Numerical Ship and Offshore Hydrodynamics
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Lecture - 03
Introduction to Seakeeping - 2

Welcome to the Numerical Ship and Offshore Hydrodynamics. Today is the lecture 3.

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So, today, we are going to discuss the following thing; like, we are going to discuss about the basic hydrostatic and then, numerical techniques to get some geometric parameters such as how to calculate the volume; how to calculate the areas; how to calculate the normal etcetera. And then, we discuss the basic algorithm to find out the areas of some arbitrary oriented quadrilateral in different ways.

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And this is the keywords; you can find this lecture in this keywords.

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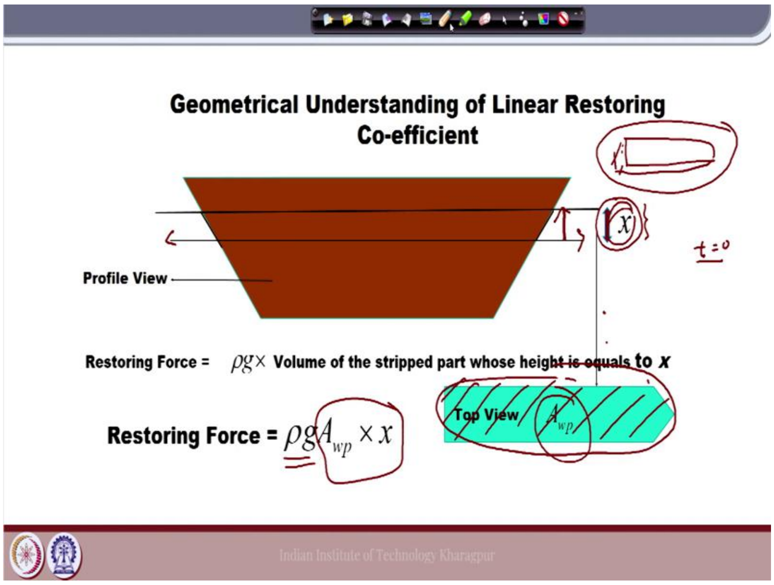

Now, let us coming back to the last lecture, where we discussed about how we calculate the restoring coefficient for heave. Now, if you look at here, you can see that that you know actually this the ship has some vertical displacement, this much which is x. Now, we can assume that at t equal to 0; that means, if everything is stand still this is the line, where you have the weight equal to buoyancy that particular moment and then, then ship has some kind of you know vertical displacement which is which defined as x. So, this is the thing when we have the vertical displacement.

Now, due to this definitely, it experiences some kind of hydrostatic force. Now, how to measure this hydrostatic force, now here you can see the restoring force is a formula it is ρ multiplied by the g and then, volume of the strip that you know that that height is x. Now, what is the meaning of the volume of the strip, let us see. Now, if you cut this ship you know in with respect to the mean if you see the ship from the top actually, now this is the profile view. I am looking at the ship from the side.

Now, suppose if I look at the ship from the top, then perhaps you know you are getting this blue region like I mean this may be the view of the ship, if you look from the top. So, therefore, you can understand then this consists of some kind of area. So, essentially, what is actually the total volume is the extra volume I would say which is nothing but this area that you are getting it and multiply by the displacement. So, this is basically the extra volume that actually we are going to get right.

So, now the term of the series called the A_{wp} right and you multiply by the x. So, it become a volume. Now, therefore, this is the extra volume that we are getting when you displace the ship by you know let us say this vertical displacement x and if you multiply with this with the ρ g, definitely you are going to get the exciting I mean sorry the restoring component in the direction of the heave right.

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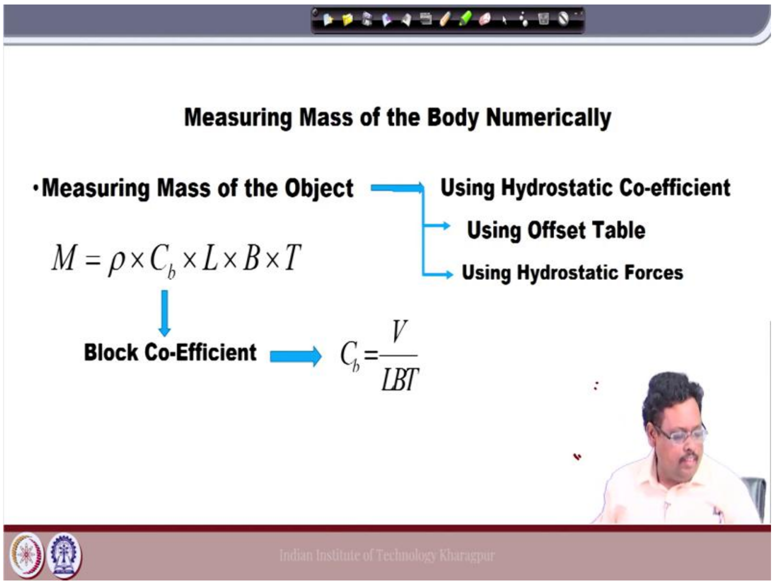

So, now, we are going to measure the mass of the body ok. So, how to get the mass of the body so, actually there are different way to measure it ok. So, first thing, we can use some hydrostatic coefficients or we can use some kind of offset table or we can use some hydrostatic forces with respect to the hydrostatic forces. So, we are going to discuss one by one all these three things ok.

So, now, what is the formula for mass? Now, here you can see like we have a mass equal to ρ multiply by some unknown quantity here which is referred at C_b and then, we have L; L is the length of the ship, B is the breadth of the ship and T is the draft of the ship. Draft means the height of the weighted surface ok. Now, this C_b is known as the block coefficient, where we are going to discuss what is the meaning of the block coefficient etcetera.

Now, this is the formula for the block coefficient $C_B = \frac{\nabla}{LBT}$. Now, we can understand that if you know; so, this is the geometric parameter that C_B is the geometric parameter that actually we are going to use like that will be the input to you.

For example, we know the C_B we can roughly estimate the C_B for different kind of vessel like for container vessel or maybe some passenger vessel; everywhere the C_B is known to you, it is a geometric parameter ok and if you know this and of course, you know what is the length of the vessel; what is the breadth of the vessel; what is the draft of the vessel. So, very easily you can find out what is the mass ok.

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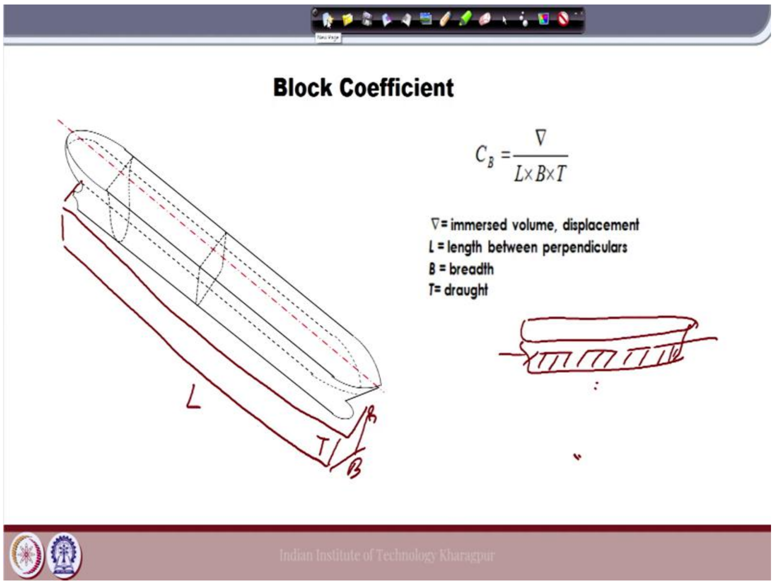

Now, let us see what is the meaning of this block coefficient ok. Now, you see here the $C_B = \frac{\nabla}{LBT}$. Now, this actually ∇ or Δ, it is regarded as the immersed volume or the displacement. The immersed volume is nothing but the volume of the ship below the water. Now, we can see that if you draw a ship, then some part is above the water, some part is below the water right.

So, now, for example, if you let us just I just draw a rough sketch. So, then, if you draw this, you can call this as a water line. So, this part is basically the below the water and this part is above the water. So, we really do not care about the part of the body which is above the water, but the part of the body which is below the water, if you calculate the volume of this and now, if you enclose this volume by some rectangular box ok. So, let us say this is the volume. So, I just enclose this the whole mass with respect to a rectangular box like this.

So, length of the box is L and B is the breadth, height is T. So, the ratio is gives you the block coefficient ok. So, if you have the block coefficient known to you, if it is give if it is given to you, then very easily you can calculate what is the volume of the vessel and then, subsequently, you can calculate what is the mass of your vessel; but actually it is not given to you sometimes, I mean, most of the times.

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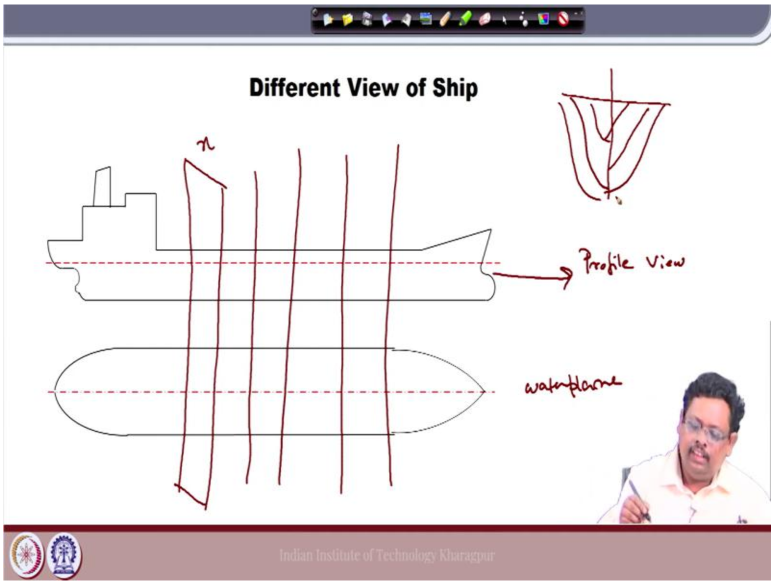

Then, actually, we have to go with the offset table. Now, before we go into the offset table, let us try to understand the different you know view two-dimensional view of a three-dimensional ship right and this visualization is very important right.

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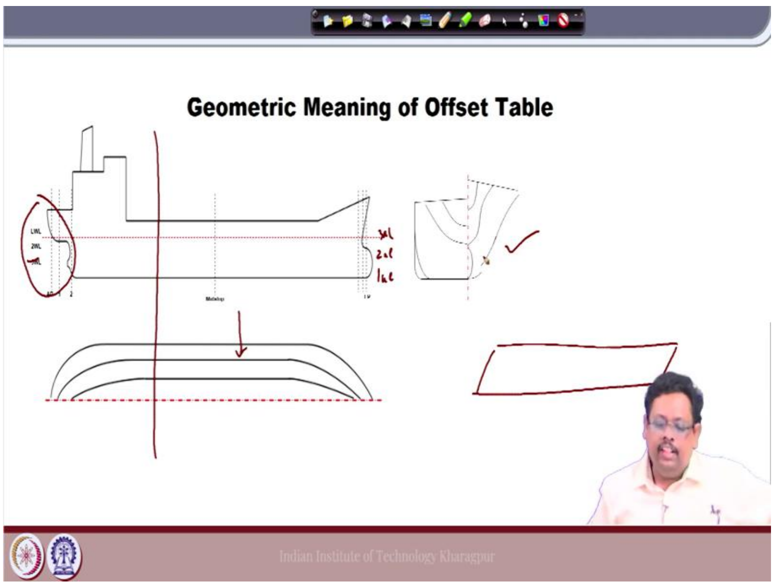

For example, now, this view is called the profile view. So, this view we call as profile view. So, that means, I am looking from the ship from this side and ship is moving this way and if I look at the ship from the top, then we can have been a water plane ok and then, this line of course called the water line. Now, where we are going to discuss later on, but you see there is a two way of defining it, but then third which is most important. Suppose, if I cut the ship in some vertical axis like this, then what is going to happen? If I cut it, then definitely, we are going to get a line. For this particular x location, I am cutting it, now this line maybe looks like this.

Now, if you keep cutting this thing with different x location, if you cut the thing in different x location, then we are getting different lines altogether right and this is very important to us to calculate everything ok and this plane is called the body plane fine. So, in the next slide, let us try to see that what is the three different plane.

Now, here you can see this is something is in the left hand side, if you see this side, it is written as some 1WL, 2WL, 3WL; actually normally it should be the opposite. It 1, 2, 3 is from the top; I mean it is the bottom line should be the this should be the 1WL, this is 2WL, this is 3WL, this is a water line.

That means, you know what I do over here is basically is the ship I am cutting from the top. Like in this horizontal plane if I cut and then, we can get this sort of line right and then, if I cut in this line, then we get this sort of line. So, this line, we can we call this is a water line and this we called as a section line one say and we can say that and this section lines actually very important for us to calculate all the volumes. In fact, both the thing you can use for calculating the volumes; but normally, we use the section line to calculate the volume.

Now, if you study hydrostatics, then you know very well what is this line right. Otherwise, lot of books available to find out that what is this profile what is this body plane what is this water plane and all about this sectional lines and the water line. So, this course, we are not going to discuss this is more elaborately. We are just taking this idea and then, we use it for calculation of the volume or mass.

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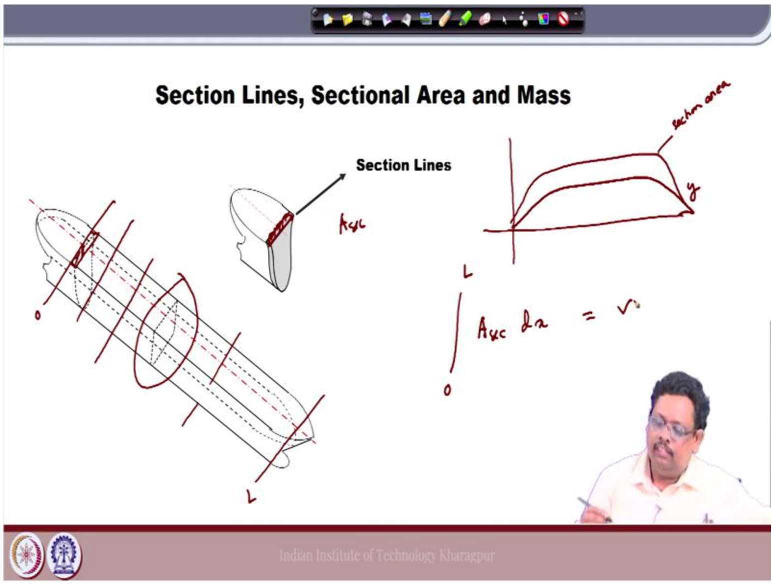

Now, you see here if I cut this, now here interestingly, if I cut in this plane, then definitely we are going to get some section line like this right. Now, here what are we going to do is from this section line, if I cut if you keep cutting, if I keep cutting over here, if I keep cutting over here, if I keep cutting over here; so, what you get? You get multiple section lines right.

Now, in that case, now if you plot a graph right, now you start cutting from this point and you just keep cutting till this point and then, if you get calculate the section lines, the length of the section lines; then, actually what you get is you can get a curve like this right. Now, what you do is this is one thing and then, if you multiply this section line with some width like this.

If you multiply this with this line, then you can get now this is basically you are getting that we can call is a y. Because I am calculating the distance this distance, we can call is y. And also, actually what we can calculate is basically we can calculate this y multiply by some depth and then, what you get we can get maybe some another line like this and this is basically the section area right.

Now, if you integrate this section area, now it is let us say starting from 0 and some L. If you integrate this section area from 0 to L and we can call this section area, let us say A section. So, if you calculate this section area along the horizontal line, then definitely, you are going to get the volume right. So, this is the one way actually how we can calculate the volume right.

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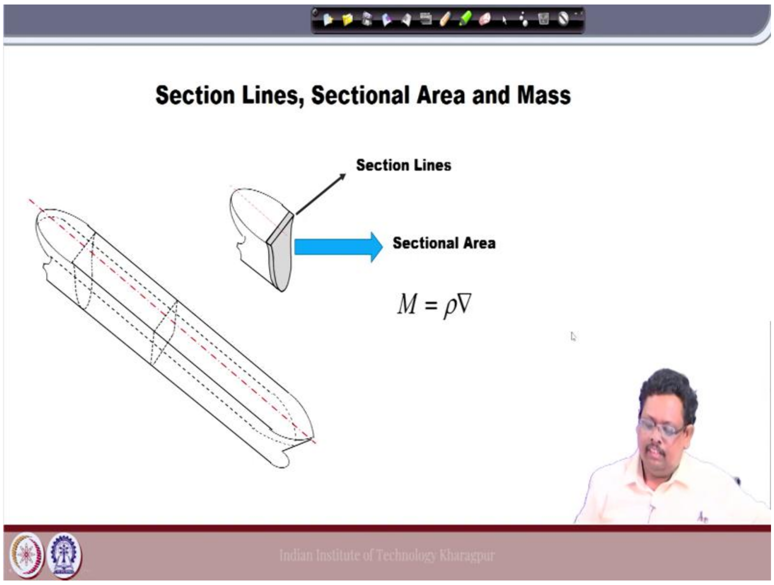

So, this is easy. Then, this is what is explained over here right. So, this is how actually you are going to calculate my volume.

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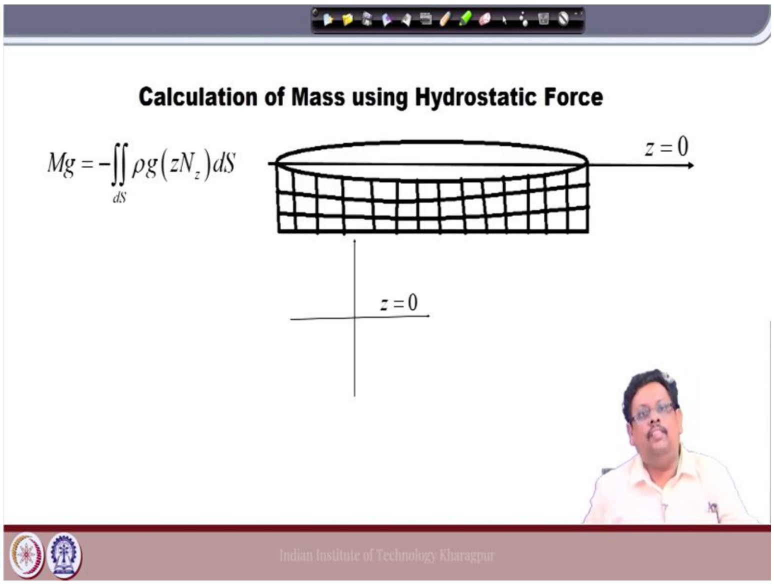

Now, let us try to find out suppose we do not have the section lines, I mean we definitely we can have the section lines; but suppose a mesh is given to you. Now, you know nowadays, what we are what actually people are going to do is they are normally have a ship, they model in some fancy software like Ansys or Maxsurf in many software's and they come up with kind of mesh right.

So, you are not really given the offset table, where actually at each you know in offset table, what you are getting is like for each section, you can have the section lines. So, this is the that information is stored in the offset table. You give in a section, I can I mean give a section like x and then, we get the y right. So, this x versus y for different x location, this is may not be given to you. Let us say it is not given to you.

But what is given to you as follows, the mesh. So, this is let us say is a very crude mesh of course; but this mesh is given to you right. And also, you can see that here our only interest is actually up to the water level 0 because after this, it is air. So, we are not really care about what is happening there. So, the mesh till the point actually it is called the weighted surface. So, below z equal to 0, all are the weighted surface right.

Now, suppose this is given to you, then how you calculate the mass? You do not have the information of the section line. So, you do not need to; you cannot get the section area multiplied by some small dx and then, if you integrate along the x, you will get it. No, this is not possible. So, how you do that? Now, here, I just for you just I am writing the coordinate system z equal to 0 is basically and then, then z is positive upward and may be negative downward ok.

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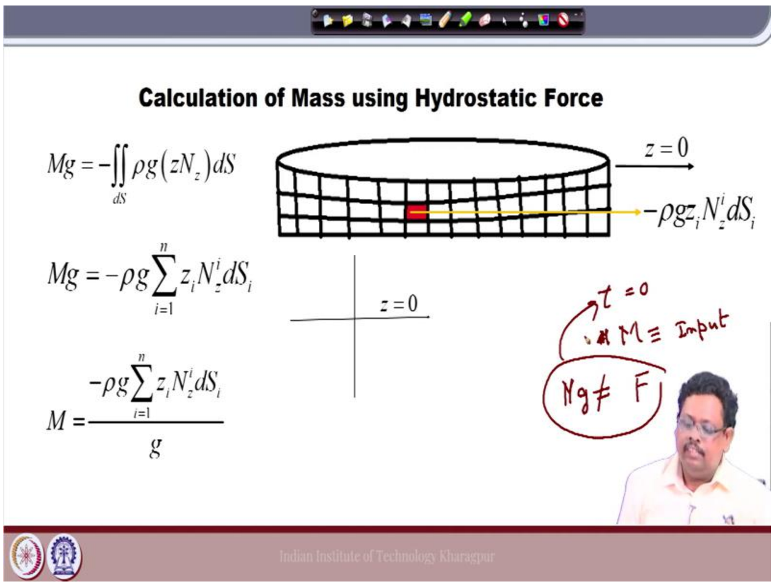

Then, what you going to do is let us take you take a patch, the mesh ok. So, once you take a patch or mesh, then you can calculate the hydrostatic force at that particular patch. Now, how you calculate the hydrostatic force? So, you can take the centroid of this patch right and then, you can define this as your z_i; you can define this as your z_i right and then, you multiply it by ρ into g ok.

So, minus ρ g z_i basically your hydrostatic pressure and this hydrostatic pressure, you multiply by the vertical because you are we are interested to find out the vertical force that mean hydrostatic or buoyancy force. So, therefore, we multiply the normal in the direction of z right of this particular panel and then, if I multiply everything with the area associated with this panel, then I can get the hydrostatic force for this particular patch right.

I am repeating again, I select a patch, the red one; I calculate the hydrostatic pressure at the centroid of that panel and multiply by the normal z direction and then, the area. So, I get the hydrostatic force at this particular point. Now, once I am getting it, once I am getting it, then actually I sum it up. So, that means, I repeat this thing for each panel right or each mesh. I mean normally, we call panel; somebody call mesh. So, at each mesh, we keep doing it and then, we sum everything. Let us say we have the N number of such number of mesh is N.

So, therefore, for each mesh, I do it and then, we sum it up. Then, what I get? I get the hydrostatic force or buoyancy force and that should be equal to my weight right. It is very obvious from your Archimedes principle; the weight is equal to the buoyancy force. So, then, I divide this whole by g and then, I get the mass right.

You see this is the idea and actually, most of the time when we are actually going to calculate the other hydrodynamic forces such as radiation force, such as diffraction force or Froude Krylov force, whatever the forces we are going to discuss later on. If we want to do numerically normally, we are going to use a 3D mesh. We are really not using the offset table.

So, at that particular time, you have to calculate the mass with respect to this. There is a reason for that. So, actually the main reason I will tell you like for example, that at t equal to 0; at t equal to 0 right that mass should be equal to the buoyancy force that if that is the equilibrium condition and you have to you have to ensure that. Now, how do you ensure this? It is you know suppose you know the mass; let us you take mass as input ok. You take this you know this M, you take this as your input ok and then, you do this all hydrostatic force ok and then, you are finding out this Mg is not matching with this hydrostatic force F. Then, what you have?

Then, basically what you are going to have is you have some unbalanced force at t equal to 0 and that cause you some kind of numerical instability. We really do not afford at t equal to 0 any unbalanced force. At that particular moment, your weight and the weight of the vessel should be equal to the buoyancy force. So, we should have a static equilibrium condition, then only we can overcome the initial numerical instability. So, that is why you know doing this is absolutely important for us ok. Now, what are the challenges for this ok?

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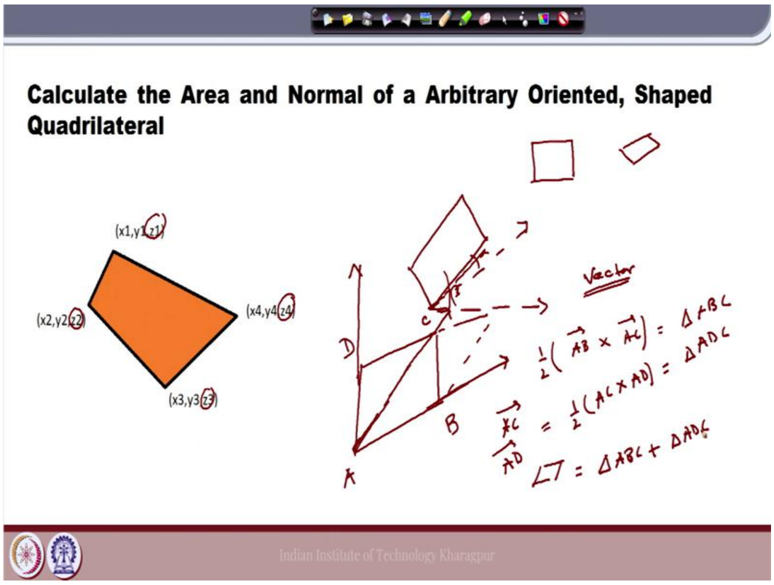

Let’s see that what is the challenges for this. The most challenge basically how I calculate the area of this mesh numerically. Now, you see here like it is not very much clear in this particular that figure that I have that I have shown you. But however, if you look at in typical ship, then actually it is possible that the mesh you are getting is not oriented either vertically or not oriented either you know horizontally. It may have some tilted that quadrilateral may be have some tilt right.

So, if I draw this axis and if I you know this is the axis of y, this is the axis of x. So, you can see it has angle in this is also alpha and this is also beta. So, you can see that you know this, this is tilted; you say you can say the surface. But all x, y, z is varying; it is not that your z is let us say constant for all point right. So, you can see here z1, z2, z3, z4 are different. If z is same, then we can think of it is a it is a horizontal plane. If let us say y is same for each, then you can say it is vertical; if x is same, then it is you know this. But here is the arbitrary plane. Then, how you can calculate the area for this?

Now, there are many methods available; but let us see one is can you can use some vector method; use the help of vector. So, how you do that? Now, you see this one, let me draw this way. I just slightly oriented this one. So, we can call this as A, let us say B and C and D. So, why what we can do is we can define a vector along AB right.

We know how to define the vector along AB and then, we can define a vector along AC right and we know the how I how we can define the vector along AC right and then, if I do this AB x AC, then we can have the area of a parallelepiped this and if you do this half, then we can get the area of angle of the triangle ABC right. And similarly, I define a vector AC, then I define a vector AC and again, I can define a vector AD. So, AC along this and then, you can have AD along this. And again, if I do the half of AC x AD, then definitely, we can get the area of the triangle ADC.

So, therefore, the area of a quadrilateral becomes the area of the triangle ABC plus area of a triangle ADC right. So, this is actually one of the method that we can do right. Now, it has some kind of drawbacks. So, what are the drawbacks? Now, you see here, it is possible like I am taking this the four point, I am assuming what is my assumption is as follows. I am assuming like let's make it in the next slide.

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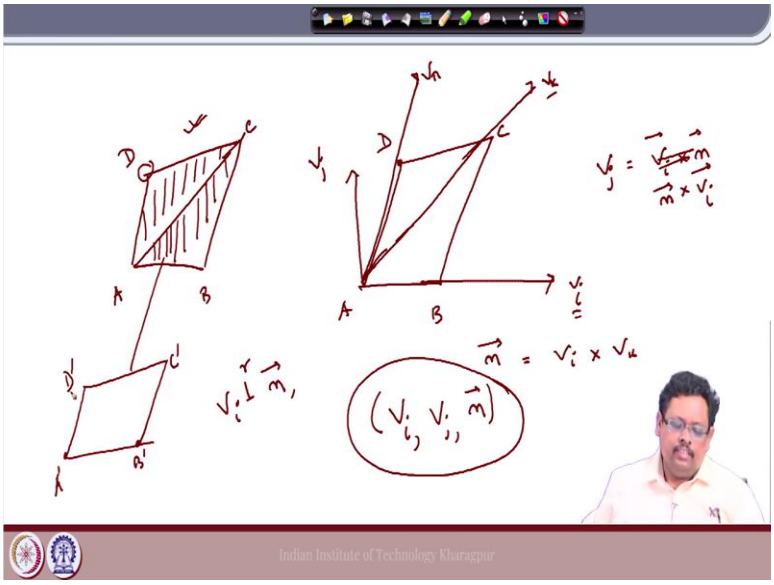

So, what I am assuming here that it is basically it is basically that all this four point is lying in same plane; but it might not be possible. Like here, you can see this four point it is A, this is B, this is C this is D and you can I just try to draw this one to show that that here, this, this and this are plane of course because you need a three point to define a plane.

However, you can see that it in all four point is not lying in a same plane right. It is possible very much; but now if you calculate in the vector method, still I can get the area of this particular. We can say it is a quadrilateral, but it is may not be the quadrilateral right. So, then, these assumptions sometimes work; this assumption sometimes does not work then, how to do this in the in this?

So, we are going to discuss this basically later on, when actually we do this panel method and all that time we discuss this issue. But right now like this is one technique that of course you can do. Essentially philosophical let me tell you what we do is as follows. We define a local coordinate right. How we define a local coordinate? Suppose now, we have this four points here ok.

So, it is now A, B, C and D. Now, I define a vector along AB and let us say it is let us say we can call this V_i let us say and then, we let us say define a vector along AC and let us take it is let us say some V arbitrary let us say V_k. Now, if I make of course, it is the unit vector along V_i ,V_k and V_i, I basically are the unit vector.

Now, I can get a normal vector n just having the cross product of V_i cross V_k. Now, what is happening here? I know that n and V_i are mutually perpendicular right. However, V_i and V_k are not mutually perpendicular right; but I need a local axis. So, I need to have mutually perpendicular another component along the z direction. So, what I do is further what I do we can get V_j by having a cross product on V_i cross n or n cross V_i; you can check it so that orientation, it should be the same.

So, therefore, we can have a local coordinate system V_i V_j and then, n right. So, if it is so then you know V_j should be n cross V_i ok. Now, what is happening now I have basically a mutually perpendicular axis. Now, here this is your local coordinate systems; I have V_i over here, then I have V_j and then, I have a mutually perpendicular V_k.

So, now I have three mutually perpendicular local coordinate system and in this mutually perpendicular local coordinate system, I project the point D. So, suppose the point D is not in a plane; now if I make the projection on this particular plane and after doing projection of all A, B, C, D. So, then I can get essentially a two-dimensional body in local co-ordinate system and then, all I can ensure now this local coordinate system A dash, B dash, C dash and D dash all inside a same plane.

So, this numerical exercise definitely we are going to discuss in later stage. But I am just sharing you the idea; but now at least after this class, we know how to calculate the mass of the body if the section lines are given to you. How to calculate the mass of the body, if the three-dimensional mesh is given to you right? The only challenges you might face that when they make the mesh and if you get the quadrilateral, not necessarily all four points lie in a same plane right.

In that case, you can use we can use this vector technique later on; but at right this moment, I think you know 90 percent case what you get is the you get a quadrilateral, where four point lie in a same plane because all this software also you know make sure that this happens right.

So, normally, this issue normally does not come; but however, to be more safe like we will in future, we are going to discuss this vector local coordinate thing and we are definitely going to discuss how we can find out the mass of the body with respect to this ok. So, today, we are going to end this here and in the next class, we are going to discuss how I can calculate the restoring coefficient numerically.

Thank you.