But when these icebergs are falling it we do not know it what it happens the in underground of this big icebergs, giant icebergs. For examples because of the heating system of the oceans there could be underwater melting. So at the surface could be iceberg is standing it but below because of the heating systems of the undercurrent the heating systems of oceans there could be a melting which is going down below of a iceberg.

As this melting it you see that at certain points it will come it. Its center of buoyancy will change it and the point of MG what we have discussing is that, that becomes a negative and it can immediately collapsed it. So that what this very there is sudden collapse of a big iceberg is happens it which because of the presence of the underwater melting of the system.

If I take a simple the specific gravity of the ice and the specific gravity of sea water, any iceberg if you look it that, the one eighth percent of the iceberg will be floating condition on the surface. The seven by eight percent will be the inside the sea. So only what you see this one by eight percent of the iceberg what we see it. The seven by eight percent of the iceberg inside cannot see that and we do not know what could be the shape of that iceberg okay.

So that is the reasons if you know it if you can see the great movie of Titanic, which is stuck in because of stuck with the iceberg in 1912 because of not under estimating, not knowing having the knowledge of the iceberg. That is what the point is because we look it from the top that iceberg of one by eight but seven by eight percent of iceberg is within the waters.

So 1912 you can know it there was not much technology to do at present what we have like the space technology, the GPS technology, the radar technology, we can do details sounding what type of the iceberg is there. What is the extent of the icebergs. We have a satellite motion to monitor the iceberg but that is what was not there. The even if you look at the Titanic movie, which is one of the largest ship in that periods.

It was very expensive interior decorations, but they did not understand the technologies necessary for to make a safety of the big Titanic ship. That is what it happened. So that is what the tragedy is committed. So what my point is to say that so, as a engineer who may built a big interior design, expensive ship but also you should look it the safety of the ship.

Or other way round, you should always should have a knowledge of the fluid mechanics, which gives us a lot of the safeties like when you are constructing a big towers, big high rise, high rise buildings, the safety is more important as compared to have a big interior or very expensive interior designs, okay. With this what I have to say that the stability of floating objects what is we are talking about it has lot of examples of the stability of the floating objects.

Natural you can see it and that is what realize the navigation systems in the oceans. It has now brought its new technology, new way to do this safer navigation as compared to the 1912 but that what is a lesson learnt for a engineers that instead of looking the making a bigger ship the best the beautiful interior, but the safety is the first. That is what my point to tell you, okay.

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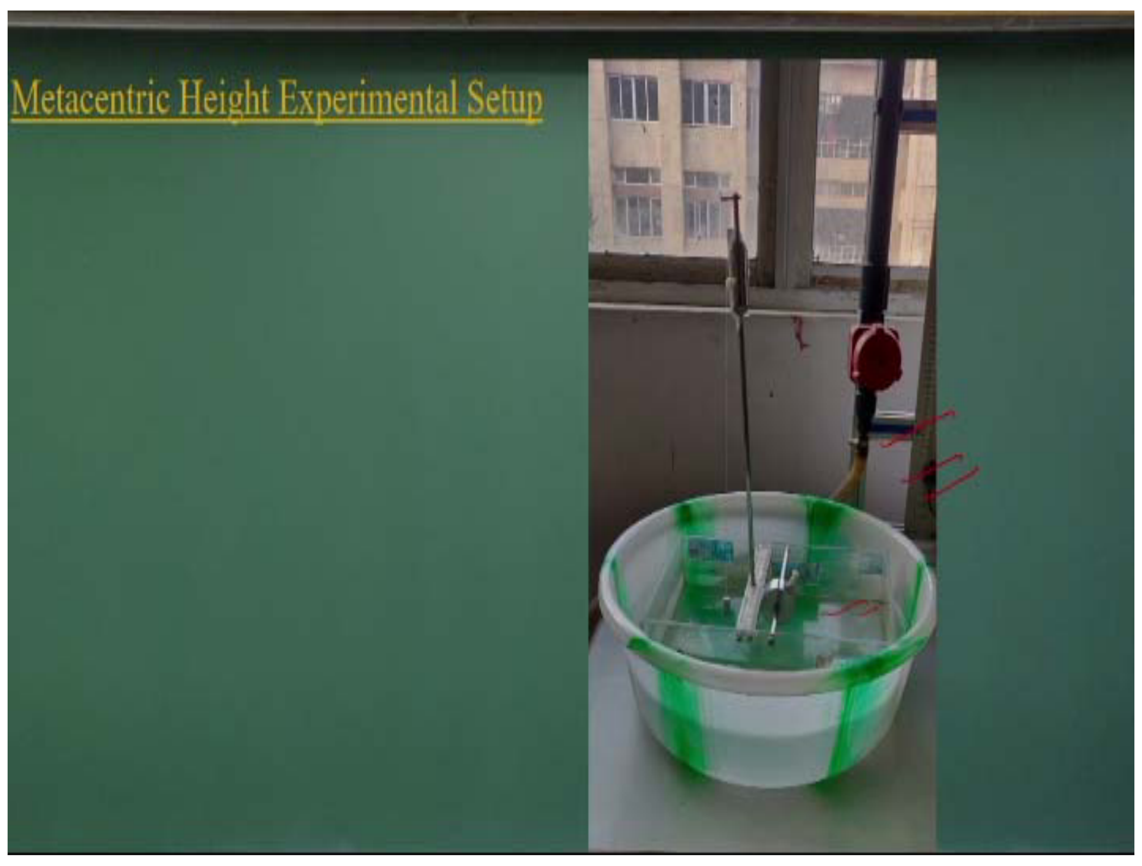

So let us look at simple experiment, metacentric height experimental setups with just balancing the weight we can measure the metacentric height of a floating object like this and this type of facilities are there any fluid mechanics lab, you can just measure the metacentric height and find out the stability of floating object.

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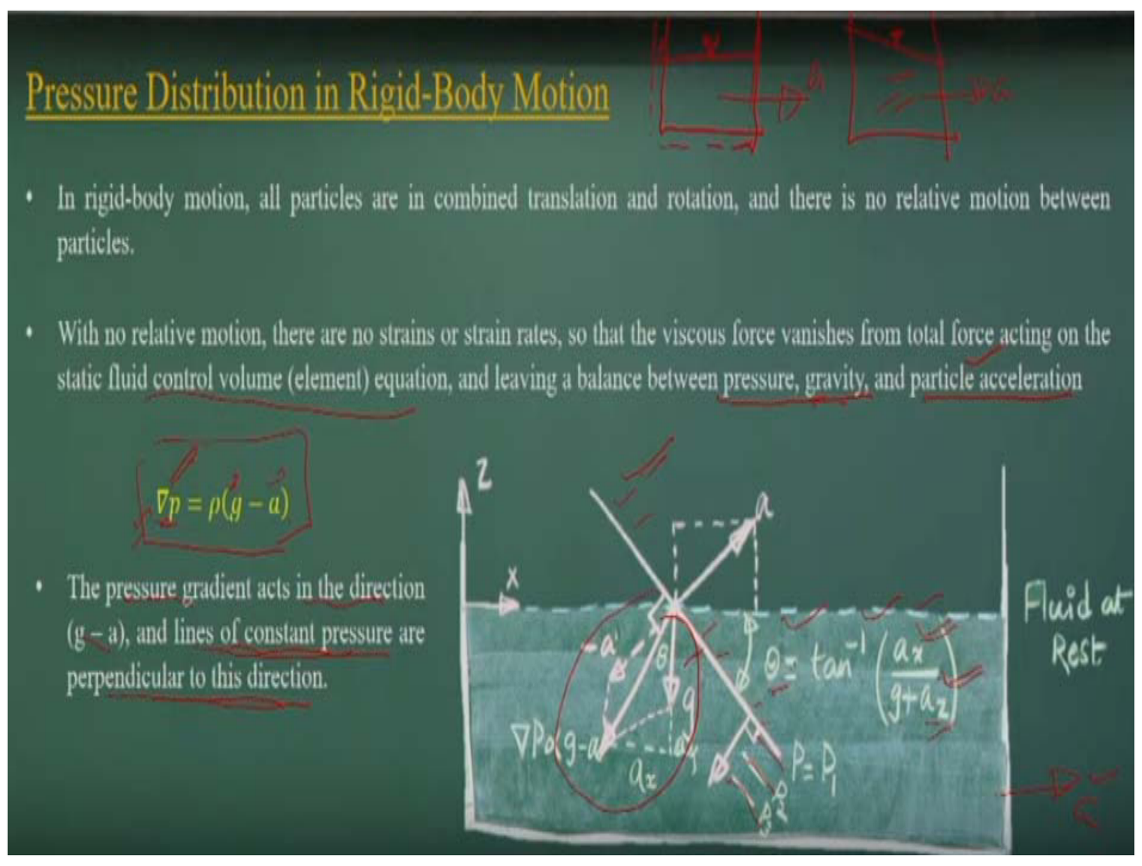

Now let us come it to the another component on fluid statics that means fluid at the rest. But we are looking it a rigid body motions. That means what it happens that if I have a half filled liquid containers. That means I have a half filled liquid containers. It has a free surface and this is the containers. If I accelerate it with acceleration a. Okay, I have a tank and I am just accelerating with acceleration a.

So we can imagine it what will happen, the fluid will slush it. That means fluid will be having a slushing, it is up and down effects. But after certain times what will come it that will be new free surface will be created, slushing will stop it. New free surface will come it and that what will move it that acceleration a. So when it comes to a stage there is no slushing, the new free surface is created.

And the fluid now behave as if a rigid body. That means there is no velocity gradient. No shear strain rate. No shear stress formations. So it acts like a rigid body motions. It acts like a rigid body motions moving with acceleration a. So it is a very simplified case that if you have a container you have a tank containing the liquid, which is a half filled and it is moving with a constant acceleration.

After certain times you can see that it will make a different free surface. It will change, the liquid will have a different the free surface and after that there will be no change of the velocity gradients and no shear strain formation or the shear stress formation. So because of that the problem is now it is quite simplified and it becomes a just as if a rigid body motions.

That means, the liquid is there but we can consider because there is no shear stress, only this have. That means what are the force components are there? The force components are one is force due to the pressure, gravity force and force due to this acceleration component. So this we have the three force components now, okay. There is no shear stress. So there is no viscous components are there.

So only we have the three force component. As I derived earlier that we have,

$$\nabla p = \rho(g - a)$$

Now if I have a acceleration this vector quantity, then you can simply consider the control volumes is moving with a accelerations a, you find out the relative acceleration to equate with the pressure gradient.

So this is the vector equations defining for a control volumes which is moving with constant accelerations of a and we are equating with pressure, gravity, and particle acceleration or the control volume accelerations what we have. Now if you look at this interesting equations, which is the simplified equations what we got it for this the liquid containers that you can see that the change of the pressure gradient and (g – a), are the pressure gradient acts in the direction of (g – a).

So that means the line of constant pressure are perpendicular to the this direction. So if you know this acceleration due to gravity vectors, you know the acceleration vectors, the vectorically difference between these two that directions will give us the line of constant pressure will be the perpendicular to that direction. That means, the free surface will tilt at it, the pressure diagrams will change which will be perpendicular to that.

Now if you look it if I draw the vectorically the components that this the object is moving like having the acceleration a. Moving as a acceleration a is a vectorical component, it can have the scalar component in three x, y, z coordinate systems. So if I just balancing this part as the vectorical additions if I do it and because of that you can see the constant pressure diagrams will have a tilting with a theta which is balancing with the force component.

Tan theta will be balancing the force component because of a_x the acceleration, the scalar quantity in x direction, the acceleration z directions component of the scalar quantity and g is the tan theta just the vectorically in this part, that part will be the tan theta of this. So what it indicates now, the surface will be tilted with a θ° and will make a constant pressure diagram.

That means, if you have the free surface that means the free surface will be tilted with a θ° such a way that these two force component will counterbalance by the force due to the pressure gradient. That is the very vectorically we are computing it. So the pressure will be changed like this. So your free surface atmospheric pressure lines also can draw it as I given the examples like this will have the tilting surface as we have a acceleration of this.

And that tilted surface the angle it depends upon the acceleration component in x directions and the z direction and g value to find out what will be the theta component. That way, we can vectorically solve these problems.

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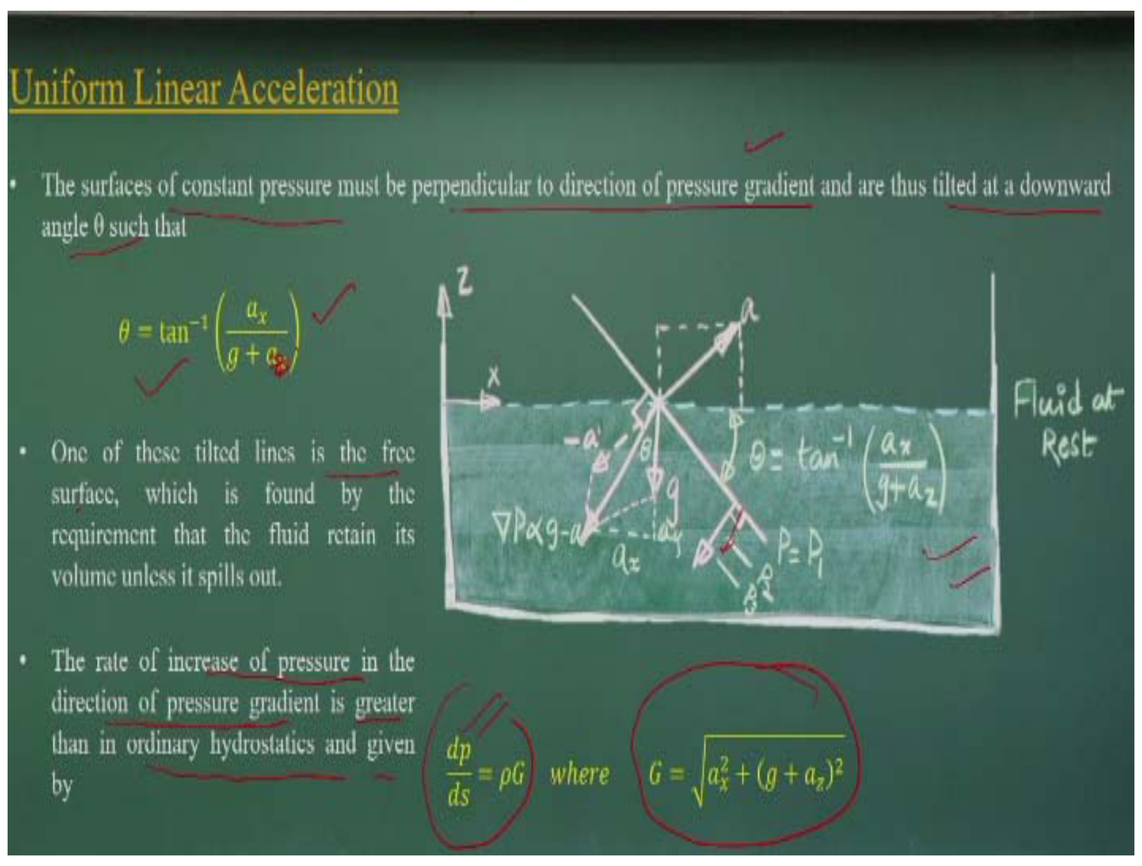

And that is what is the explanations that the surface of the constant pressure must be perpendicular to the pressure of gravity and it will be tilted downward such a way that theta is this part x a z okay, it will be z here. So tan θ will be same diagrams. So if you have it the free surface also will be tilted as I explained it the free surface also constant pressure diagrams free surface will be the tilted on that way to get it.

But if you do not have the enough the wall length the sorry the wall height, sometimes liquid can spill away from this because of like for example, you have the containers and moving with a particular acceleration. Again you increase the accelerations further and further okay, it will come it a such a stage that it may overflow from the liquid from the tank, open tank if you have.

If you have a pressurized conditions, you can solve it a problem like that when I will solve the numerical problems. So the basically what you can try to know it that as we move with a constant acceleration, the free surface changes, the pressure diagram changes it and that what equate with two force component, one is particle acceleration component and other is the gravity force component.

With a simple hydrostatic equations we can write it.

$$\theta = \tan^{-1}\left(\frac{a_x}{g + a_x}\right)$$

And similar way the rate of increasing the pressure in the directions of pressure gradient will be the greater than the ordinary pressure statics, which is definitely true now, which will be the

$$\frac{dp}{ds} = \rho G \quad where \qquad G = \sqrt{a_x^2 + (g + a_z)^2}$$

It will be the perpendicular to this will be the rho G you can compute it what will be the conditions.

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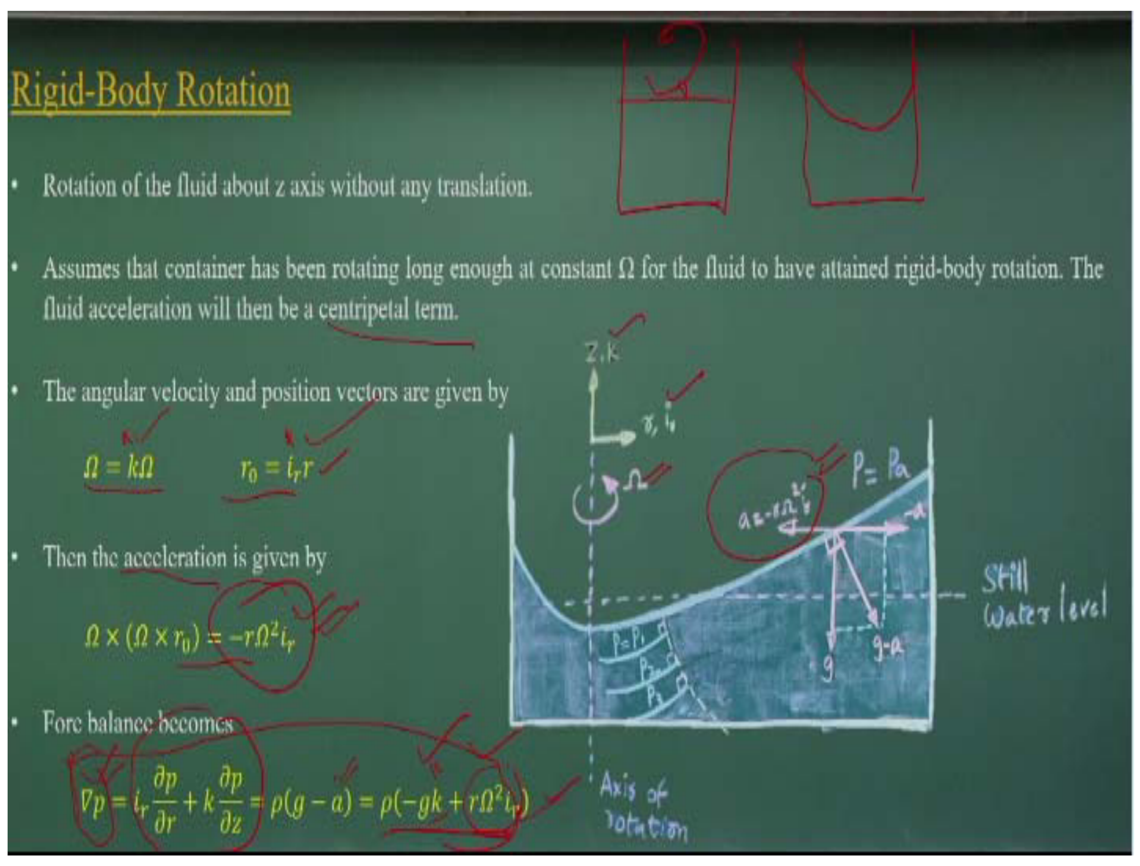

Now let these conditions consider similar way of rigid body rotations, okay. Now we are talking about the rotations. If you look it any chemical industry, the dairy industry many times we do the mixing of the two liquids. What we do it we actually do the uniform rotations of the liquid contents okay.

So if you do a uniform rotations of liquid containers, so you can understand it that if I have the liquid filled with this ones, and I start the rotating of this ones, so definitely you can after certain times, it will have a shape like this. So when it comes to a constant, the shape, since this is a uniform rotations and we are doing it they will be the same conditions. The velocity gradient will not be there.

No shear strain rate also shear stress. So it is again as if like a rigid body motions. That means a ball is rotating with a uniform rotations. It has a two components. One is the centrifugal forces another is the gravity forces. That what we will equate it. But in this case, we are talking in terms of cylindrical coordinate systems, vectorically we are representing it.

That is the reasons you just look it because this is a quite general problem any type of rotations, we can solve it considering the cylindrical coordinate systems like k and i are the unit vector along the radius will have a r and j and we have a uniform rotations we are doing it and because of that you can understand it the centrifugal accelerations will be this part okay. Here it is representing as a vector notations okay.

$$\Omega = k\Omega$$

$$r_0 = i_r r$$

What is the position vectors, angular velocity that the centrifugal accelerations what will be come it you can as you know it,

$$\Omega \times (\Omega \times r_0) = -r\Omega^2 i_r$$

That what will come it? Now this component will be balanced by the pressure gradient component,

$$\nabla p = i_r \frac{\partial p}{\partial r} + k\frac{\partial p}{\partial z} = \rho(g - a) = \rho(-gk + r\Omega^2 i_r)$$

we know it the centrifugal acceleration component what we have got it.

So if you look it that, if you have a constant translations accelerations or uniform rotations, the gradient of P is equal to rho times of the vectorical difference between acceleration due to gravity and the x.

In case of a uniform rotations, we are using the centrifugal acceleration component. That is $\rho r\Omega^2 i_r$. And here we represent in terms of vectors. That is the reasons I, r is a unit vector in radial directions and the k is the unit vector in the z direction. As the vector components we have put it then finally we get a equations. This equation need to be solve it to determine what will be the pressure.

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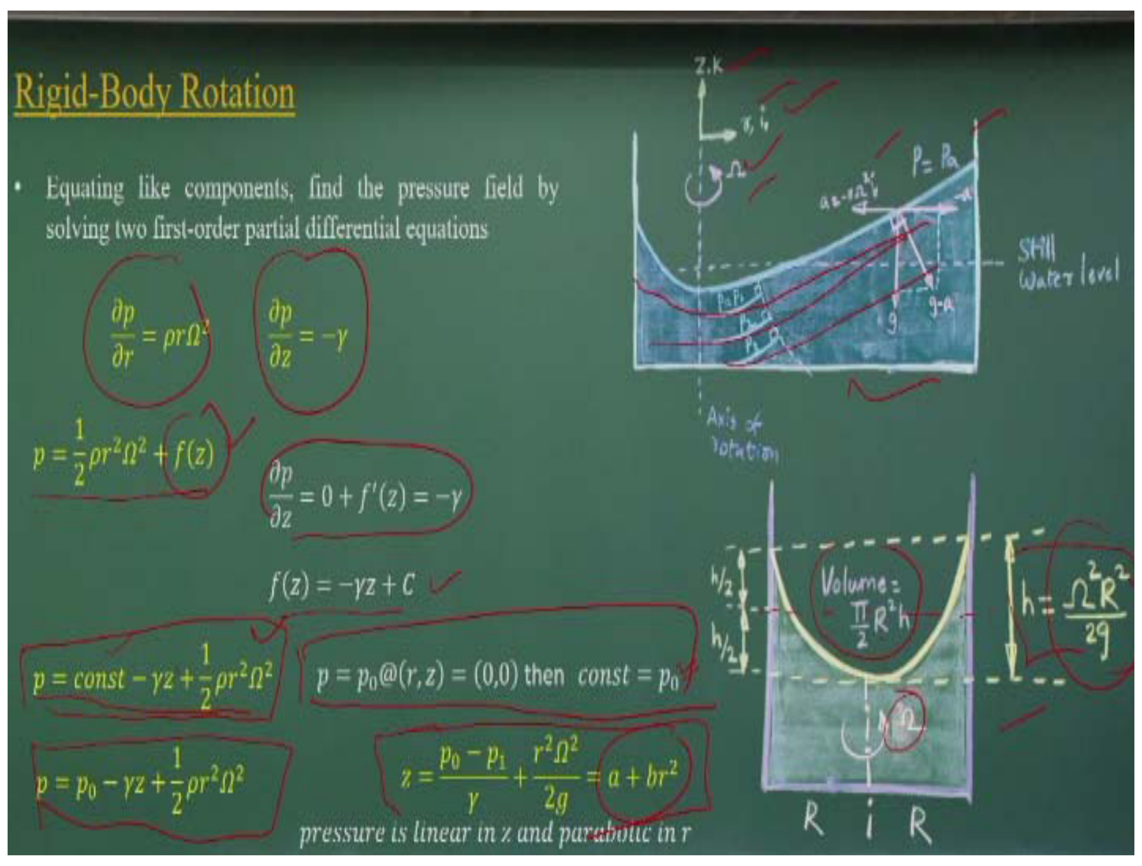

Now let us show it the solving this part. We can solve this one pressure field considering two equations, component wise. Okay one is a z component another is i r component.

So you can integrate this separately and substitute the boundary conditions to get what will be general equation form. So first integrations will come it this with a constant of integration will be absent.

The second integrations will come it this which is partial differential equation in z direction. P is a function of z and the r. So finally, if you use this two terms with additional constant the pressure will follow like this,

$$\frac{\partial p}{\partial r} = \rho r \Omega^2$$

$$\frac{\partial p}{\partial z} = -\gamma$$

Then you substitute the boundary conditions. That you give it, you are arranging in such a way that the pressure let be p naught at that location.

The origins of your coordinate axis where you will have a pressure is p nut then this constant becomes a p nut okay. Then you will have a the pressure equations like this

$$p = \frac{1}{2}\rho r^2 \Omega^2 + f(z)$$

or if you just rearrange it you will get this part which will be a parabolic equation format. That means, as we already discussed is that when you rotate uniformly the your free surface will follow a parabolic shape.

$$\frac{\partial p}{\partial z} = 0 + f'(z) = -\gamma$$

$$f(z) = -\gamma z + C$$

It will follow a parabolic shape. As the free surface follow the parabolic that all my the pressure diagrams also will follow the similar way p $_2$, p $_3$, p $_4$ will follow that. For a simplified case because this is very general case, if you take a cylinder which is very simplified case, okay its radius are having a uniform radius that then you can find out this parabolic shapes.

$$p = const - \gamma z + \frac{1}{2}\rho r^2 \Omega^2$$

$$p = p_0 @ (r, z) = (0,0)\ then\ \ const = p_0$$

$$p = p_0 - \gamma z + \frac{1}{2}\rho r^2 \Omega^2$$

$$z = \frac{p_0 - p_1}{\gamma} + \frac{r^2 \Omega^2}{2g} = a + b r^2$$

$$pressure\ is\ linear\ in\ z\ and\ parabolic\ in\ r$$

And from the basic concept of parabola you can find out the volume, you can find out that the half of water will be displayed from the surface the initially conditions to the top and you can find what will be the height. Which is very easy because in case of cylindrical with a radius r we can simplify these general problems and you can get it a direct equation to compute these ones.

But the real life problems when you have let you have oil tank in a rocket which moves with the rotations component will be the vectorical component not a cylinders are rotating in a like a chemical or a dairy industry where everything is fixed. So it can be rotating only we can consider a simple cylindrical case and solve the problems.

But real life problems like there is the fuel tank in a rocket and the rocket is moving with different acceleration field at different field, what would be the fuel tank pressure diagrams and what would be the conditions of the fuel tank when the pressure what will be exerted because of these.

Those need to be studied that is the reason look it in a vectorical form to solve these problems, where we just have to have remember it, the gradient of pressure is equal to the density times of the vectorical difference between acceleration due to gravity and the centrifugal acceleration component because of uniform rotations.

Then you solve this problems which can be done it for any shape of container as compared to the simplified case like cylindrical containers rotating with a its center of axis which is a very simplified case that can be also used for as I said that where we know the rotations, we know the cylinders and we rotate with a uniform rotations for mixing up the liquids that can be used a simple formulas but in case of real life problems, the rocket fuel tank in rocket we have to look it vectorical form.

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Or you can see this type of forced vortex experimental setups which will be having a motor arrangement to make a uniform rotation. Then to measure the shape of the free surface with a gauging systems. With different rotations you can have a different free surface and you can compare with the theoretical value whether what you are getting from experimental do they match each other.

If not, then you find out why it is not. Definitely if you can understand it, what you will get a theoretical case like having a uniform rotation, the free surface what you get it for a cylinder case that may not come it in experimentally because in case of the experimental we have lot of uncertainty in the measurement the making uniform rotations perfectly. That also not possible.

So you try to understand it there will be a difference between the experiments as well as the theoretical consider. Because that what does not have an any uncertainty in a measurement in any uncertainty in the experimental system that what is considered as a uniform rotations theoretically it is possible then what it happens it. But that the condition to do in an experiment, it is not that easy.

That is the reason there will be a difference between an experimental profile and the theoretical profile.

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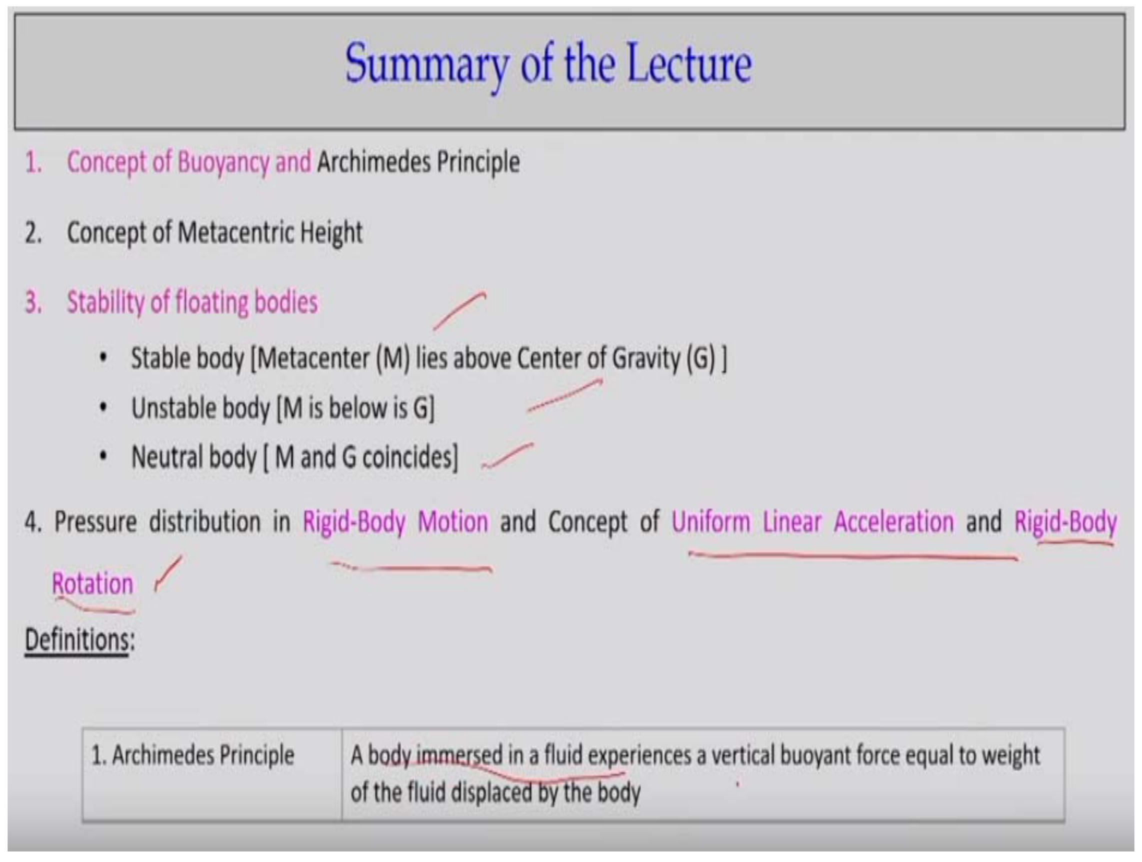

Now let me summarize today's lecture that we introduced a center of buoyancy concept. We discussed about two or three basic concept of Archimedes which is very simple concept of that. We discussed of the metacentric height. And also we talked about as you have to remember of metacentric height in terms of metacenters lies below or above or MG is coincides we have a different conditions like stable, unstable or the natural conditions.

And we discussed about the rigid body motions, uniform linear accelerations, rigid body rotations, the pressure diagrams. I can again tell about you Archimedes principle still holds good okay even if we are in 21st century that a body immersed in the fluid experience a vertical buoyant force equal to the weight of the fluid display by the body. This process makes lot of the process from micro level to macro levels.

All this natural process what it happens from micro water vapor to big water global circulation pattern the buoyancy force also acted. So we make with giving a lot of respect to this Archimedes principle, which helps us to understand very complex process with this point force concept as well as the center of buoyancy, metacentric height. Thank you lot.