Introduction to Fluid Mechanics and Fluid Engineering
Prof. Suman Chakraborty
Department of Mechanical Engineering
Indian Institute of Technology – Kharagpur

Lecture – 09
Fluid Statics (Contd.)

We continue with our discussion on force on a plain surface submerged in a fluid. And we take up the same example that we do in the last class and we will try to find out the force on these surfaces by direct integration without going into the standard expression for force. So, here if we recall what is the objective of this problem is to solve that what is the force that is required to keep this gate stationary.

And to do that what we require is to find out the moment of the distributed forces acting on this semicircular plate with respect to the heat point flow that was one of the objectives for writing the equation of equilibrium.

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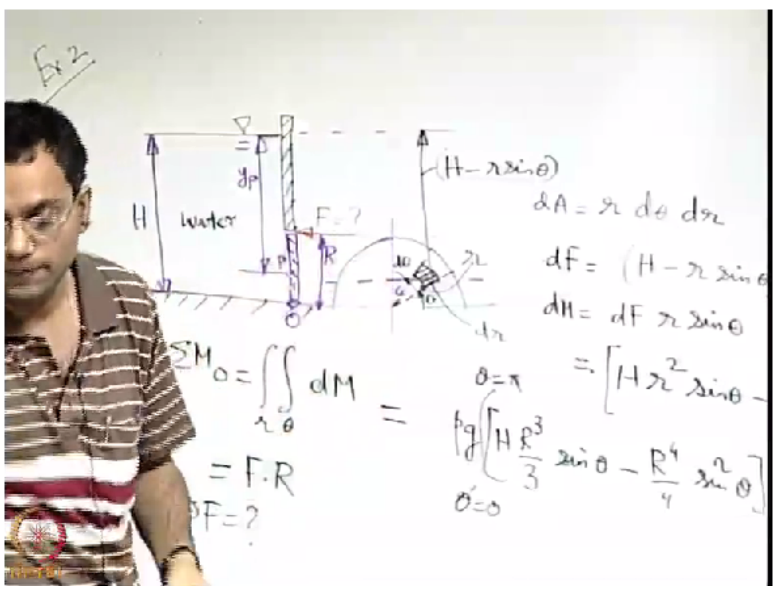

So, to do that what we can take? We can take small element so when you take a small element here you have a, consider a radial and circumferential element simultaneously. So, we can consider a small element shaded like this what is the specification of the small element? It is located or centered around r, theta that means we consider that this is located at a radial location of r and angular location of theta.

The angle subtended by the element is d theta. The radial location is small r which is the radial location of the element. The radial width of the element is dr. So, what is the differential area that is being represented by the element, no question I just shaded element the shaded area. So, it is roughly like a rectangle one of the sides is rd theta another side is dr. So, rd theta dr. What is the force that acts on this element due to pressure? What is the pressure acting on this element?

It is located to the local height of the element. What is this local height? So, H is the total height, -r sin theta. So the force acting on this df =H-r sin theta* rho* g* r d theta dr. What is the movement of this force with respect to o? So this into r sin theta so if we can break it up into 2 terms multiply these by r sin theta. So, it will be H r square sin theta –r cube sin square theta * rho g d theta dr.

Now, the total moment of this distributed force with respect to the .o is integral of this dM. Now, when you consider the integral, the integral is with respect to both theta as well r. It is a double integral. So, you may evaluate the integral with respect to r first or theta first. It is irrelevant. Let us say that you want to evaluate the integral with respect to r first. So, you have first the integral with respect to r. So, when you have integral with respect to r small r varies from 0 to R.

So, the first term becomes this is r square dr that means r cube/3. This we are integrating with respect to R sin theta –this is r cube dr so R to the power 4/4 sin square theta d theta. Now, integral with respect to theta. What is the limit of theta? 0 to pi. The remaining work is very simple I need not complete this one. There are very integrals and you can complete yourself. So, once you complete these integral.

You will get an expression for resultant movement of the distributed force with respect to 0 in terms of HR and of course rho and g. And this resultant movement =F*R so that will tell you what is the value of A. We have seen that why it is so because all other forces acting through it will pass through o so they will have no movement with respect to o. So, this is just like these are the 2 counter acting.

So, this example shows that whenever you have a force on a surface it is not necessary that you have to go by the formula that we have derived you may as well take a small element consider pressure distribution over the small element and find out what is the resultant force due to that pressure distribution resultant movement and so on by fundamentally integrating into over the entire area without going into the formula.

Next what we will consider is force on a curve surface. Now can you tell me what is the fundamental difference or what do you expect the fundament difference to be as compared to the force on a plain surface.

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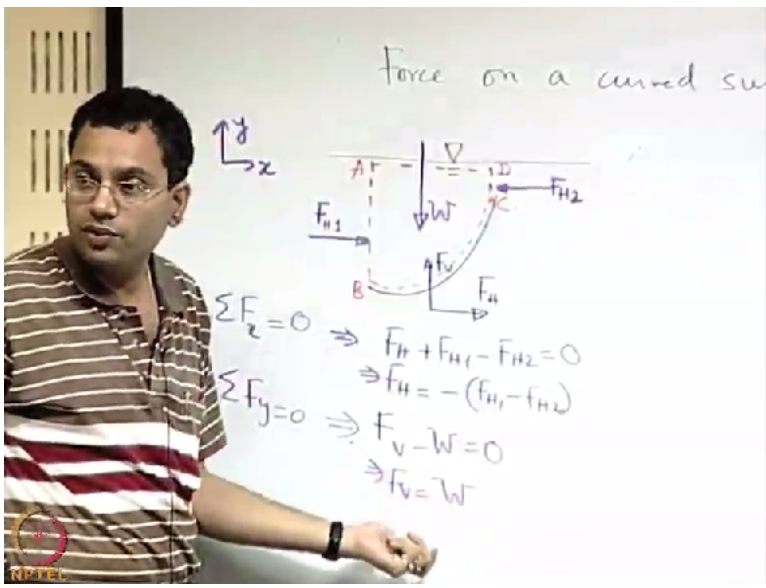

How you expect force on a curve surface to be different conceptually? Force on a curve surface, again what is this surface? This is immersed in a fluid at rest that we are not repeating. Let us say the surface is something like this. Again if you see this surface is actually something like this and there is some fluid on one side and that fluid is exerting some force on the surface. So, this is again edge view of the surface.

Earlier we were concentrating on force on a surface like this which is a plain surface now it is a curve surface. So, you can understand the geometrical difference that is why fundamentally in terms of basic mechanics how do you expect these to be different as compare to that for force on a plain surface. Force direction changes as you move from one point to the other point that means it is not a system of parallel forces.

So, the plain surface has to deal with a system of parallel forces so you can treat it like a scalar addition problem or a scalar summation problem. Where as in this case it is having the pressure always acting normal to the boundary. Normal to the boundary is a direction that is changing from one point to the other and therefor the resultant force is being dictated by a varying direction of the surface.

So you no more have a system of parallel elements which is giving rise to the resultant. So, whenever you are adding here to make the resultant force it has to be a true vector addition. It is not just by adding it up in a scalar way. Integration is nothing but summing up the individual components and you could see that a very simple integration gives the same result for force on a plain surface.

For a curve surface therefor fundamentally the principle the same that is you take element of the curve surface to find out what is the force acting on it. The force acting on it will be normal to it. You may break it up into components horizontal and vertical component in this way for each of the elements you can find out the horizontal and vertical components algebraically sum them up and make the vector addition.

So, this is something which is very trivial. Now, it is possible sometimes to reduce the calculation a little bit by taking some help from the concept of force on a plain surface. Let us see how? Just consider that there is a fluid column like this. This is a volume of fluid which we are considering to be located within the projected part of this curved surface. So, in this end of the curve surfaces are projected to the free surface.

Whatever volume is contained within that contained volume is enclosed by this dotted line. Now, let us say that we are interested on the forces which are acting on these volume of fluid. So, these volumes are now having 2 plain surfaces. 3 plain surfaces but forget about the top surface. Just for the time being consider the side surfaces. So, if you consider the volume say A, B, C, D the surfaces AB, and CD are plain surfaces.

And let us see that what are the forces which are acting on this plain surfaces? So, we are essentially trying to draw a free body diagram on the volume element which is enclosed by this dotted line. What are the forces which are acting on this? So, when you have the left phase there is some fluid towards the left of it that exerts a force due to pressure. What will be the direction of that force? Let us say we set up coordinates like this x and y.

So, what will be the direction of that force? x, so we call it a horizontal force assuming that x is a horizontal direction. Let us say that if H or FH1 is the horizontal force acting from the left towards this element. Similarly, if you have some fluid again on this side there will be a horizontal force FH2 acting from the other side towards this remember this force is due to pressure. It is compressive in nature so whatever is the fluid element located on the other side.

It is having a tendency to compress it. And that is how the sense of these vectors are there. There are the horizontal components of the forces on these sides. What are the additional forces on this element? It should have its own width. So, whatever water or fluid is contained here that will have its weight say W. Any other force? There is a reaction between the surface and the fluid and that reaction again is likely to have 2 components.

One is the horizontal component and other is the vertical component. So, let us say that it has horizontal component FH and a vertical component FV. What are these? These are the components of the reaction forces exerted by the curve surface on the fluid. Now, the fluid is in equilibrium. So, when the fluid is in equilibrium you must have resultant force along x =0 so you have FH+FH1-FH2=0.

That means FH = - FH1-FH2 then resultant force along y =0. What it means? Fv –W=0 that means Fv=W. From this apparently very simple calculation we come up with a very interesting result that is if you have a curve surface still whatever forces which are acting on it you may resolve it into 2 components. For the horizontal component it is basically the resultant force on the horizontal projections or on the projection of these curves.

Ends of the curves on a vertical plan or so called horizontal components of the forces on vertical projections of the ends of the curve. That means if you have a curve like this when you consider the end this end when you consider its projection the projection is just like this. So, we are basically having to consider a horizontal component of force for the left. A horizontal component of force for the right and the difference of these 2 are actually giving the horizontal component of net force.

For the vertical component it is just the weight of the fluid that is being contained within these extended volumes. So, if you somehow can calculate the weight of the fluid and that is as good as calculating the volume of the fluid. Because then you can use the density to calculate the weight of the fluid. So, whatever fluid is contained here within these doted lines, weight of that fluid is the vertical component of the force.

And whatever the horizontal component of force or whatever is the force because of pressure on the projections taken from the sides of these curves that contributes to the resultant horizontal force. And remember that these are the forces exerted by the curve surface on the fluid. We are interested in the other thing the opposite thing that is what is the force on the curve surface. So, by Newtons third law those are just negative of this one.

So –FH and –FV are the forces which are exerted by the fluid on the curve surface. Let us take an example to see that how we calculate it.

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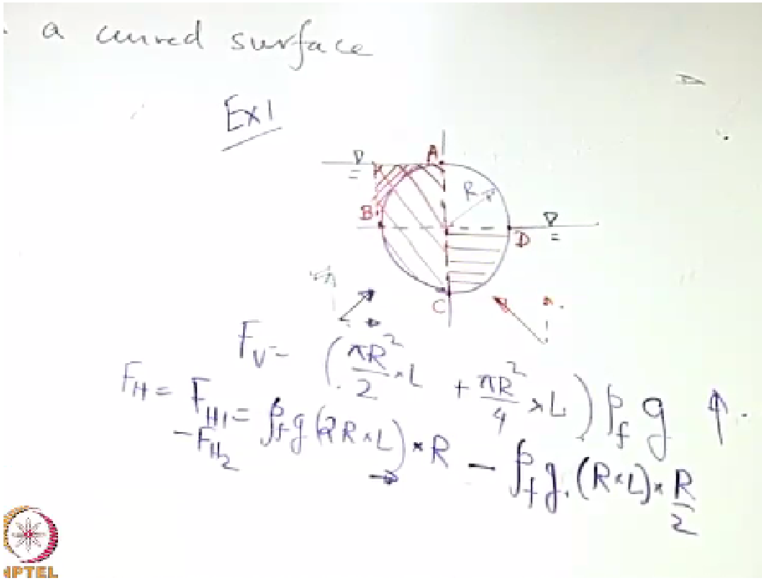

Let us say that we have a long circular cylinder and you have the free surface of the fluid in this way. So, on the left side this is the free surface on the right this is the free surface and the solid material is a circular cylinder long its length is perpendicular to the plain of the (()) (18:12). We are interested to find out what is the resultant horizontal and vertical component of force exerted by the fluid on this (()) (18:21). So, what we will do is we will keep some names of or we will keep some markers to important of the surface.

Say the 4 important points A, B, C, and D and we will consider the forces acting on this curve surface one-by-one. So, if let us consider the force acting on AB, first let us consider the vertical components of forces then we will do the horizontal component. So, for vertical component what we want? We should raise projections from the end of the surface till reaches the free surface. Whatever is the volume of the fluid contained within that it is the weight of that.

So, for the part AB it is like this. Next, let us consider the part DC so when you consider the part AB and you know the vertical component of force is it downward or upwards? It is downwards from common sense it is clear that the pressure is being exerted in such a way that it is vertical component is downwards. Now, consider BC. So, for BC what we do again we raise the projection from one end it is like this.

From C we raise the projection up to the free surface so whatever is the volume that is contained within this. So, what volume is contained within this? This is the volume that is contained between BC and its projected parts up to the free fluid surface. So, this is an imaginary volume of fluid and what will be the direction of the vertical component of the force acting on it? Upwards or downwards?

How do you make it out? just see that if you have BC like this you will have the pressure acting on it this way its vertical component will be upward. So, it is such a distributed pressure over BC. So, look into the fundamental origin that will give you the guideline whether the resultant force is upward or downward on that part of the surface. Now, when you consider this 2 together you can see the common part.

Which is shaded once it has come downwards another it has come upwards. So, they have canceled out so what remains is the fluid equivalent to the volume of half of the cylinder for this half part. So, what is the vertical component of force acting on say A, B, C. It is nothing but the equivalent to the weight of the volume of half of this cylinder. Weight of what? Weight of the fluid equivalent to the volume of the half of the cylinder.

So, that means as if it has displaced up to it equivalent to its volume and that is exerting it an upthrust. This is nothing but the Archimedes' principle that you have learnt in high school physics. So, in effect what is happening when the solid is being immersed in a fluid it tends to displace a volume of fluid which is equivalent to the volume which is immersed and that tends to exert an up thrust, net up thrust and that up thrust is nothing.

But same as the weight of the displaced volume of fluid by that particular volume of solid. Now, if you come CD so for CD how you calculate the force vertical component of the force? So, you extend it up to the free surface so for this part the free surface is up to the level shown. So, it is nothing but the volume of this much. So is it upwards or downwards? It is upwards. So, if you have the pressure acting in this way its vertical component will be upwards.

So, the resultant is upwards with what magnitude if r is the radius of this cylinder? So, what is the volume corresponding to the left part that is pi R square/ 2*L where L is the length of the cylinder. Then this part is pi r square/ 4 * L. This is the volume that multiplied by the density of the fluid. Not density of cylinder but density of the fluid * g and acting upwards. So, this is the resultant vertical component upwards.

How can you calculate that what is the location through which the resultant of these force passes? So, it will definitely be passing through the centroid of the displaced volume and then it boils down to the calculation of the centroid of the displaced volume. We are not going into that you can do it by simple statistics. How do you calculate the horizontal component of force? So, again you have something in the left and something in the right.

So, when you have this A, B, C on A, B, C what is the horizontal component of force? Let us say that is FH1 just following this symbol and on CD there is a horizontal component of force say that is FH2. So, FH1 is what? What is its projected area on which you are considering that because this is now equivalent to force on a plain surface. So, 2R is the height and L is the length.

So, its projection on the side view is 2R is its height because 2R is the height of the cylinder and L length perpendicular to the plain of the figure. So, if you recall what is the resultant force flow of the fluid g into A, what is A? 2R*L that is the equivalent projected area*AC. What is AC? AC is just R so when you say HC, HC is the location of the centroid of the projected area not the curved area.

So, it is the location of the centroid of the projected area from the free surface. So, that is FH1. Is it towards right or left? It is towards right because again you can see that its horizontal component is towards right. So, this is towards right and then on CD what is FH? First of all it is acting towards left, its horizontal component. So, we put a minus sign again rho g. What is the projected area?

Into R*L* R/2 which is the location of the centroid of the projected area vertical location from the free surface. So, this is FH1 –FH2 that is FH hence you can calculate what is the resultant. So, these are 2 individual components you can find out the resultant by vector addition so that is trivial. Let us consider a second example.

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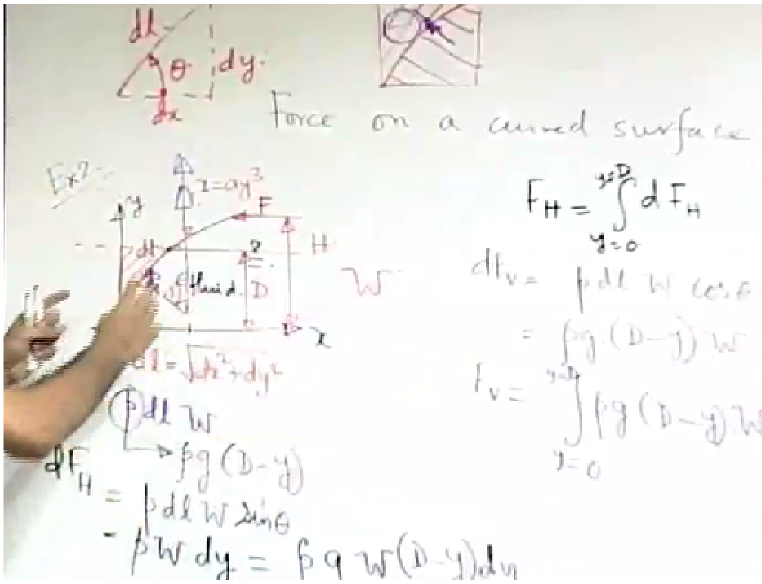

Let us say that you have a curved gate instead of a plain gate you have a curve gate and there is fluid on one side of it. Say you have fluid on this side there is a free surface of the fluid given by this and this fluid tries to exert some force on this curve surface and there is some balancer so there is some external force which is applied here to keep it in equilibrium and the location of this external force is given by this H and the depth to which this fluid is filled up is D.

So, why such problems are practically important? Let us look into maybe 1 or 2 practical cases to see that why such effects are important? So, we will look into some example applications. (()) (28:48) If you clearly see this is like a dam. So there are forces which are exerted by water and these force components are like these are quite heavy or large forces huge forces which are acting and the structure must be strong enough to sustain it.

And it is very common and to save us from floods or other calamities there are many occasions where there are reservoirs in which these water supply the store. So, until or unless the rainfall is very, very sevier it retains its height. But once the rainfall is so strong it cannot retain its height so some of the water has to be released. And when the water is not released it is under static condition and it has to be calculated on the bases of fluid statics condition.

The resultant forces and the situation of equilibrium of course when the water is very, very dynamic then we do not consider the fluid statistic. But you consider even the dynamic effect of water as it (()) (30:14) on the surface. So, you can see the shape of the so called dam it is not really a plain surface but it is a curve surface. It is like an arch type. There are fluids at different ends and it is important to calculate that what is the resultant force that is there.

So, that is the motivation behind solving such a problem that it gives you a clue of how to design may be dams or sluice gates where across which you have different fluid elements which are exerting forces. So, here on one side you have some fluid element as say water on another side say atmosphere. So, on the right side there is water in this example and we want to calculate what are the resultant force so what we will do we may solve this in again 2 ways.

One is by looking into horizontal and vertical components of forces according to the principle that you have just seen. Or maybe just by direct integration of the forces on elements. So, if we do that the second one is little bit may be easy to begin with. So, let us say that we have considered a small element here at a location x, y. For idealization let us say that this curve surface where its projection is considered.

It had the equation x=ay which is the equation of this curve. So, at the x, y if you consider a small element say of size dl then what is the resultant force due to pressure on dl. First of all, how to specify this dl? Say at x, y we can consider a dl which is comprising of the resultant some displacement along x to dx and some displacement along y say dy. So dl may be written as good as square root of dx square + dy square.

So, if you draw a magnified figure if this is dl it is like sum of dx along x dy along y. If this is a small part of the curve this is approximately tangent to the curve at this point. At that x, y and so you can consider that this angle theta is in net the local slope of the curve at that point where it is aligned with the tangent to the curve at x, y. So, we know what is dl if you know what is the width of the fluid or what is the width of the gate say w is the width of the gate.

Then w into dl is the area on which the fluid pressure is acting. So, what will be the direction of the action of the fluid pressure? It is acting in this way normal to the surface. So, that will have 2 components one is the horizontal component and another is the vertical component. So, how do you calculate the horizontal component and the vertical component? First of all, what is the force because of this.

It is P *dl into W, where p is the pressure at x, y so how it is related to the depth capital D? So, how can you write express p in terms of the depth D? rho g* so the height of this is D-y from the pre-surface. This is the resultant force but if we break it up into component that is what is our objective and we should break it up into components. Because, we cannot just integrate it like this.

Because the direction of such force on each element is changing so we cannot just algebraically or scalar add. We should take out extract individual components and then add up the components. So, when we take the horizontal component, what is the horizontal component because of this? So, this is the resultant force so the dl makes theta with the horizontal. So, normal to the dl should make an angle theta with the vertical.

So, the horizontal force is p dl w* sin theta. Now, if you look into this figure dl sin theta is nothing but dy. So, p*w*dy so let us call this as dFH because this is just on a differentially small area. So, rho g w D-y dy. How can you calculate the vertical component of the force? So, calculating horizontal component straight forward you just integrate it. So, when you integrate it let us try to write the complete expression.

I will leave the integral on you but at least let us write the complete expression. So, FH is integral of dFH. What should be the limit over which you integrate? Y=0 to y=D. Something very interesting it shows as if this is independent of the function of the graph x=ay cube. It does not matter what is x. And intuitively it is supposed to be that way because when you take the projection of the surface in the side plain.

Does not matter how it is curved because the projection will always be straight. So you just required to know the extent of the depth and you can verify that this will be nothing but the projection on the surface which is basically surface projected on a vertical plain. And the same horizontal component of force will come out that exercise. What about the vertical component of the force? So, dFv so it is pdl w cos theta.

So, rho g D-y *W, what is dl cos theta? dx. So, now you may express either x in terms of y or y in terms of x. The function is given and if we integrate you will be getting the total vertical force. So, Fv is so tx you can write as say 3 ay square dy and you can now take the limit from y=0 to y=D. We will not go into the integration in details because it is a very simple integration and it is not worth to waste time just on that.

But we will focus on something which is bit more important. That is let us say that we want to find out the same vertical component of force but using the method of the weight of the fluid that is contained within that projected field. One way to see that whether it is correct or not is that if we find out that weight and we come up with an expression it should be same as this one. So, that you can of course find out the way.

And check that the expression at the end is the same as what you get out of this integral. But even before that how you qualitatively assess it. So, what was our method? You project from the corners vertical lines which meat the free surface or its extended form. So, one line projected here and another it becomes a point and it should be the shaded volume of (()) (40:26). If I were in your place the first question that would have come to my mind is there is no fluid here.

So, how can you claim that weight of this shaded volume of fluid will give you the vertical component. So, just think in this way. Let us say that this is a curve surface and let us consider that there is volume of fluid one on this side another on this side. If that was the case, then you can see that in a static condition it is naturally in equilibrium because what is the force due to pressure from one side? The same is the force due to the pressure on the other side.

So, the 2 sides are keeping it in equilibrium. Now, when you do not have a fluid here that means that this part is minus it is subtracted. So, it is a condition equivalent to a deviation from equilibrium because of a lack of presence of this rather than the real presence of this. So, the deviation from equilibrium is because of this equivalent volume of element which is in the upper part.

So, if you calculate that volume of fluid and find the corresponding weight of that you will see that you will get it exactly the same as this one. And you can clearly tell that what should be the direction of vertical component of force acting on this. Upwards or downwards? Upwards because the vertical component of this one is like upwards and directed in this way. So, it is not apparently the vertical component of this shaded volume of fluid.

Because it will appear that if there is a volume of fluid here its weight should act downwards. You have to remember it is an imaginary volume of fluid and it is just giving you the equivalent volume that needs to be employed for calculation of vertical component of force. the exact sense of the force has to be determined from the physical meaning of these type. So, if you subtract a kind of volume like this it is as good as extra upward force.

Because something is missing some weight is missing from the top. Otherwise also from the direction of pressure itself it will follow. So, either way whenever you are calculating either by the fundamental method of finding force components or individual elements summing the vector, summing them up that means summing up scalar forms in terms of the x and the y or the horizontal or the vertical components or finding out the vertical and the horizontal components.

By the alternative method that we have seen. Whatever is it you must asset it in the correct sense from the physical condition and that will not always be dictated by the rule based. It will come from the consideration of where is the volume of fluid that is present is exerting the force and what is the sense of that force when it is exerting a pressure on the (()) (44:01). So, that consideration should give you the proper sense of the vertical component of the force.

Now, we have considered force components on plain and curve surfaces. We have seen that there are some simple ways by which we can evaluate these force components. Now what we have assumed is that when the surface is put in the fluid the surface is in equilibrium and that equilibrium is not disturbed. But if there is a slight tilt because of whatever reason then that equilibrium may be disturbed.

And if that equilibrium is disturbed what will happen we will have to understand. So, we have to now go through the concept of stability of floating and submerged bodies.

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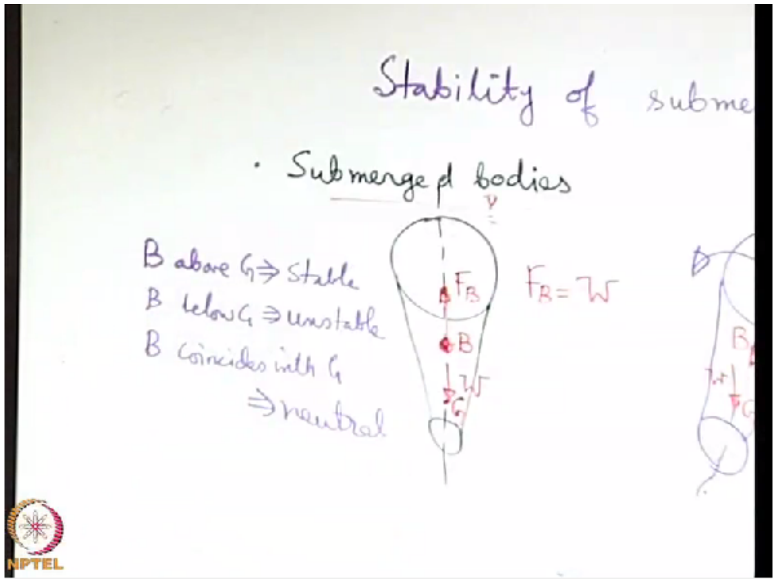

Let us say that first we consider submerged bodies. So, submerged body is something which is completely immersed in the fluid and floating means a part is at the top I means above the free surface and the (()) (45:34) below the free surface. So, let us take an example. Let us say that we have this kind of a body likes like a parachute type. The top is light and bottom is heavy because of the added mass.

Initially it is completely submerged and the resultant forces whatever are acting on this you may write in terms of the buoyancy force and the weight. So, the buoyancy force will be acting through some point and the weight will be acting through some point. So, the bouncy force is based on the volume which is submerged not the mass. So, when you consider the volume that is submerged the greater portion of the volume is at the top.

So, may be the resultant buoyancy force act through this. But the mass is more concentrated towards the bottom so the weight may be is more concentrated of the resultant force due to the weight distribution is passing through the point which is g, or the center of gravity that is located somewhat below. And the resultant buoyancy force is now acting through some point B. So, what is the point B?

So, B is the so called center of buoyancy that means whatever is the location of the centroid of the displaced body. So, it is fully a geometrical concept whereas when you have Ge this depends on the distribution of mass over the body. So, this is something where for equilibrium you have FB=W it is in equilibrium. Now, let us say that you have slightly tilted it. So, when you have slightly tilted it, it has a deformed not deformed but deflected configuration like this.

So, its axis has got tilted from the original vertical one may be because of some disturbance. Now, the entire body is within the fluid therefor the location of the center of buoyancy force and center of gravity relative to the body does not change because the entire body is within the fluid itself. So, if you have say this as G, this still remains as g if you have this as B, it still remains as B.

Because it is already totally within the fluid so its volume distribution within the fluid, its mass distribution everything it does not change. So, you have FB acting like this you have W acting like this. Only thing what has now changed is that no more FB and W are collinear. So when they are not collinear they will still be equal and opposite forces but not passing along the same line so it will creat a couple moment.

So, what will that couple moment try to do? So, if you see the sense of this couple moment what it will try to do? So it will try to create a rotation like this which is shown in the figure. If you look into the senses of the forces and these rotations what they will try to do? It will try to bring it back to its original position or configuration. So, we call it a restoring movement. On the other hand, if g was above B then this would have been downward.

And this should have upwards and that would have tried to increase the angular displacement even further. So, what is the whole mark of a stability, stable equilibrium that is if you have a slight displacement it will try to come back or be restored to its original configuration. So, this type of situation ensures that it takes to come back to its original configuration. However, if g was above me it would have tried to increase the angular displacement even further not restoring.

But helping the disturbance. So, in that way it will be unstable equilibrium. What would be the situation if B and G are coincident somehow so wherever it is there still it will be a collinear say you have somehow an arrangement where you have this as B, the same point is G. So, this is B this is as good as G. So, whatever is the weight and the buoyancy they are always acting along the same line no matter whether it is tilted or not.

So, wherever it is tilted it will locally attain equilibrium and that equilibrium is known as neutral equilibrium. So, the stability of submerged bodies the equilibrium condition depends on the relative location of B with respect of G. So, what we can summarize from this if B is above G what it will imply. It will imply stable equilibrium. If B is below G it is unstable equilibrium and if B coincides with G that is neutral equilibrium.

So, far so good but we have to remember that submerged bodies are not the only types of bodies that we need to consider many practical examples are cases of floating bodies like ships. So, a part is within the fluid and the part is outside the fluid. So, what will be the situation for that let us take an example. Let us consider a floating body. So, when you consider a floating body let us see that how is it different first from a submerged body.

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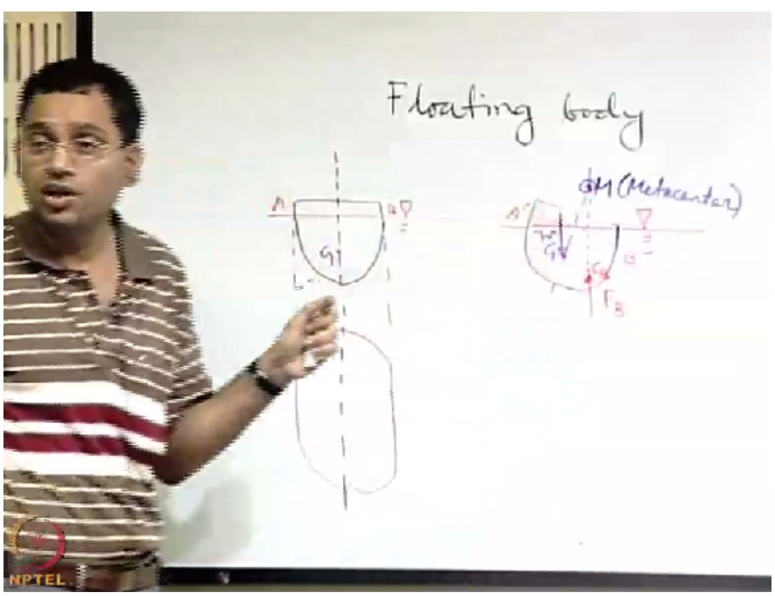

So, let us say that this is a free surface of a fluid. This is the body which is floating something like a boat shape or similar to that. If you consider its intersection with the free surface of the fluid that is the sectional view of the intersection with the fluid. Let us say that it is something like this. So, this part which we have drawn is like this one whatever we have drawn that plain is like this. Now, this we are assuming that this is having an axis of symmetry.

Say this is the axis of symmetry now let us say that this is tilted. Let us see what happens this is tilted? We will assume that this is tilted very slightly because when you test the stability we just give a small displacement and see how it responds to the small disturbance. So, we just tilt it like this and it comes to this configuration. So, whatever the line of interface before now say that line of interface has with relative to the body whatever was the line say AB.

Now say it becomes A prime, B prime. If it is symmetrical with respect to the axis over which it tilts, you will see that one interesting thing has happened. What is that interesting thing? Some new part has gone down into the fluid. Some new part has come up and if it is very symmetric these 2 parts are of same volume. So, the volume that was earlier immersed is the still the same. But the distribution of the volume has changed.

So, once the distribution of volume has changed what has happened? The center of buoyancy has changed. So, there is no sanctity with respect to the location of the center of buoyancy that is very, very important. So, for the submersed body when you have the location of the center of buoyancy relative to the body it does not change whereas when you have a floating body depending on its tilted configuration.

There will be an extent of dominance of one side of the body relative to its immersed condition with respect to the other and accordingly there will be a bias. There will be a preferred side across which the center of buoyancy will be moving. So, the center of buoyancy cannot be one of the fixed parameters with respect to which we may decide whether it will be stable or not that is the first thing. So, the stability criteria for submerged bodies will not work.

So, whenever we are trying to learn something new we have to understand that why are we trying to learn it afresh. I mean if the same criteria for submerged bodies would have worked we would not have not have gone into this exercise. So, first we are getting that motivation that how or where is the difference? The difference again I sum up is like this the center of buoyancy location is now not fixed with respect to the body but it goes on evolving as the body is tilting.

So, let us say that the center of buoyancy now comes to this possible say CB. We expect that it would be coming towards this direction because it now tilted towards the right. So, more part of body is now into the fluid towards the right. So, you have the center of buoyancy in this way. So, you have the resultant buoyancy force like this. The center of gravity is something which is fixed with reference to the body that does not change.

So, if the center of gravity earlier was say relative to the body here. Let us say that the center of gravity is still here. So, the weight of the body is like this. So, now again you can see that there is a couple moment and whether it is restoring or helping it depends on that if it is extended where it will meet the axis. If it meets down of phase 1 then it is one way. If it meets above g it is the other way. So, where it meets the axis that point is known as metacentre.

So, in our next class we will see that what is the consequence of this meta center and how the location of the meta center will dictate the stability under this condition. So, it is not the center of buoyancy that is important here but the location of the metacentre relative to the body is what is going to decide whether the body should be stable or not for a floating body. That we will take up in the next class. Thank you.