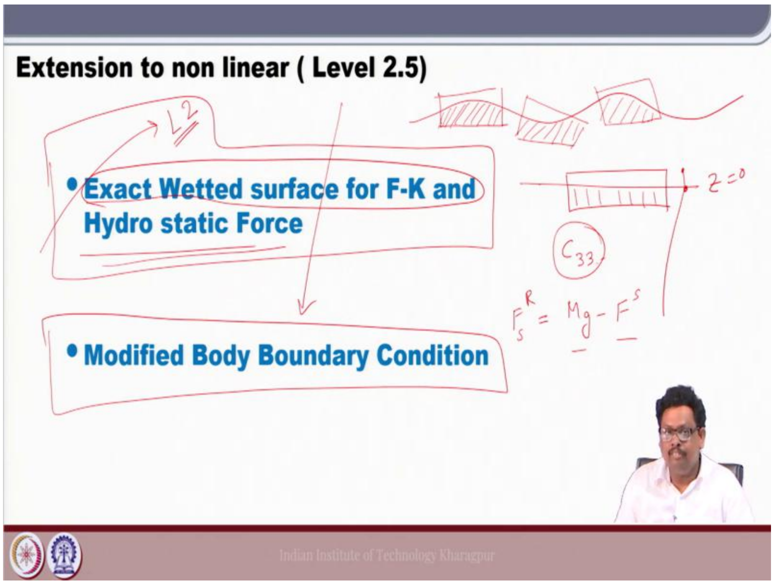

If let us say this is my let us say the free surface. So, now, what we are considering the ship is actually under this the wave. So, let us just make a some rectangle then it is easier for you and then we consider right kind of this situation. So, what is happening here now you can see this wetted surface is continuously changing with respect to time this wetted surface is continuously changing with respect to time.

Now, if you do the linear thing if you do the linear analysis that time your this ship is always this triangle is sorry this triangle is always look like this. So, this under wetted surface does not change with respect to the time. So, this is the first thing when we incorporate the nonlinearity. So, and also the Froude Krylov force if you remember we assume that this Froude Krylov force we have already discussed right it is always it is we do up to we do up to Z = 0, right.

And we assume that whatever the Froude Krylov force at Z = 0 that the same is happening at Z = a also see this is our underlying assumptions of the linearity. Now here the major challenge is when you incorporate the wave then in the exact wetted surface how I can define my Froude Krylov force. And similarly the same it is same for the static the hydrostatic force also earlier this is my thing. So, we can go with the definition C_{33}.

Let us only talking about the heap let us forget the other part ok just talking about the heap. Now when you do the exact you know wetted surface so; that means, you have to calculate the exact static force and therefore, this it is no longer C_{33}. So, at that time you must consider the resultant the force resultant static force, which is FSR which is the weight minus the static force the buoyancy.

So, these are the change that you have to consider while you are doing with the nonlinearity. And the second part and this is actually this things when you do started this things this started with the level 2, so I just write it L2.

So, if you only do this much if you only do this much then it is actually the level 2. Now when you just modify the body boundary condition little bit and actually this is something that new that is and. So, when you make some kind of approximation in simplistic way then it becomes level 2.5. So, now, when you incorporate this part this becomes level 2.5. Now why it is 2.5? Why it is not 3 what is not 4. So, let us try to understand this.

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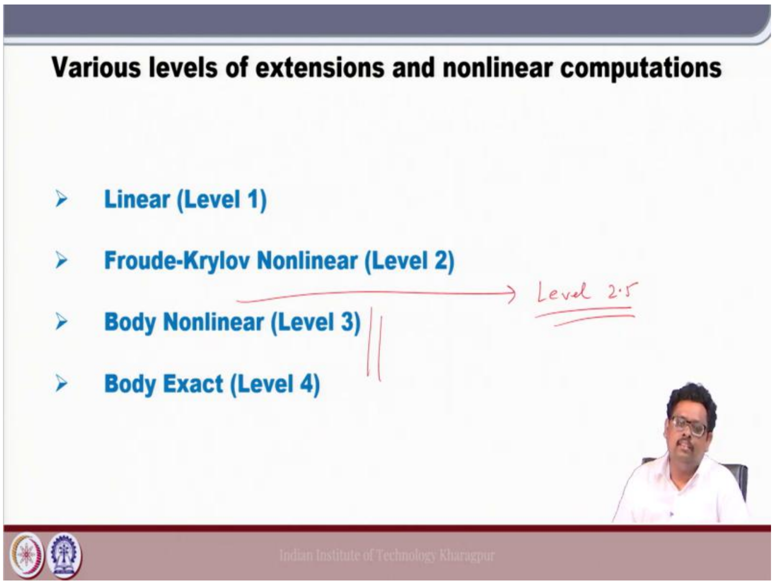

Now, let us see that this is our conventional level. So, it is level 1, level 2, level 3, level 4 and then fundamental questions comes over here. Why I am why I am concentrating on the level 2.5 of course, and why we are not going with direct level 3, level 4, right? So, we discussed level 2, linear level 1 already we have discussed right. Though still we have to figure out many things at the end we are doing it when do the actually computer coding some logic everything how to do that this definitely we are going to discuss at the end.

But at least at some level we know what is level 1, what and what is when what we are going to do there, what is the difficulties arising when it is numerically instable if it is numerically instable then how to make the code numerically stable all these discussion we have done right.

Now on we try to find out that the non-linear thing like the level 2 we already discussed the level 2. So, whenever we discuss level 2.5 it includes level 2 and level 2.5. Now here we are going to definitely answer at the end where why we are using this level 2.5 and what is the advantage of level 2.5 over the level 3 and level 4 ok. Now let us try to understand all the levels one by one.

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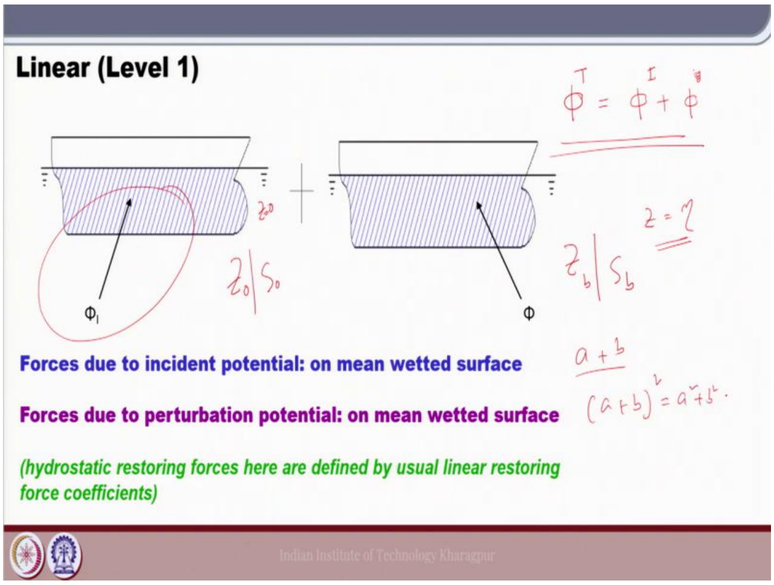

Now in level 1 we have you know two components. If you remember my total potential ϕ_t is divided into ϕ incident plus ϕ disturb or we can say simply ϕ. Now if you do that then you can see here in this picture that phi incident as I know that Froude Krylov force that we have computed on the mean free surface.

Now, if you remember that when it is Z = 0 we called as a mean free surface and when we call the Z = η we called the wetted exact wetted surface. So, this normally we called at Z_0 and this we normally called as Z_b right or body or sometimes we can call this a S_0 and we can call sometimes this as S_b. So, these all the notation that we have to understand what is the meaning of the notation.

Now in case of a level 1 our Froude Krylov force diffraction force, radiation force, all the forces actually we have computed calculated at mean free surface or at Z= 0 right. And then it is actually consistent why? Because then I take a linear thing and I can linearly add the thing.

Now, when remember here one very important like concepts when even we say it is a non-linear it is not purely non-linear. Why? Because you see that in non-linear you cannot add right like a +b it is not possible for $(a + b)^2$, you cannot do like $a^2 + b^2$, you know you cannot do that right.

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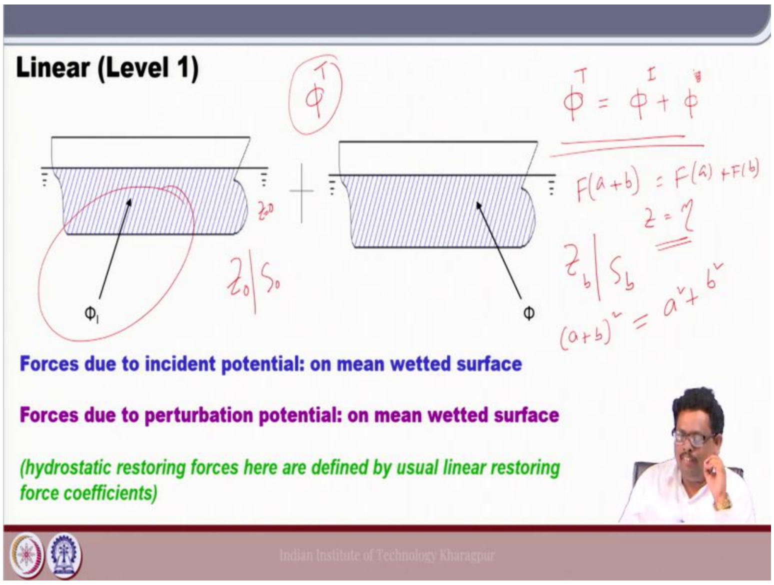

Now so therefore, so when you do you know $(a+b)^2$ is a purely non-linear thing. Because as you know that we really can do this equal to a^2+b^2 it is not possible, but $F(a+b)=F(a)+F(b)$. Now suppose we have some force a is a component b is a component we can simply linearly add.

So, this is something we called a linear. Now when you say the non-linear one has to understand that when you say the non-linear it is not purely a non-linear. Now what is purely non-linear? So, if I take ϕ total a sole ϕ and we do not take any component of it and we are not adding anything then we can call it is a purely non-linear problem ok.

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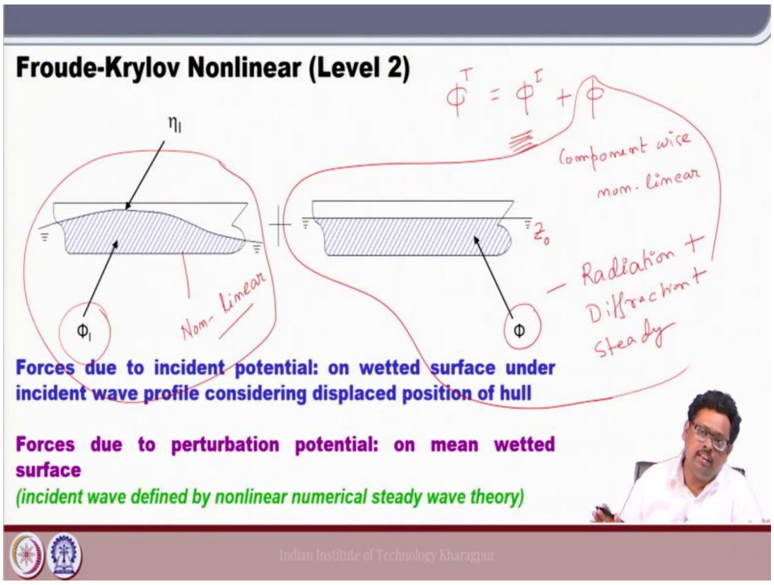

But; however, if you see here in the level 2 what we are going to do as follows still we are taking my total $\phi^T = \phi^I + \phi$. Now, when you do this it indicate that I am going to use the linear superposition technique now when you do the linear superposition thing then I cannot call is a non-linear is it not.

But still if you go through all this journal paper they say that is a non-linear problem, non-linear time domain panel method you can number of paper actually you can get. In fact, in reference after end of this course I listed out all this reference there also I will show you that very commonly we use the term that non-linear right you know. So, then you have to be very careful and you have to be very sure that it is not purely non-linear.

Now, let us say what is happening here. Now here when you solve this ϕ^I when you solve this ϕ^I am using the exact wetted surface. Now when I am using the exact wetted surface so it is a some part that force I am getting I call that force is non-linear. So, therefore, this can we can called as component wise non-linear ok, but it is not purely non-linear.

So, here what we are doing in level 2 when I calculate the Froude Krylov force that time I am using the exact wetted surface. However, that radiation or the disturb potential, which gives me the radiation and diffraction which gives me the radiation force and the diffraction force and also the steady force and also the steady part of it.

So, when you calculate this that time I am using our exact wetted surface Z_0. So, here level 2 is that when we do this ϕ^I and we are using the exact wetted surface, but when you do the ϕ we do not use the exact free surface. Now what is the advantage?

Now here you see in level 1 it is said that level 2 is most advantageous for all levels ok. Why it is so? Because you see here since I am only using this component the Froude Krylov force part of it actually and I am not touching the second part. So, I am not touching the second part then still I can use the same invariant mesh what is the meaning ok.

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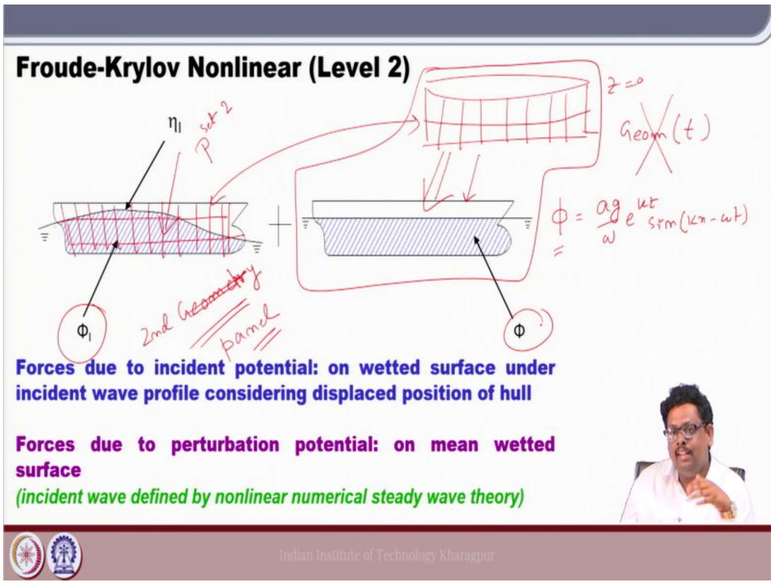

Let us see it means that suppose I have this panel, I have this panel ok. Now it is about the Z = 0 and I am so this panelling I am not changing over the time. So, this geometry I can call geom this is not also again it is not the function of t no not like that. So, because it is here; however, if you remember now if I do the time domain I am using the simple $\phi = \frac{ag}{\omega} e^{kt} \sin(kx - \omega t)$ something like this that is what I am using. I am using a analytical function to calculate the pressure on a analytical surface right.

So, to do that we really no need to you know do the re meshing all the time. Because here which is purely numerical this part that actually I am doing for the radiation diffraction problem. However, that we can have we can use a separate machine for the Froude Krylov part.

So; that means, we do not disturb this part we do not disturb this part we are using the simple panelling and we are using it for solving this particular portion and for this second part this second part what we could do actually I can have the second geometry. I can have the second geometry, which actually or second panelling rather say second panelling I can use the second panel, which is panelling up to the main deck.

So, this panelling is up to the main deck. So, what is happening? If it is up to the main deck then I use this I can say the panel set 2 I can call this panel set 2 P set 2. I use this panel set 2 to calculate the non-linear Froude Krylov forces. However, I am using the panel set 1 to calculate the linear force.

So, thing is that at this particular time that I am using two different mesh. Because this mesh and this mesh is not at all connected ok these two meshes are not connected. Because I am from this mesh I am getting the component ϕ the force because of the ϕ. And then with this mesh I am getting the force because of the ϕ^I and nowhere ϕ^I and ϕ^I are connected to each other.

So, I can simply use the linear superposition between these two. So, therefore, this is the level 2 and this is this is advantageous. Because I am not doing the panelling I mean the panelling for the ϕ^I am only doing the panelling for the incident and which is easier. Why? Because if you look at the next level.

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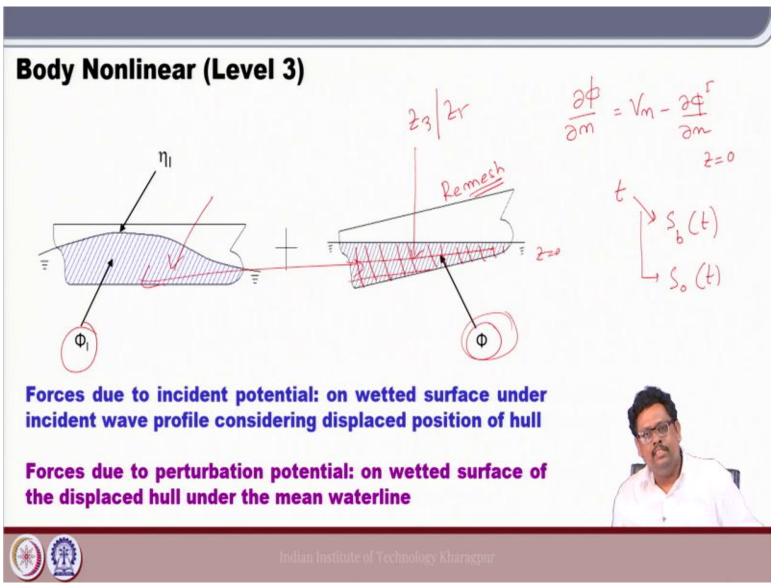

Here what actually I am doing now you see I am incorporating I am incorporating the motion of the body. So, now here you can see that I am incorporating the let us say Z_3 and Z_5 and I extract that what is the exact wetted surface at Z = 0.

Now this is little bit tricky and little bit complicated to and. So, we need discussion on this here what we are what we are looking. Here you can see now I just write down that body boundary condition which is $\frac{\partial \phi}{\partial n} = V_n - \frac{\partial \phi^I}{\partial n}$ and this must apply at Z = 0. Otherwise I cannot use the greens identity I cannot use the greens theorem.

So, since I cannot use the greens theorem or Greens identity. So, therefore, all the time I need to know that what is the mean wetted surface. Now in linear it is very consistent with thing we do not change the geometry it is always same we are not incorporating the vessel motion into the body boundary condition.

However, here what we are going to do is we are incorporating the vessel motion into the solution and each moment. So, at each time instant *t* I try to find out what is my wetted surface I can call that s_b is the function of t now right. So, also or we can say that it is we can say at it is S_0 at t.

Because I have always try to figure out what is the mean wetted surface now this surface with changing with respect to time you see the all it is. So, complicated we are going to discuss this all this problem in future classes, but at again as a surface level at least we understand one point is that here I require panelling at each time instant right.

So, here we need re meshing we do re mesh we do re mesh at each time instant and also we need to re mesh this as well. Now at therefore, this level 3 in level 3 I am solving this ϕ^I on exact wetted surface, but here ϕ at exact mean surface here I am not taking the wetted surface right I am cutting it at Z = 0. So, I am taking that what is the exact location of the ship and then I intersect at Z = 0 and I figure out what is the wetted part and then I solve ϕ for this.

Now, frankly speaking this body non-linear or the level 3 is not very popular and not very consistent also. And people normally do not use the level 3 as such ok. Because you see that it is a complicated thing like it does not have any solid mathematical background like when till level 1 I have the solid mathematical background. But from the level 2 onwards we do not have the solid mathematical background ok.

So, everything is intuitive and then there is no solid mathematical background to figure out this is consistent. And if you ask me that I cannot say that if you use it is what we call like give you the exact feel of the physics that is also not possible we try to incorporate some kind of nonlinearity. We have some kind of approximation into it and we try it right. However, people find that this body non-linearity it is not that useful and this method that is why not that popular.

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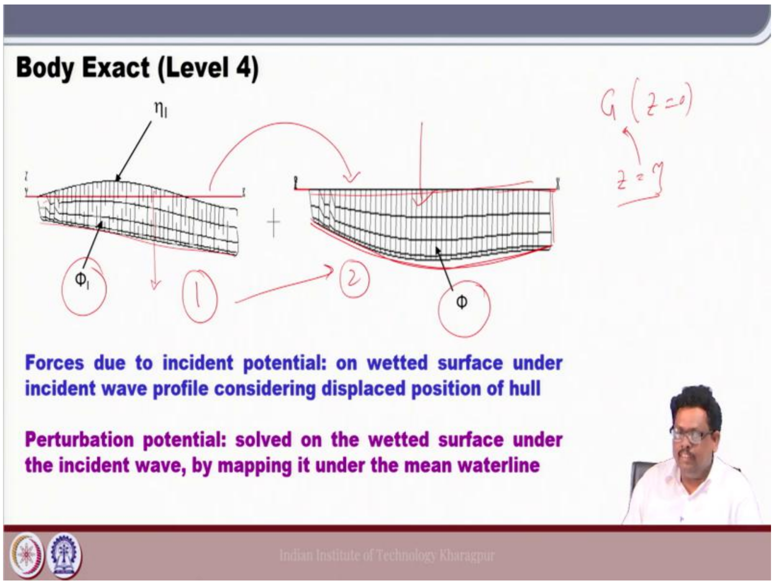

So, people using we call the weak scattering problem and which is the level 4. Now, here at level 4 what we are doing is now if you see that if you consider level 3 this exact wetted surface is not same for both the force and that is why people have problem. Now when you calculate this phi I this surface and we calculate the ϕ there is a lot of difference.

Now here we try to in level 4 actually try to sort out this problem. How we do that we take this wetted surface then actually modify the ship geometry for the ϕ such a way that wetted surface become invariant. Now what is exactly level 4 is that I am solving the ϕ^I in the exact wetted surface and also I am solving the diffract potential ϕ also at exact wetted surface.

Now how it is possible? Because you know at greens function G is only valid for at Z = 0. If you take $Z=\eta$ you cannot use the boundary element method. So, to use this you have to have it is on the mean wetted surface. Then how it becomes exact?

Now, what we do we use some transformation? Now what is the transformation you see? If you look at this figure the left hand figure let us say call this figure 1 and figure 2 you can see that here this is the wetted surface it is little bit top. So, what we are doing is? We make it down and then actually then this profile which is at eta one we are doing it a downward here. And then this part actually you can it is not that exactly I am just making it this way it is not like that we use some transformation which convert this into figure 1 into figure 2 such that wetted surface become invariant ok.

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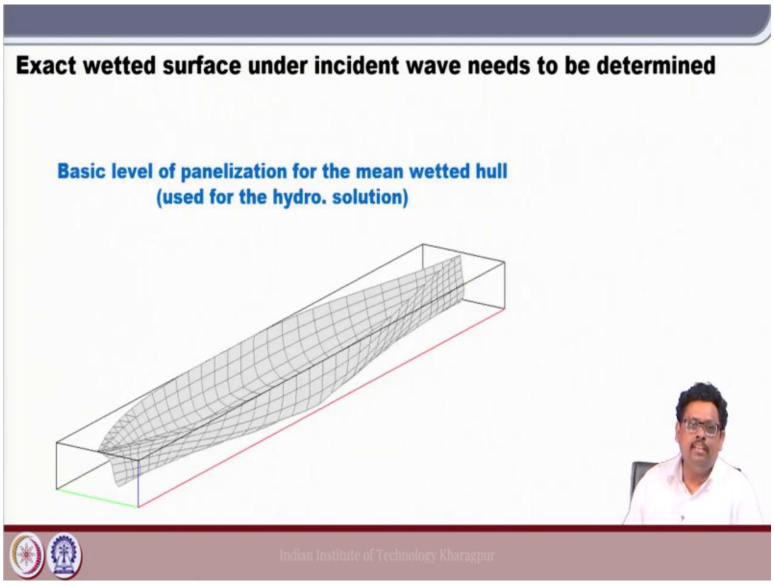

So, this is how we can do the panelling.

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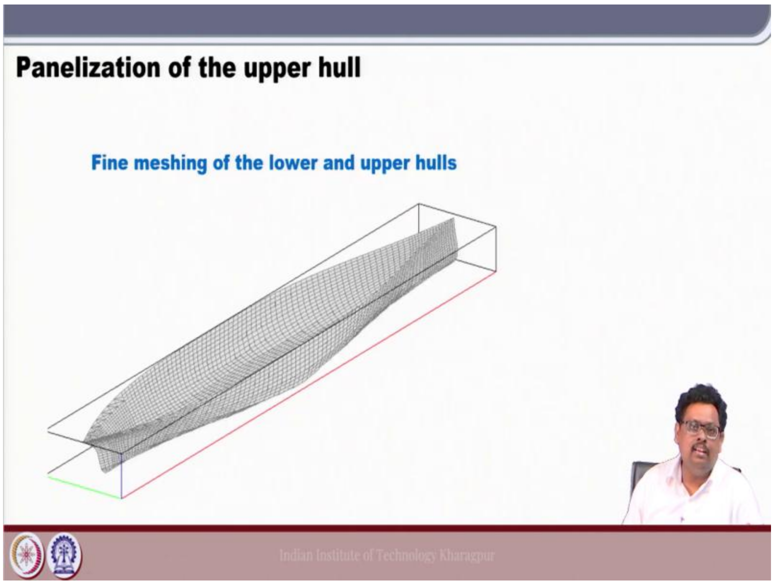

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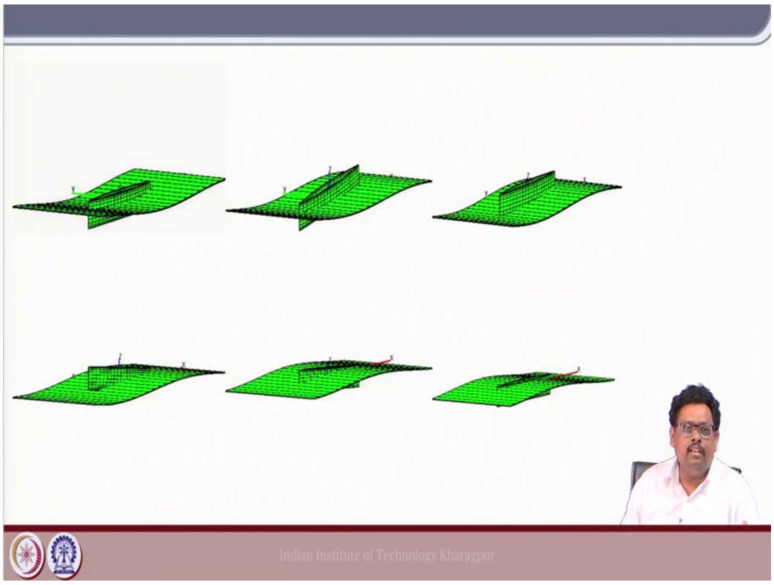

So, let us keep it now this will again going to discuss later on.

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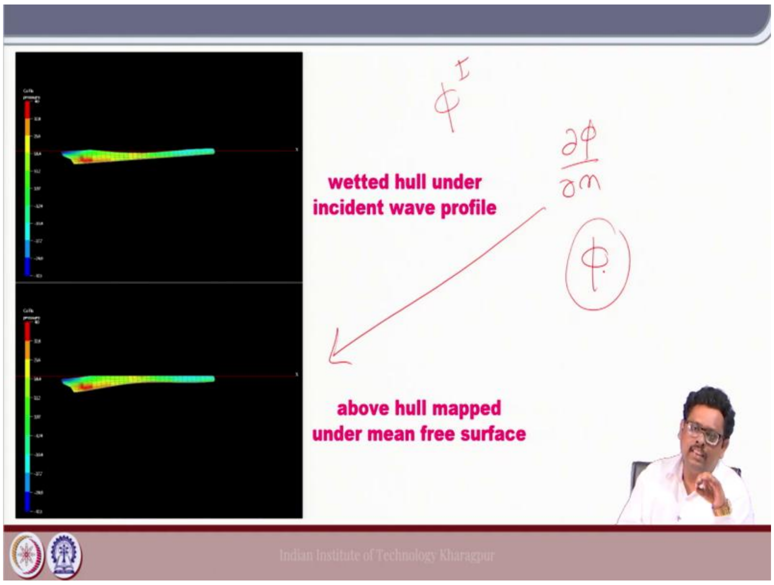

So, now you see here this is what I am talking about the exact wetted surface. Now you see in the top figure I can see the exact wetted surface and in the bottom figure it is the transformed wetted surface. So, that is actually here we are using. So, we are what we are using my you know $\frac{\partial \phi}{\partial n}$ that I am using in this particular thing.

Now, you can see that here over the time again the panel got changed. So, we need to do the re meshing right. So, it is not only the re meshing right and it also about the rate of change of ϕ that rate of change of ϕ not ϕ^I. ϕ^I we are not because the analytical expression, but phi is a purely numerical thing.

So, now, if I change the panelling then how the ϕ also change that also we need to consider. So, this is I mean we are really do not go into that complexity I am just telling you that where actually these four level at does ok. So, it is just to just you can say like a very elementary information about the level, level 2 level 3 and level 4.

Now from the next class onwards we are focusing on the level 2.5 and that particular time we are going to discuss very elaborately about the how to calculate the Froude Krylov force on the exact wetted surface. How to calculate the body boundary condition on wetted surface not mean free surface. How to incorporate all these things that actually and why and where this level 2.5 is different from level 2 and level 3 what is the advantage and all everything we are going to discuss in the next class.

So, today we only discuss about the all four different non-linear level and what is the advantages, disadvantages, those things we are going to discuss from the next class. And then why 2.5 is more beneficial over all these four. I mean not 4 a level 1 is a linear all 3. That means 2, 3, 4 why 2.5 is beneficial that also we are going to discuss from the next class ok.

Thank you.