**Introduction to Fluid Mechanics and Fluid Engineering**
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**Lecture - 08**
**Fluid Statics (Contd.)**

We continue with our discussions on fluid statics and what we will first do today is we will see some other mechanisms by which you can measure the pressure of the fluid. In the last class we saw the example of barometer today we will first see the example of a manometer.

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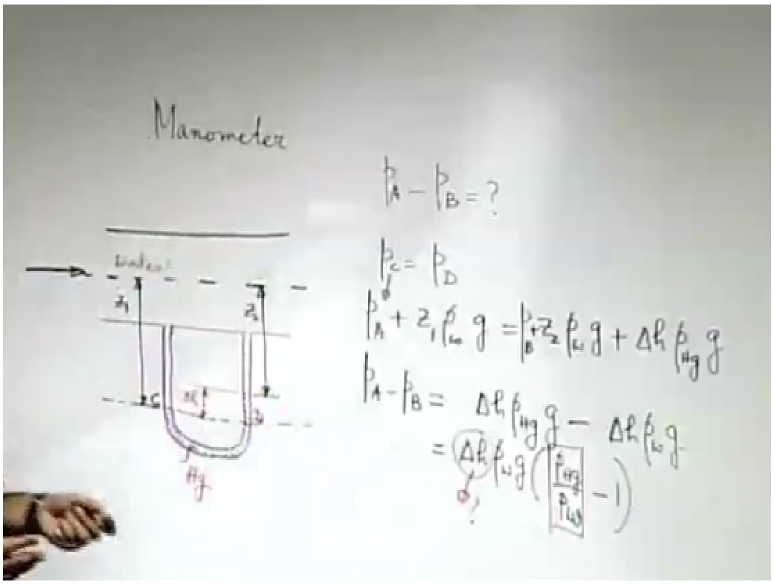


Since this concept is well known to you, we will briefly recapitulate it through an example. Let us say that there is a pipe and there is some fluid which is entering the pipe. There are 2 different sections say mark by A and B and we are interested to find out what is the difference in pressure across these 2. To do that what we will do we will be considering a U tube connected across these sections.

This U tube will be the so called manometer and it will try to measure the pressure difference between these 2. To see how it actually does let us say that this device contains some other fluid, of course there is a fluid which is passing through the pipe say that fluid is water. Now the fluid which is a part of these U tube manometer it is something different because it is the difference in density of these 2 fluids which will dictate the principle of operation of this device.

Let us say that, that fluid is mercury as an example. Mercury is a very common fluid for manometers and we just take that as a specific example. Now when the fluid is flowing from A to B which side you expect to be a higher pressure A or B? You expect A to be a higher pressure, we will see later on that it is not always true that fluid will flow from higher pressure to lower pressure it will definitely flow from higher energy to lower energy.

And here other components of energy being unaltered as an example like the kinetic energy and potential energy. Therefore, the pressure differential is the sole driving parameter for the fluid flow to take place. If A has the pressure > B and if we have some fluid here which is not water but some other fluids say mercury on which side you expect it to be more depressed, on A side or on B side?

So, wherever the pressure is more it will depress it more. Let us make the sketch accordingly and let us say this is mercury and let the difference in level in the 2 sides or the 2 limbs of the manometer will be delta h. What is our objective? Our objective is to find out what is the difference in pressure between A and B. So, we want PA – PB that to be evaluated. To do that we will just considers some reference dimensions let us say that this is a Z1, let us say this is Z2.

The difference between these 2 of course is delta h. What fundamental principle we will use here? We will use the fundamental principle that in the absence of any other body force when the fluid is at rest within this manometer the pressure in a connected system is same along the horizontal line it does not change. So, if you mark this point say C and D you must have the pressure at C and pressure at D as same.

So, how can you write the pressure at C in terms of pressure at A it is = pressure at A + C1*the density of water because this is filled up with water except for this red dots the remaining is water. So, this into rho water*g that is the pressure at C. What is the pressure at D? It is because of a combination of some column of water and some column of mercury. What is the column of water? So, first pressure at B + Z2 rho water g + delta h rho of mercury*g.

From here it follows that PA – PB = you can write this as delta h rho mercury g – it will be the rho water g taken as common*Z1 – Z2. Z1- Z2 is delta h as you can see from the figure.

So, it will be delta h rho water g. So, it is delta h rho water g if you take as common it is also written in this form. So, you can clearly see that by measuring what is delta h this you can experimentally measure.

The difference in the height of the 2 limbs you can clearly find out what is the difference in pressure between 2 points. What is the factor that is dictating your result is the relative density of 1 fluid over the other? And of course, not only that what is the density of the original fluid that is also important. So, this is in a very simple way what is the working principle of a manometer?

You may have manometers in series connected from one point to the other point and if you want to find out the pressure difference between 2 points what you may do is you may start with the point and traverse along the manometer. When you were traversing along the manometer along the same horizontal level if you have the same connected system you may consider the pressures to be qual.

So, you may neglect whatever is there below that and that is how you may go from 1 point to the other calculate the pressure difference. Go on calculating the pressure difference, it is like coming down and going up like a snake ladder game. So, you come down somewhere find out what is the increasing pressure again go up find out what is the decreasing pressure so on.

Along whatever fluid you are traversing you have to consider the density of that corresponding fluid for calculating the pressure differences. You can clearly see that these devices although we say these are pressure measuring devices but that is a very loose way of looking into these because these actually measure pressure differences not really absolute pressures.

So, whenever you have a fluid you expect that they are may be different pressures at different points and these mechanism is only trying to find out pressure at one-point relative to the other not in a very absolute sense. The other important remark is if you see that the resolution of these device strongly depends on what is this delta h. Because if this is very small there can be a lot of reading error.

And that will magnify the error in the determination of what is PA – PB. So, if this is quite large or magnified it may be easier for us to read with better accuracy. To do that sometimes people use inclined tube manometers. To understand the working principle, we will again take an example.

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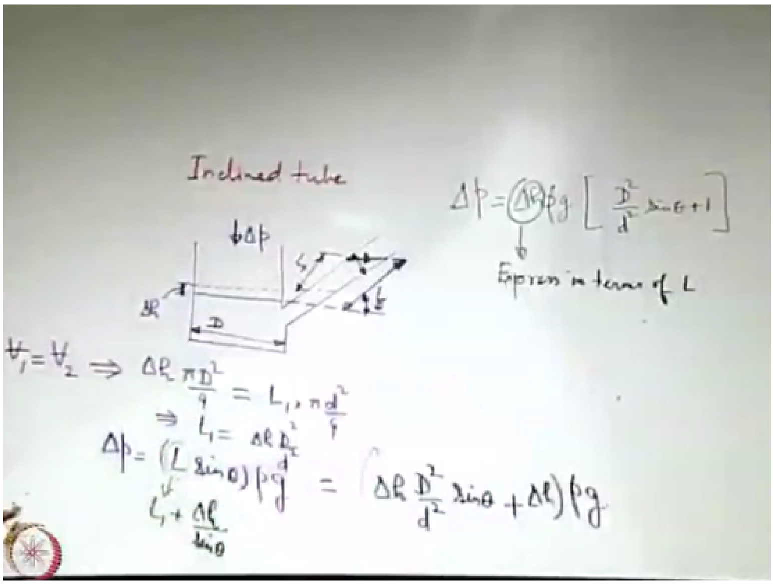


In an inclined tube example, it did not always be a U tube. It is basically having a measuring tube it may be a collection of measuring tubes may be U tube but the axis of the tube is inclined with the vertical. It is not vertical. So, let us say that you have a tank like this and you have a tube connected to it in this way.

Initially everything was exposed to atmosphere and let us say that this red colored dotted line represents the initial height both in the inclined limb as well as in the tank. Let us say that capital D is the diameter of the tank and small d is the diameter of the tube, assume both of circular cross section. Now let us say that you apply a pressure differential. That is you apply a higher pressure from the top.

If you do that this level will be depressed, it will come to a new location let us say it comes to this location. When it comes to this location obviously there is a drop in height and where this extra liquid will go? It will climb up the incline. So, it will come say to some height like this and therefore now have a net difference in the level as say L. L is the new level difference, earlier there was no level difference.

But because of the application of pressure differentials delta P the fluid in the big tank has gone down the same volume has gone up along the inclined tube and the level difference now is L. This is inclined difference and that is what you can read. If you graduate with lines on or markers on this inclined tube you can read the length very easily just like a scale. Let us say that you have the angle of inclination as theta with the horizontal.

Now one important principle that may guide you that what should be the corresponding rise if you have length up to this much say L1then you can clearly relate L1 with say that distance by which the level has gone down in the big tank. Let us say that that is delta h. Since the big tank, this may be small seen this is of smaller cross section the change will be large. So, we can say from the conservation of volume that delta h*pi capital D square by 4 = what?

L1*pi small d square by 4. So, this is from the consideration that the volume at state 1 is same as the volume at state 2 that is what is the principle that is guiding this very simple expression. From here you can find out what is L1. So, that is delta h*capital D square by small d square. Now, what is the difference in pressure now between the 2 levels? It is that difference delta P.

Because if one end is exposed to atmosphere then the other end is subjected to a pressure of say difference of delta P then that should give rise to the difference in level. So, delta P will be what? Delta P will be L sin theta*rho *g. You can replace L with what L1 + delta h/sin theta and L1 you can write in terms of delta h. So, these you can write as delta h*capital D square/small d square*sin theta + delta h rho g.

You can take certain terms as common. So, delta h rho g it will come to. You may of course replace delta h with L1 again because at the end it is not delta h that you are measuring. It is L1 or L that you are measuring. So, you can write it express in terms of say L. So, either way I mean, mathematically you can express either in terms of delta h or in terms of L.

But when you come to the final expression it is more convenient if you express in terms of L because that is what you can experimentally read more clearly and that is the whole objective of keeping it incline. So, when you keep it incline you can see that the for the same vertical height you can get more inclined distance and pressure differential is dictated not by the inclined distance but the vertical height.

So, for the same vertical height we will have the same pressure difference but with more inclination you can have more inclined length and that is how you may have a greater length for greater readability or for better readability for the pressure difference measurement. If you have say the same system but with vertical tube say with water as a fluid, then that will be equivalent to some h water*rho water*g.

So, the L/h water is an indicator of the sensitivity of this device. That h water for a vertical tube may be very small but for an inclined tube the corresponding L which shows the same pressure difference may be quite large. So, it adds to the sensitivity of the device. So, L/ that equivalent h water is also an indicator of the sensitivity of the device. Now it is not just the manometer that is commonly used for measuring pressure differences.

If the pressure differences are not very large sometimes there are inexpensive means of measuring pressure differences and one such example is a pressure gauge. So, pressure gauge it is an indicator of pressure at a point relative to some other reference pressure. Very often that reference pressure is the atmospheric pressure and therefore it implicitly many times reads the gauge pressure.

We have earlier defined that the gauge pressure is the pressure relative to atmospheric pressure at that location. So, we see an example with a demonstration to see pressure gauge. The example that we will be seeing here it is known as a bourdon gauge. So, if you look at this one, we will see the example once more. But if you see that it has a tube and the tube is connected to a mechanical arrangement and one end of the tube is fixed and the tube is of say elliptical cross section.

It is a deformable tube. When fluid enters the tube then what happens? When fluid enters the tube the tube gets deformed and the section of the tube tends to get more circular as compared to the elliptical one. So, what is happening is there is a fluid that is entering the tube one end of the tube is fixed the other end of the tube is moving or movable. As the fluid enters the tube there is a deformation in the tube and that deformation is being read by a dial indicator.

So, the deflection of the indicator in the dial gauge it gives an indicator of the deformation of the tube and the deformation of the tube has taken place because of application of a pressure differential. Earlier it was 0 deformation or a base state deformation now with application of a pressure difference there is a change in deformation from that. So, if this is calibrated then one may calibrate the deformation as a function of the applied pressure difference.

It is just like calibrating a spring because of application of a force. So, it is just like a spring mass type of arrangement. So this, name of this device is bourdon gauge. So, that is an interesting on a simple way of measuring pressure. The more advance ways of measuring pressure are not these ones. The more advance ways are by utilizing principles of certain things known as transducers.

So, what the transducers do they convert may be one form of signals and mechanical form of signal into an electric form of signal. So, there are certain piezoelectric pressure sensors.

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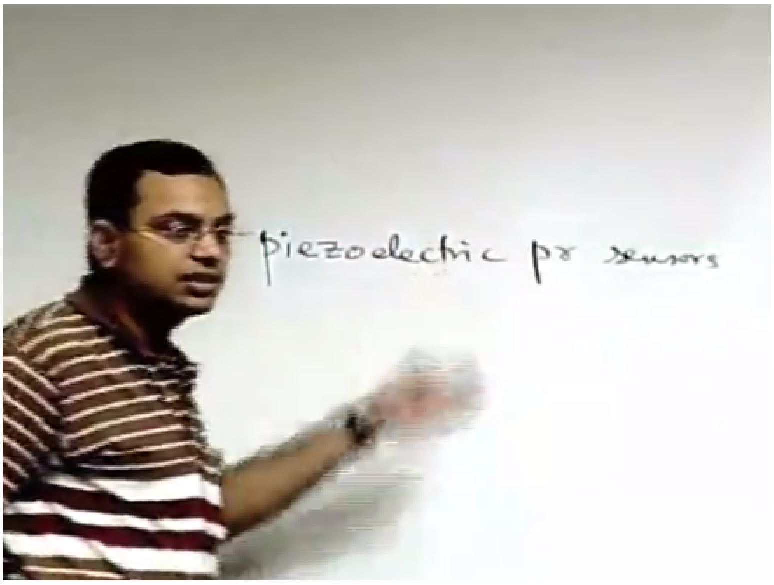


So what do these do, say piezoelectric pressure sensors. So, these are made up of materials which when subjected to a pressure difference converts that into an electrical voltage signal. So, that electrical voltage signal is read by a convenient mechanism and that is how you may have a digital output which does not directly show the pressure difference but it shows the corresponding electrical voltage that is developed.

And if the pressure difference is calibrated with that voltage then it is possible to very accurately describe that what is the pressure difference that actuated that voltage, one obviously needs to calibrate these type of device. But once it is calibrated it may be very, very accurate. So, it is based on the transformation of signal in one form say mechanical form into a signally another form like the electric form.

In a summary what we may say that we have discussed very brief about different pressure measuring devices starting from the simple barometer to manometer, pressure gauges and pressure sensors in piezoelectric form. With these pressure sensitive devices what we may experimentally find out is what is the value of pressure at a point may be relative to some reference. What we will do with that pressure?

When we are discussing about fluid statics one of our objectives will be that to find out because of that pressure what is the force that is acting on a solid surface? The solid surface may be a plain one or may be a curved one.

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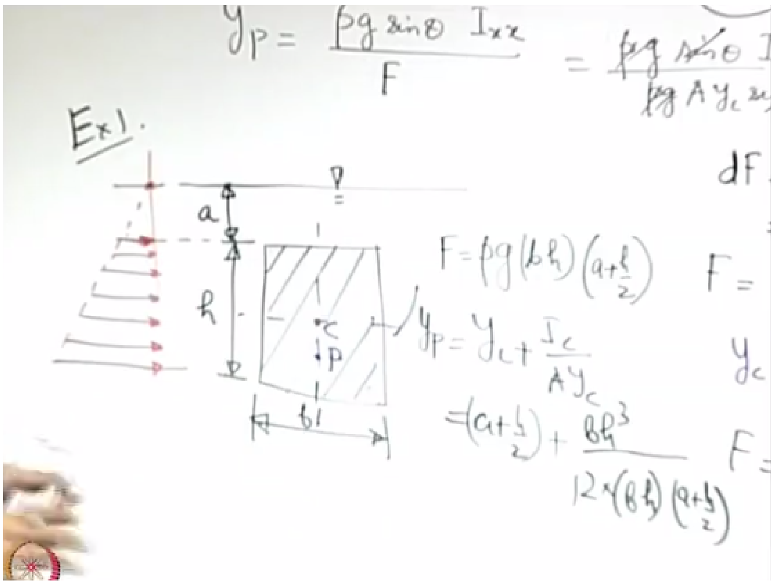


We start with an example of force on a plane surface. What is the special characteristic of the plane surface? that is such a surface that we are considering that is emerged in fluid at rest. We will try to make a sketch of the arrangement let us say that this is the free surface of the fluid that means on the top there may be atmosphere in a bottom there may be water as an example. There is a surface the h view of the surface is like this. It is a plane surface.

So, how does it look? Let us try to have a visualization of this assume that the surface is like this, okay. So, this is a plane surface and when you are seeing its projection in the plane of the board it looks like just the edge view that is the line. So, whenever we draw a line you keep in mind that it is some kind of arbitrarily distributed flat surface. The edge of which is represented by this line.

So, such a surface is there in a fluid and we are interested to find out what is the force on this surface because of the pressure distribution in a fluid. With that objective in mind let us try to maybe draw the other view of the surface. It just may be very, very arbitrary. So, it is a plane surface of some arbitrary geometry. So, let us say that this is the section of the surface when look parallel to it.

We will set up certain coordinate axis let us say we extend this and it meets the free surface at this point. So, we will call this as y axis and maybe an axis perpendicular to that as x axis. Our problem is actually a very simple problem. It is a problem of finding out the resultant of a distributed force because pressure distribution gives rise to a distributed force. Why it is a distributed force because pressure varies linearly with the height.

Different elements of the plate are located at different heights from the free surface. So, it is a distributed force. The advantage of handling with the plane surface is that this distributed force is the system of parallel forces. So if you have, for example if you considered a small element at a distance y from the axis, let us say the thickness of the element is dy. So, what is the force due to pressure that acts on this element?

Let us say that dF is the force that acts on this element due to the pressure distribution. This is the fluid at rest. So, what is dF? dF is the local pressure on the element times the elemental area. Let us say that the elemental area of which we are talking that can be represented in the other view completely. Let this be dA. It just corresponds to this dy. So, dF is the local P at the location y*dA. What is the local P?

Yes, rho g*y sin theta, if you call it, call these angle as theta. Because y sin theta is nothing but the vertical depth from the free surface to the location under conserve. That multiplied by dA. So, what is the total force that acts on the plate? It is integral of dF, so it is integral of, so rho g sin theta those are like invariance with respect to the integration. So integrating with respect to dA integral of ydA and integral is over the entire area.

Say capital A is the shaded red colored area. Pressure at the free surface is the reference pressure. Say, if the water was not there at the bottom. Just consider this example. Let us say that this is a surface. Now there is no water say it is surrounded by air from all sides. If it is in equilibrium that means air pressure is cancelling the effect from all the sides together. The net effect is that the sum total force is 0.

So, whatever force is acting on the surface is because of the difference from the atmospheric pressure. So, whenever you are calculating the resultant force on a surface remember what that you are implicitly dealing with the gauge pressure not the absolute pressure. Because the atmospheric pressure if atmosphere was existing otherwise it would have kept it in equilibrium.

Now, you are having some pressure over and above that why atmospheric pressure? Any other pressure, if there is a uniform pressure acting on a close surface we will see that later on that if you have uniform pressure acting on a close surface then the resultant force of that is 0. That may be proved by a very simple mathematical consideration that you have a distributed force which is always normal to the boundary then integral of that over a close boundary is 0, if the intensity of that pressure is uniform throughout.

So, if you have, if you want to find out what is the resultant force you may eliminate that common part and consider only that part which is over and above that. That is why we are considering only the water effect. Now, you can clearly see that what does integral ydA represents, moment about x axis moment of what? The moment of area so to say. So, the first moment of area and first moment of area gives what give the centroid of the area.

So, if you recall the formula for centroid say y coordinate of the centroid of the area that is integral of ydA/A. We will use the formula here and we can straight away write this as rho g A yc sin theta. Let us say that the centroid is somewhere here, so what we are talking about we have some distance yc and this height which we may give just a name say hc this is yc sin theta which is the vertical depth of the centroid of the plane surface from the free surface.

So, we can just write this as rho g Ahc. Now, this gives the resultant force but since it is a distributed force we also need to find out what is the point through who is the resultant of the distributed force passes. So, the point of application of the distributed force. To find out that let us say that there is point P we give it an mp and say that P is the point over through which the resultant of this distributed force passes.

So, what we can do to find out what is the location of P, location by location of P we mean the y coordinate of the point P. So, our objective is to find out what is the y coordinate of the point P through which the resultant of the distributed force due to pressure passes.

For that we will just use the very simple principle which we have learned in basic statics that if you consider an axis with respect to which you take the moment of forces then the moment of the resultant force with respect to that axis is nothing but the summation of the moments of the individual components of that forces with respect to the same axis. This is known as Varignon's theorem and we will try to use that for finding out the location of yP.

So, if F is the resultant force and the moment that we are trying to take this moment with respect to the x axis then F*yP gives the magnitude of the moment of the force F. This is same as the sum of the moments of the individual components. So, individual component is like you have a dF that is an individual component. So, what is the moment of dF with respect to x, so that is just dF*y local y. So, the total moment is integral of ydF.

So, rho g sin theta integral of y square dA. So these are second moment of area. Sometimes also loosely called as moment of area moment of inertia just by virtue of its similarity with mass moment of inertia. This is not really a fundamentally moment of inertia it is better to call us second moment of area. So, we can write this as the second moment of area with respect to the x axis. So, Ixx. So, we can write what is yP rho g sin theta Ixx/F.

What is F? F is rho g*A into Yc sin theta. So, we cancel the common terms Ixx represent the second moment of area with respect to some arbitrary axis. It is more convenient to translate that to an axis which is parallel to x but passing to the centroid and because centroid is a reference point with respect to a particular surface and to do that we may use the parallel axis theorem to translate it to C.

So, if we consider an axis which passes through C and parallel to x with respect to that axis we can write that Ixx is nothing but Ic that by c we mean this axis which is passing through c and parallel to x. That axis is totally visible from the view parallel to the surface. So, this is Ic

+ $A*Y_c$ square that $/AY_c$. From these we get a very important expression that $Y_p$ is $Y_c + I_c / AY_c$.

This point P is given a special name in consideration of fluid statics and that name is center of pressure. So, center of pressure is the point through which the resultant of distributed force due to pressure passes that is known as center of pressure. We can clearly see from this expression that $Y_p$ is $> Y_c$ because $Y_p = Y_c$ + the positive term that means the center of pressure in terms of depth lies below the centroid, right and that is a very important observation.

So, the 2 things that we learned from this simple exercise one is to find out what is the resultant force on a plane surface which is emerged in a fluid due to the pressure distribution and where is the point through which this resultant force acts. We will consider a simple example to begin with to demonstrate that how we may calculate this.

Let us say that you have a surface which in its sectional view is like this and this is a vertical surface emerged in a fluid. So, this is the fluid and this subject is a, or like this object is a rectangular section with the dimension b and h. What is the resultant force due to pressure acting on this? Let us give a dimension of this say a. This is example 1. The question is what is the resultant force on this shaded surface because of pressure?

So, take an example like this. So, this is like a surface what are our fluid some other fluid is acting on it from one surface and you are interested to find out what is the resultant force because of pressure distribution on this. So, this is a special case of the inclined situation. So, the inclined situation was like this. Now we had made it vertical, okay. So, it is also an inclination with theta = 90 degree.

So, for such a surface now if you want to find out what is the resultant force that acts on the surface. What is that? You look at the formula, this one rho g $Ah_c$. So, what is A is $b*h$. What is $h_c$? So, c is the centroid of this area. So, if it is a homogeneous area it is $a + h/2$. What is the location of the center of pressure? $Y_p = Y_c$ + first letters write the formula and then we will substitute the value.

What is Yc? Here y and h are the same because it is just a vertical one. So, a + h/2 is Yc + Ic. So, you have to now figure out first that is it second movement of area with respect to this vertical axis or this horizontal axis. So, try to recall that when this was the inclined plate the second moment of area was taken with respect to this axis, right. So, now when it is vertical you have a second moment of area with respect to this axis and that is translated to the centroidal axis.

So, that means the correct axis should be this one. Just try to visualize it will be, it is trivial but it is very, very important. Because based on the orientation you have to figure out that with respect to which x axis you are having to calculate the second moment of area. Because centroidal axis is not something which is unique you have different axis passing through the centroid.

So, Ic will be based on this axis what will be that bh cube/12. This is the expression. If you want to find out or if you just make a sketch of how this force is distributed let us try to make a sketch of the pressure distribution. To make a sketch of the pressure distribution what we note the pressure varies with the depth. So, here the pressure is 0 which is the reference pressure not 0 in an absolute sense but relative to atmosphere.

And then it will linearly increase with the depth. So, at this height this will be the pressure at the bottom height this will be the pressure and it is a distributed force like this which varies linearly with the height. And you can clearly see that the area under this loading diagram will eventually give you what is the force. These kinds of examples you have already gone through in basic engineering mechanics and you can verify it for the case of fluid at rest very, very similar.

Now, what is the state of stress in which fluid at different depths they are the fluid elements at different depths they are subjected to. To consider that we will refer back to the stress tensor which we introduced earlier when we were discussing with the traction vector. We are trying to relate the traction vector with a stress tensor.

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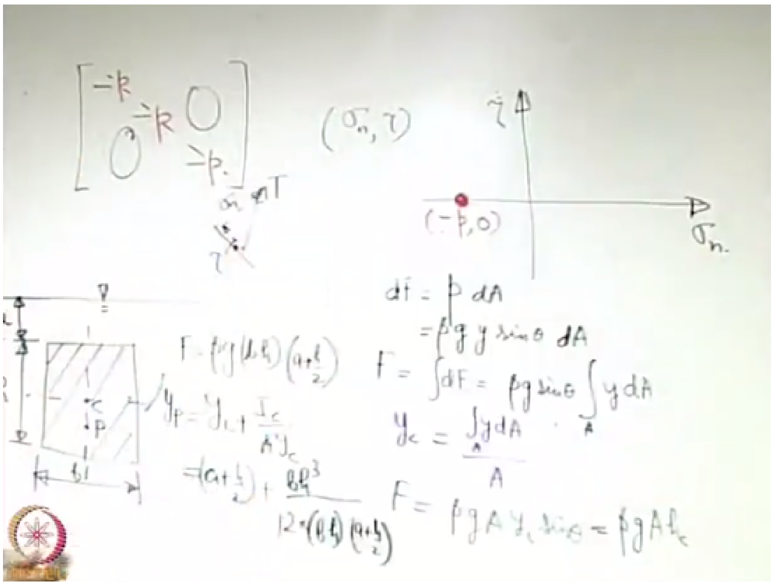

So, whenever you have a fluid element at rest let us say that we are interested to write the 6 independent components of the stress tensor. So, now you tell, so we have the diagonal elements and off-diagonal elements. If you recall the diagonal elements represent normal components of stress and off-diagonal elements represent the sheer components of stress. So, what will be the off-diagonal components they will be 0 because it is fluid at rest.

So it is not subjected to sheer because with sheer fluid will deform. So, these are all 0's. When you come to the diagonal element you have only the state of stress dictated by the normal component which is just pressure and that acts equally from all directions. So, all the 3 components will be – P – P – P. Tau 11, tau 22 tau 33 and the reason of putting – is obvious the positive sign convention of normal stress is tensile in nature, whereas, pressure by nature is always compressive.

Now let us say that we have the task of drawing a more circle of distribution of state of stress. If you recall what is the more circle, so if you consider that there is an elemental area which has an inclination say theta with respect to some reference that has a resultant force and that resultant force is given by the traction vector components area. You can decompose it let us say that the traction vector component is like this.

You can decompose it into 2 parts, one is a tangential component another is a normal component. Let us say we call it sigma n and let us say we call it tau. So, depending on how you orient the area you will get different combinations of sigma n and tau. If you draw the locus of that then that is what constitutes the more circle, right.

So, more circles give you the visual appeal or a visual feel of what is the state of stress of different locations or at different locations based on the choice of different choice of orientation of the area or maybe at the same location with different choice of orientation of the area. So, when we are drawing one particular more circle we are concentrating on one particular point but changing the orientation of the area to get the feel of the normal and tangential components of the forces on that.

So, we are having 2 axis, one is sigma n and there is tau. Our locus is or our objective is to find the locus of sigma n versus tau or tau versus sigma n. So, how will the more circle look like for such a state of stress. This state of stress is a very unique one and this is known as hydro static state of stress. The reason is obvious it represents a hydrostatic physical situation. So, how will the more circle look like?

See at a particular point you have the normal component of stress that is because of pressure and it acts equally from all directions. That means if you change the orientation of the plane sigma n will not change. Sigma n will be unique and what will be tau? Tau will be 0. That means no matter whatever plane you choose sigma n = - P and tau = 0. So, the locus of all states of stress converts to a single point with coordinate – P, 0.

So, the more circle becomes a point say – P. So, this is just a point not a circle I have encircled it but it is just like to show that it is a point, okay. So, this is a very important interesting limiting case when the more circles shrink to a point signifying that there is no change in state of stress we change in orientation. Next, we will consider another example on force on a plane surface.

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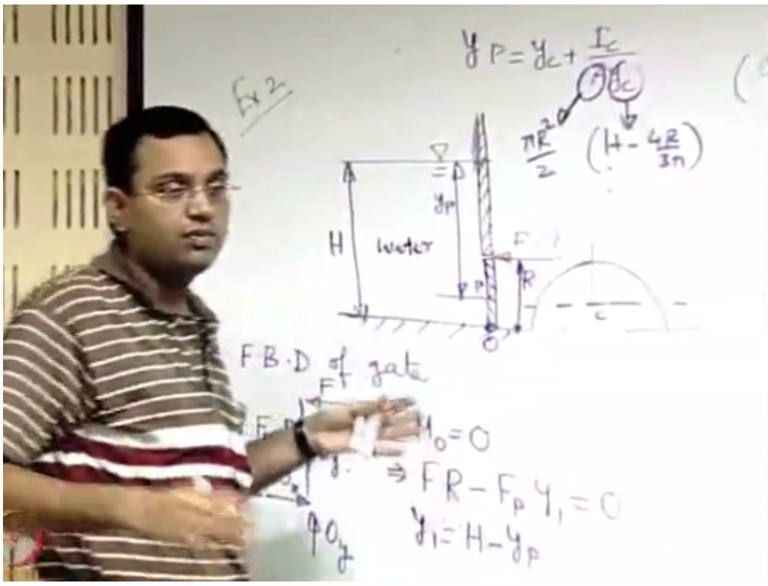


Example 2. We will make this example a bit more involved than the previous one. Let us say that there is again a free surface there is some fixed structure. There is a base and there is a gate like this. So, it is something like say a sluice gate. So, on one side there is water and it is saw that this water is being confined in a particular place and this gate has a tendency to move because there is a resultant force of water from the left side.

And there must be some mechanism, some holding mechanism by which this gate is kept at rest at equilibrium. So, there is some force which is acting on the gate say the force is this F by some support or whatever there is some force F which acts on these to keep it in equilibrium. This gate may be of different shapes and let us take an example which the gate shape as a semicircular one like this. So, this is the section of this gate.

This is like it is fixed with something. So it is, there is a separate structure that goes within. So, we are not going to concentrate so much on the upper one. We are, I mean it may be extending even beyond the free water surface and so on. But we are more interested with the gate. So, on this gate there is a force due to water and that force you may calculate by considering some dimensions.

One of the dimensions say this is capital H let us say that the radius of this semicircular gate is capital R and the density of the fluid of course is given and G. This gate is hinged at this point say O. So, this is a situation where if you want to find out what force F should keep it in equilibrium you must calculate what is the resultant force due to pressure acting on the gate. This is a plane surface.

Shape of the plane is a semicircle but it is still a plane surface and you may use the formula for force on a plane surface. So, let us try to draw the free body diagram of this gate. So, our objective is that what should be this force to keep the gate in equilibrium. So, we draw the free body diagram of the gate. You have a force F; what other forces you have? You have the hinge reactions say let us say Ox and Oy, the 2 components this has its own weight.

So, some mg and the force due to pressure distribution in water, let us say Fp which passes through the center of pressure. So, for equilibrium the resultant moment of all forces with respect to O should be 0. The reason of choice of O as moment center is obvious it eliminates all unknowns except the F that we are interested to find out. So, what it will give? It will give capital F*R – Fp*say these distance Y1 = 0 and how can you calculate Y1?

Y1 is capital H – Yp, where Yp is the location of the center of pressure from the top surface, right. Fundamentally, you can calculate Yp/the formula that is Yp = Yc + IC/AYc. So, what is Yc? Yc is the y coordinate of the centroid of these semicircular area. So, this part the location of the centroid from the bottom is 4R/3 pi, okay. So, Yc should be H – 4R/3 pi. To that extend find A.

What is A? Pi R square/2 that is also quite clear Ic something which we always forget, right if you ask me to recall I will be in a great tension. I have really forgotten what is Ic, I mean second moment of area with respect to an axis of a semicircular thing which passes through its centroid. Of course you may derive it but we will see that this derivation is not necessary.

Because we will try to avoid this route of this formula base determination of this and we will just do it from the fundamental method of integration by which you find out the resultant of a distributed force, the resultant moment of distributed force and so on. And the entire reason is that there are certain simple areas for which we may remember the expressions for the second moment of area with respect to the centroidal axis quite easily.

But it is not so convenient for many complicated areas. This is not complicated as such but even for that we should not tax our brain by remembering that. I mean that is not a very special information that we should remember. So, what we will do is in the next class we will try to see we will keep this problem in mind. We will see the alternative way by which we will be solving this problem.

You can of course solve this problem by substituting the value of Ic here expression and this expression is given in the appendix of the text books in statics. So, you can find out the expression or you may even derive it if you want and just substitute it to get what is Yp and from that you can get F. But we will see that whenever possible and whenever convenient it may also be alright if we just find it out by simple integration of the distributed forces. So, that we will do in the next class let us stop here. Thank you.