So for a very simple case, we can get an analytical solutions like u and v and w and the pressure and that analytical solutions can help us to know the velocity, the pressure distribution of these problems and it satisfy conservation equations, mass conservation equations, linear momentum equations. Also it satisfies the boundary conditions at the floor also flow inject what is coming it.

So that is what I say that there is a experimental way to do that thing. Very simple case, we can simplify it and we can like it a two dimensional incompressible steady flow, this is what the total simplification of problems or these assumptions are hold good for these type of problems. Then you apply the mass conservation linear momentum equations. Then you get these solutions.

How to get this u and v equations and the pressure that what we will discuss later, but at present you know that we can get it the functional relationship of u, v with respect to a Cartesian coordinate of x, y, z and these problems becomes a steady problem. So there is no time component. So we will have the solution of u, v, w and the pressure component.

Okay, so from that two examples, one the wind flow over a weather radar setup, second is a simple flow jet impacting on the floor. We tried to understand it, the pressure field and the velocity field.

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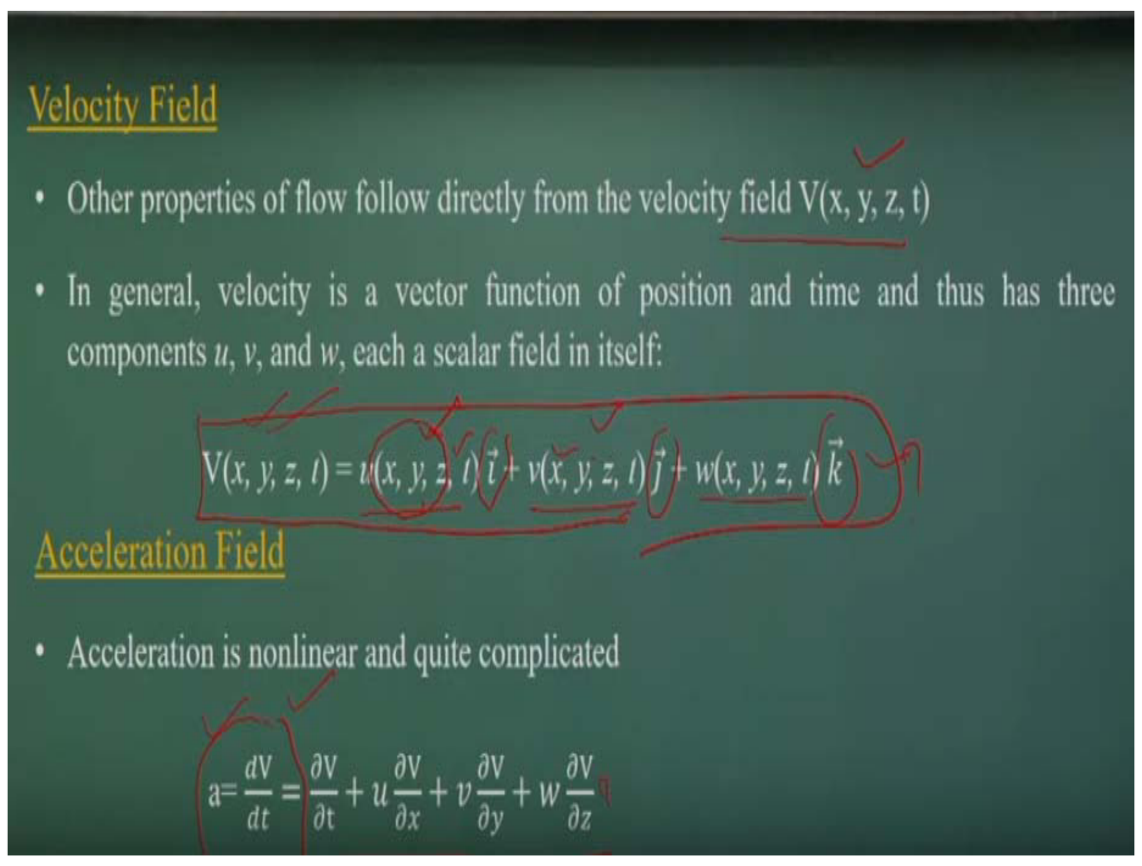

So now I am just defining them the velocity field, when we are talking about we are talking this velocity as a vector quantity, which vary in a space in case of the Cartesian coordinate system of x, y, z and the time. But most often for easy point of view, we resolve this velocity vector component into its scalar component in Cartesian coordinate systems like the i and j and k.

As you know from vector rotations of x and y, j these are the unit vectors. So you will have the u velocity components along this x direction, $u(x, y, z, t)\,\vec{i}$. The v velocity components, v velocity component in y direction and w is a velocity component z. All will have a scalar component having a functions with the space x, y, z and the time; v will be $v(x, y, z, t)\,\vec{j}$ and w is $w(x, y, z, t)\,\vec{k}$. So we define a velocity field.

$$V(x, y, z, t) = u(x, y, z, t)\,\vec{i} + v(x, y, z, t)\,\vec{j} + w(x, y, z, t)\,\vec{k}$$

That means getting a velocity field either from experimental study or analytical study. Similar way we can get it from computational methods, which later on I will introduce to more detail to you. So that way we will get a velocity field. Similar way if I know the velocity field, we can compute it what will be the acceleration, the rate of change of the velocity gradient, velocity, you know it the accelerations that the component you will get it.

$$a = \frac{dV}{dt} = \frac{\partial V}{\partial t} + u\frac{\partial V}{\partial x} + v\frac{\partial V}{\partial y} + w\frac{\partial V}{\partial z}$$

About these derivations we will come it when we have fluid kinematics. We will talk about that, but you can see that any of the flow field conditions we can have a velocity field. That means we know the velocity distributions with respect to space and the time. Similar way if I know the velocity distributions, we can compute the acceleration distribution over that the fluid flow problems.

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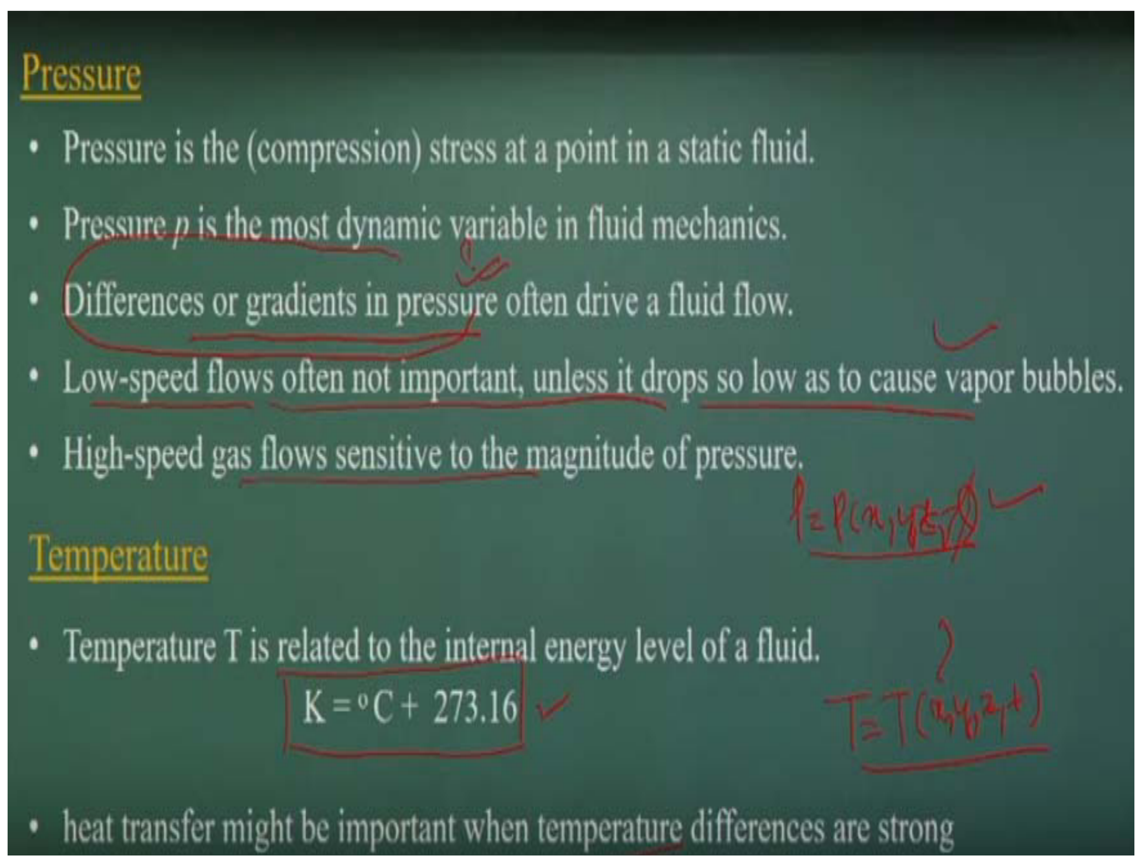

Now as already I discussed that we talk about the pressures which is very dynamic variables, the pressure distribution play the major roles because as you know it the flow is come from high energy to the low energy. Many of the time this pressure the gradients indicates for us which directions flow will be there. So that is the reasons we always look at the gradient of the force which drive the flow.

Mostly this energy drive the flow, but many of the cases the other component whenever is less, the pressure gradient itself will indicate it which direction the flow is going on. So the computing the pressure and the pressure gradient that what is major component in the fluid flow problems. Some of the case studies like is there we also very worried about the places that when it goes below a particular pressure this vapor pressure then the water converts from the liquid to the vapor.

So that is what creates the problems of cavitation. That what I will just discuss in a example problems, how the cavitation processes occurs it. So we try to look it which are the reasons we have low flow speed flow zone or the high speed flow zones, how the pressure distributions are changes it. All we can try to look it in a fluid flow problem, if I have either pressure variation if I know which varies with respect to the positions and also the time. That means is a scalar component.

It varies with a space to space, the locations to locations. Also it varies with time. So in case of steady problems, we the time component goes out. So we have the pressures which varies with space only. So if you know the velocity field that means velocity variations with space and time, the pressure variations with space and time then more or less you have solved that fluid flow problems.

But some of the cases like when you have the heat exchange is going on drastically in a fluid flow where there is a lot of temperature gradients are there, then we apply the first law of thermodynamics to get it the temperature field. So there are the, the problem here is not only the fluid flow problems there will be the heat transfer problems.

There is a lot of gradient of temperatures are there, the heat transfers are there. The same way for that fluid flow problems, we can have the temperatures is a function of the space and the time. So to solve this, we have to follow first law of thermodynamics, the heat transfer equations to solve this problem. Mostly in this fluid mechanics course I will not go more detail about these thermal flow, the heat transfer problems more, the flow due to the temperature gradients that part.

$$K = {}^{\circ}C + 273.16$$

And this is as you know is very basic things that how the temperatures related to the at different centigrade to the Kelvin scale. That is what the point.

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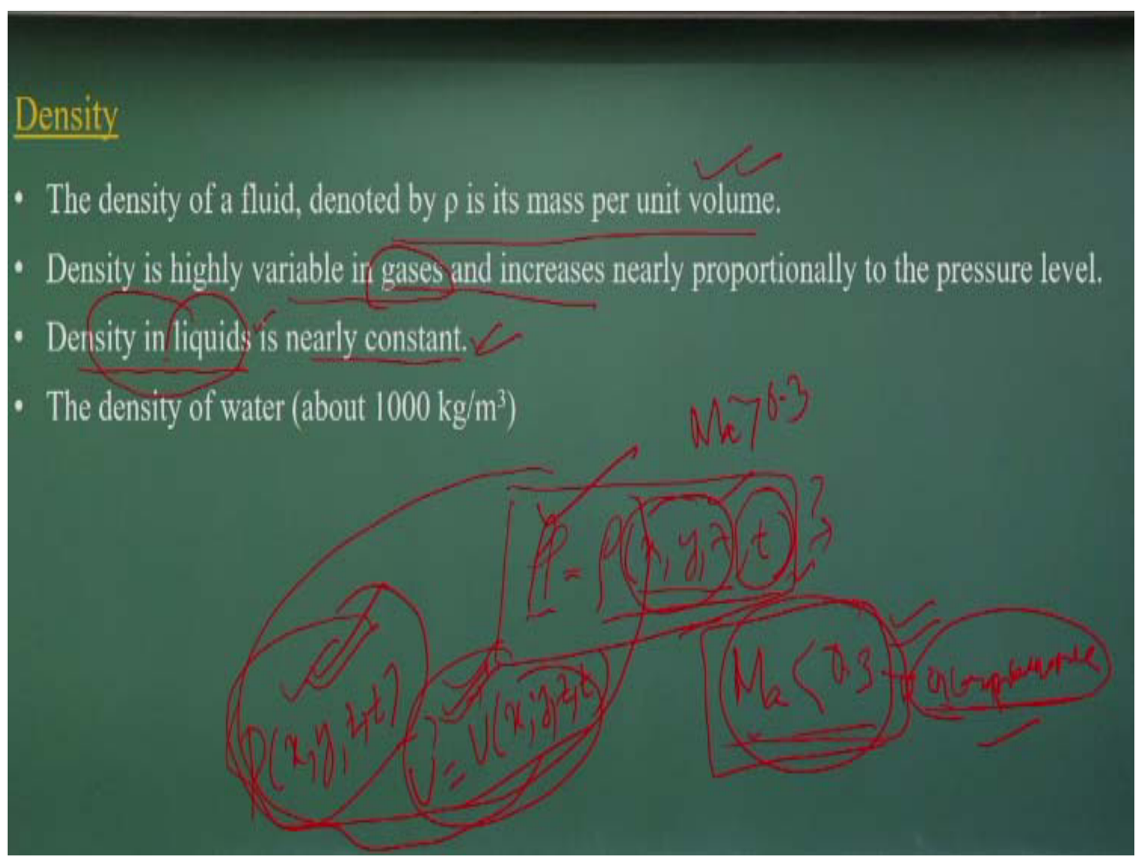

And second point what I am to discuss is the density of the flow. You know it this mass per unit volume or it indicates the mass of the fluid and that what per unit volume we quantified it. So if you multiply the volume, you know this what is the amount of the mass is there and based on that we can find out which is a heavier mass or the lighter mass, the fluid as they have a heavier and lighter mass.

There, the energy, the kinetic energy, potential energy and how that is what varying it that is what is related to the mass properties. So that way the density plays a major role for us. Some of the cases when you have the flow is compressible, your density is also the significantly varies with the positions and the time.

So we can solve the problems to get these density variations with positions and the time and that is a variable for the gases, but for the density in the liquids nearly constant as most of the examples what I have I will discuss it. We will talk about the liquid flows not the gas flows. So that is the case if the density of the liquids will be really constant.

Even if in case of the gas flows also as discussed earlier, when you have a Mach number less than 0.3 also we can consider as incompressible flow. So density does not vary significant. So that way, if you look at that, as a fluid mechanics specialist, we will try to solve only two fields, pressure field and the velocity field.

Because most of the fluid flow problems what we have considered where the Mach number is less than 0.3 unless there is supersonic flow and all which is for the rocket flow and all the concept. So we need not to have a density field that for this problems, what we consider it, but the major things what we look at how the pressure field and the velocity field. How does it vary with the space and the time.

These two things are more important for us, the pressure field and velocity field. Since we consider the problems which the problem, the flow is a Mach number is less than 0.3. So flow is incompressible in nature. So we can just need to know it the pressure field and the velocity field.

If it is not, then you have to go for that means if your Mach number is more than 0.3 conditions in your flow field conditions then we have to consider the density variations which will be the varies with the space and the time component. So in that case, we will have a the pressure, the velocity, and the density variations. So three fields we need to know, define the flow when you have a flow incompressible.

But when you have the Mach number greater than 0.3 the flow is compressible. Then you need to have a density field, the pressure field, and the velocity field. These three field we need to define it when the flow is compressible. If flow is incomprehensible, that what we can get it when the Mach number is less than 0.3. In that conditions only we need a pressure field and the velocity filed.

So what I am to tell you that fluid flow problems are very interesting problems. It is a solvable problem at present. Only we need to know it how the pressure varies it, how the velocity varies it. But as I showed it two examples, one is the flow around a bird which is very complex geometry and another is the flow load on a weather towers which is looks like a spherical ball.

So if you look it that as we go for a complex problem, so getting these pressure filed, velocity field, it is not that easy. So that is the reasons we follow experimental methods, analytical methods, and numerical methods to solve the problems. In fluid mechanics problems, a specialist who can visualize the flow better and then he can simplify the flow problems and then he can solve the problem.

The flow visualization is a major issue and how to visualize the flow. That means how to determine that how what could be a tentative flow patterns or the flow patterns are obtaining from either experimental results or analytical methods or the computational fluid dynamics methods we should try to understand what we are getting the flow patterns.

Are they correct or a fluid mechanics specialist he can looking these problems he can visualize it that this could be expected flow pattern could be there. So define these flow patterns we define technically three lines.

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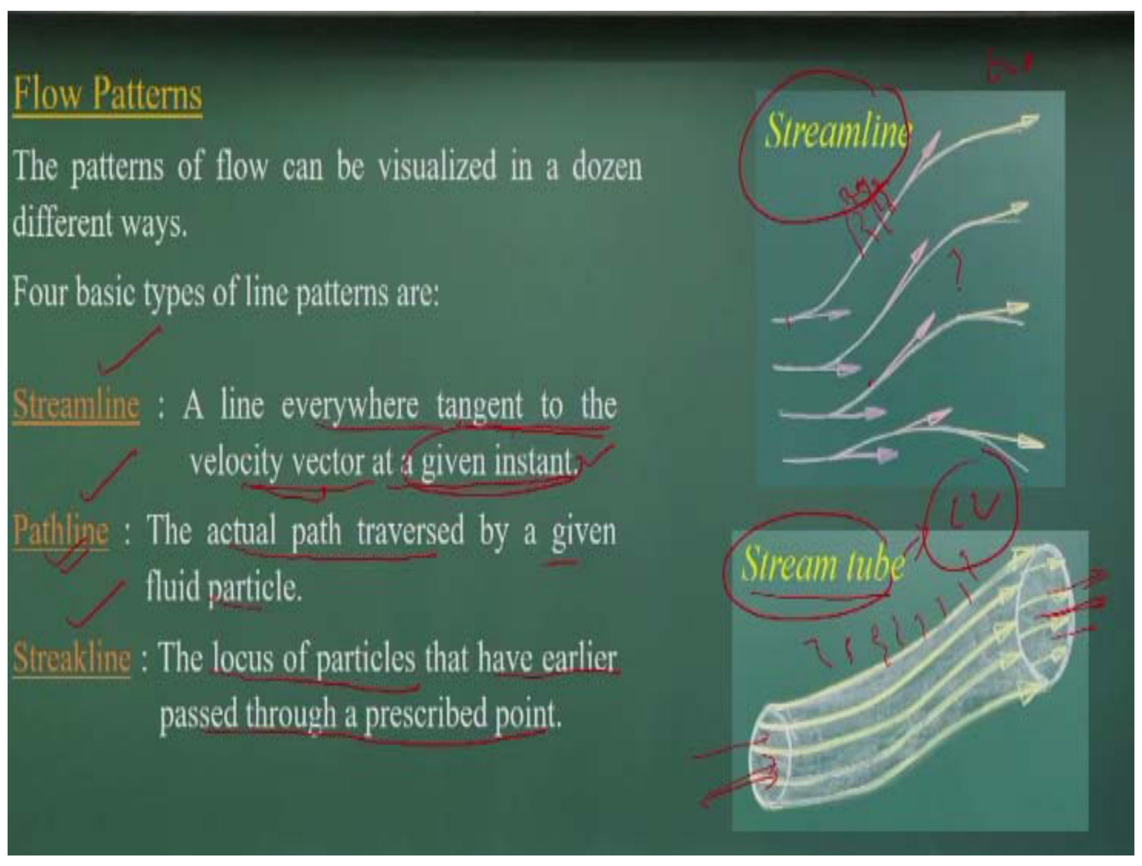

One is the streamline, pathline, and the streakline. Let us look at the definitions. The streamline, a line everywhere it is a tangent to the velocity vector at given instant. That means time equal to zero or we take a snapshot, okay. And at each point, if I draw this the tangent that tangent should give a directions of the velocity vector okay. So if you look at this that as I draw this, these tangent line, this line tangent should match with the directions of the velocity.

So if that is the conditions and join that line is called the streamlines. So if you look at that one case, the streamline goes like this, one case streamlines go like this, like this. like this. Other way round, if you have that streamlines at a point if you draw the tangent and that the tangent is a direction of the velocity. So we can find out the directions of velocity if I know the streamlines.

Or if I know this direction of the velocity by measuring any experimentally work and connecting that lines such a way that it will have a tangent to that velocity. Tangent and the velocity direction matches each other. That what will give a streamline. So we will have the streamline patterns like that.

So if you look it that the flow is going this direction, this direction, and this direction, but one of the easy things here in the streamline if you look it if this is the velocity, the direction of the velocity, velocity, that means there is no component is working on this time. There is no velocity component. The normal component is zero. The flow is going tangential to that. There is no component on this.

That means, there is no flow goes through this one. That is the reasons of what we define it if I have draw the streamlines, and it is occupied a certain space like this the steam tube. In that case is a very simplified case is now the only the flow will be entering from the side and go out from this. Since the streamlines does not allow any flow cross through that as the definitions indicates for us.

So there will be no flow will go through these ones. So we consider a streamline, a stream tube which is composition of streamline such a way that there will be inflow and outflow and across the stream tubes, there will be no flow component. So this is what the imaginary the stream tube will generate it to solve the problems because it gives us that there is no velocity, no mass flux, no momentum flux comes into that.

So some of the times we consider the stream tube as a control volume. We solve the problems as a stream tube as a control volume, then we solve it because we get imaginary the boundary where there is no mass flux, no momentum flux. And it is easy for us to solve the problems because it is only having inflow and the outflow. So we use the stream tube concept and the streamline concept.

So again I am to repeat it the streamline is a line everywhere the tangent through the velocity vector at given instant of time, as a snapshot. You take a snapshot, at that snapshot, if you draw a line each tangent of the line will indicate us the directions of the velocity. So that is the basic point. That is what we call the streamline. Second is the pathline.

If you can understand it that the actually path traversed by a given fluid particle. You consider a fluid particle and at different time interval you find out where that fluid particles.

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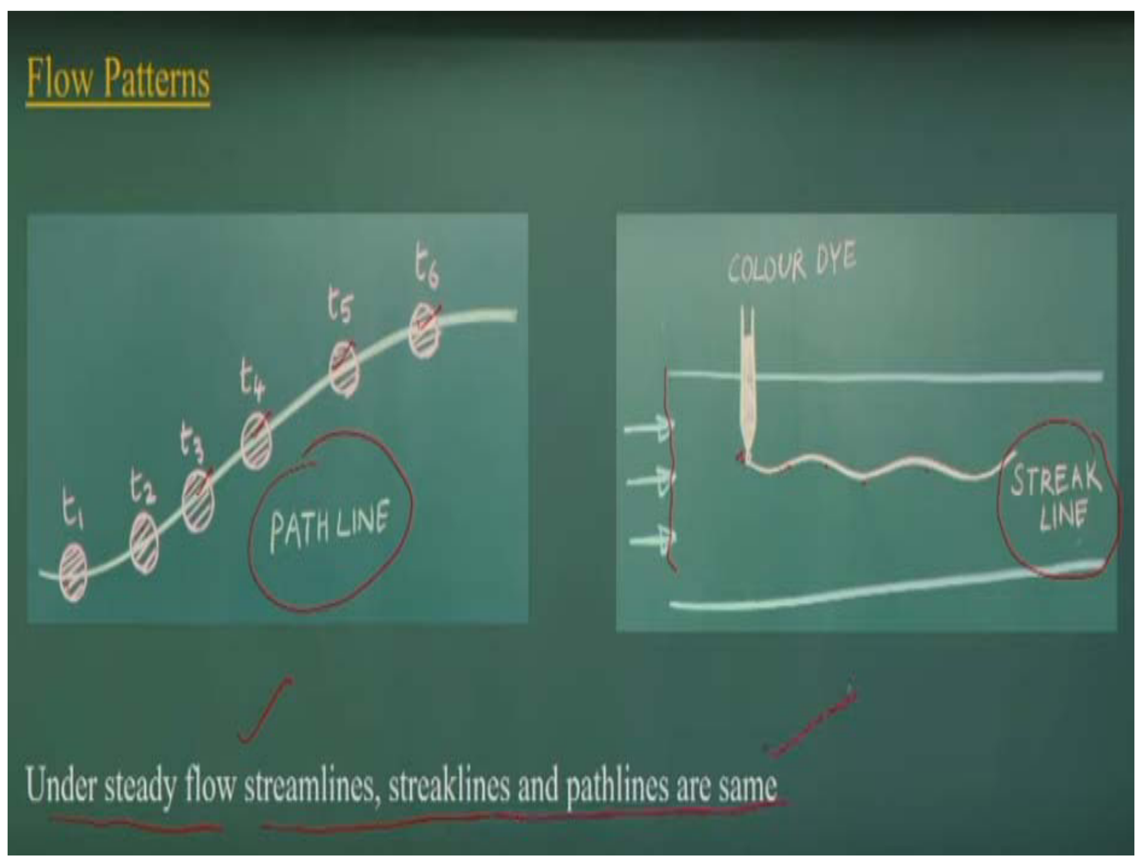

Like the next examples, like I have a fluid particles at these points at the t_1 time and t_2 time, t_3 time, t_4 time, t_5 time, t_6 time. It is a different time. How from this position to this position, this positions like this. Then if I draw this line which is called the pathlines. That means we define the path of the fluid particles, but it is traced by the maybe last few minutes, last few seconds drawing that will draw the pathline.

So it is a time information are there the how the fluid particles are passing through at different time. So we are tracking over fluid particles, we are talking about that. So how the at the different time it is moving it. This is called the pathline. Similar way if you look at this, another point is the streakline. What it says that the locus of the particles that have earlier passed through a prescribed point.

That means you have defined a point, at that point the fluid particles are passing through that. So that means the position is fixed. At that point, which are the fluid particles have already passed through that and those if you color it or those you mark it that the lines will indicate as the streakline. So if you look at these problems that let I have the flow like, this is coming from these.

We have a channels. I have at this point I have a color dye putting into there. So that means which are the fluid particles are coming to where I am making them to either a red color or the blue colors okay, any of the colors okay you can use as a color dye. So put in a color. So as after few minute if you look it these particles will move it the second particles will move it and this color dye pattern what will get it after t 1 time that what will give us the streaklines.

So try to understand there is the streamline, pathline, and the streaklines. The streamlines talks about the how presentations of the velocity vectors at a particular instant of the time. Whereas the pathlines which talk about us the path traversed by a fluid particles of a durations of t. What are the path, what is the different positions it should path.

The streaklines what is talk about that it is a locus of the particles which have passed through a fixed point. So if you look at this way, we use a pathline for some problems to solve it. The streaklines to solve some problems, to visualize the problems.

Similar way we use the streamlines more upon we use the steamlines which as I try to explaining is that if you know the streamlines you know these the velocity the directions of the velocity vectors, which gives us that there is no flow cross through that and we can compose a stream tube concept as a control volume and you can solve the many problems.

So mostly in case of the analytical methods we follow the stream tube or streamlines methods more accurately, but the experimental technique when you visit either we follow for a technique like a pathlines like we track a fluid particle at different instant of time then trace on that or we do a dye a color a series of the fluid particles then find out the color dye pattern. So that patterns will be like a streakline.

So these two most upon use for an experimental works to know it how the flow patterns or flow visualizations will do it. Then later on with wind lab experiment I will demonstrate to you how interesting flow patents we get it for different conditions. So but very interestingly that you see that if you have a steady flow okay if the flow parameters characteristics the velocity, pressure they do not change with the time then all the steamlines, streakline, pathlines are the same.

So definitely they are not will be the different the same things will happen it if you have the steady problems. That means your pressure, the velocity that they do not depend upon the time variabilities. With this let us come back to that just to have a if you look at any fluid flow problems which are very complex and most often this fluid flow in a natural systems is much more complex as compared to manmade systems like as I given a example of bird and the weather towers.

Similar way you can imagine very complex problems would it happens is that. So as I told you that we need to visualize the flow. If you visualize the flow you solve the problems.

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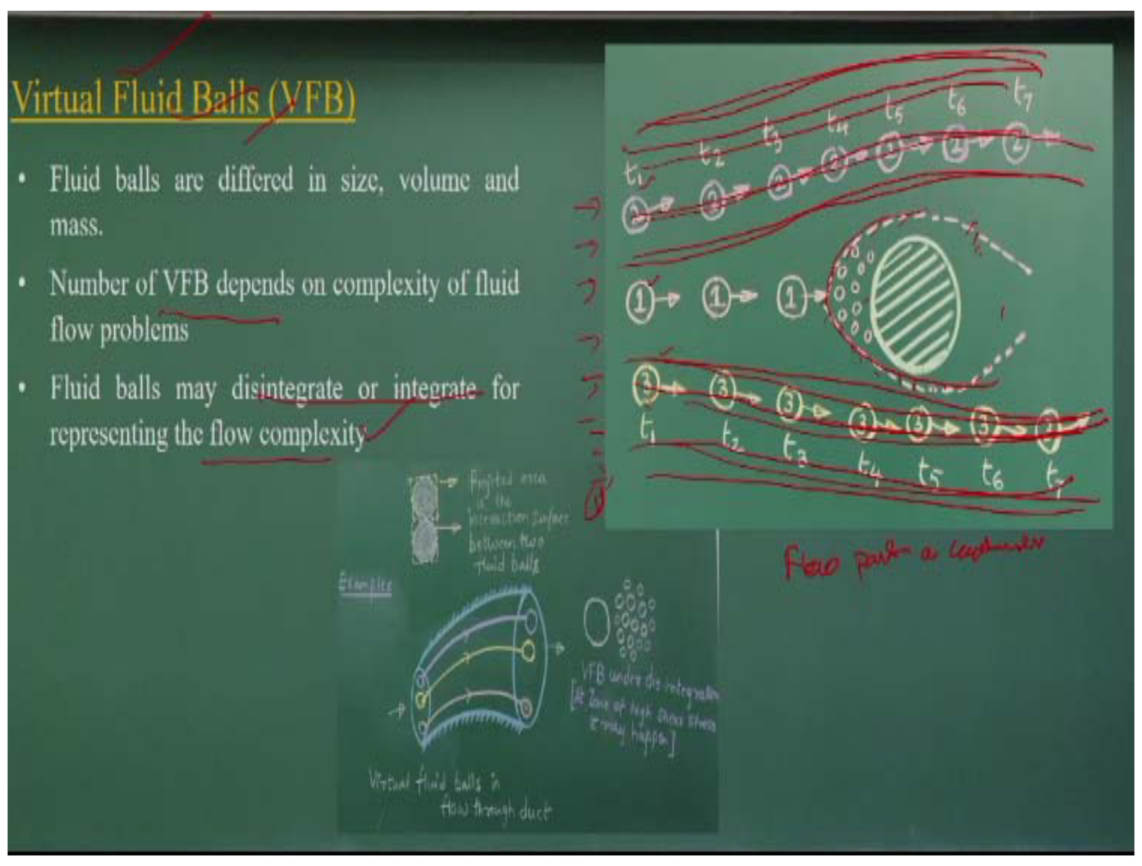

The for example, if I take these problems that flow passed a cylinder. That means I have a cylinder, a velocity of v uniform velocity of v is passing through this. okay? As I told it earlier I will have a virtual fluid balls okay it is not real fluid balls these are virtual fluid balls. I have a ball 1, 2, and 3 and this is the fixed. And these balls are having a velocity v as equal to the velocity of uniform flow.

And as you can see it very clearly that the ball 2 at t_1, t_2, t_3, t_4, t_5 will move like this, which will be defined as a streamlines in case of the steady flow it will define a streamline or pathline or streaklines. Similar way if I take a fluid flow ball is third one that what will we define it the another streamlines, pathline, streaklines like this.

So we can, with help of this conceptualization we can draw it what could be the approximate the streamline conditions when flow passed on a cylinder. But what it happens to the 1 which the ball is goes after certain time dash over this. As you know it at this point the velocity will be zero. So this concept what we have said it this is what approximately can draw the flow field the streamline patterns.

But when you close to the cases when you have a velocity reduces and we have a hypothesis now, that it may degenerated it make it bigger ball to smaller ball and we can find out these are what zone of influence. So if you have an art, how to draw a streamlines of a flow conditions that means you can solve many problems.

See here I am with a example of a virtual fluid ball concept, you just think it balls are rolling it and dashing over a cylinder is there. So because of the dashing there will be a regions which will have a effect, there will be regions will not have a effect. The balls of these ones will move like this. So if I can draw that, I can draw the streamlines. I can draw the streamlines.

So that means I am just hypothetically I am considering the balls are rolling with the velocity v and there is a zone of influences and those the regions the balls will be disintegrated into smaller part beyond that, they may not have a effect and that what we can move it. So just to visualize the fluid flow we have brought this concept of virtual fluid balls.

That means if you want to have a very complex problem you can change you can make a more number balls are moving it and interacting with the structures and how the zone of influence how the streamline patterns will be there, that what we can generate it and we will try to use this concept to define the laminar flow and the turbulent flow which is will be more interesting to you to visualize the flow.

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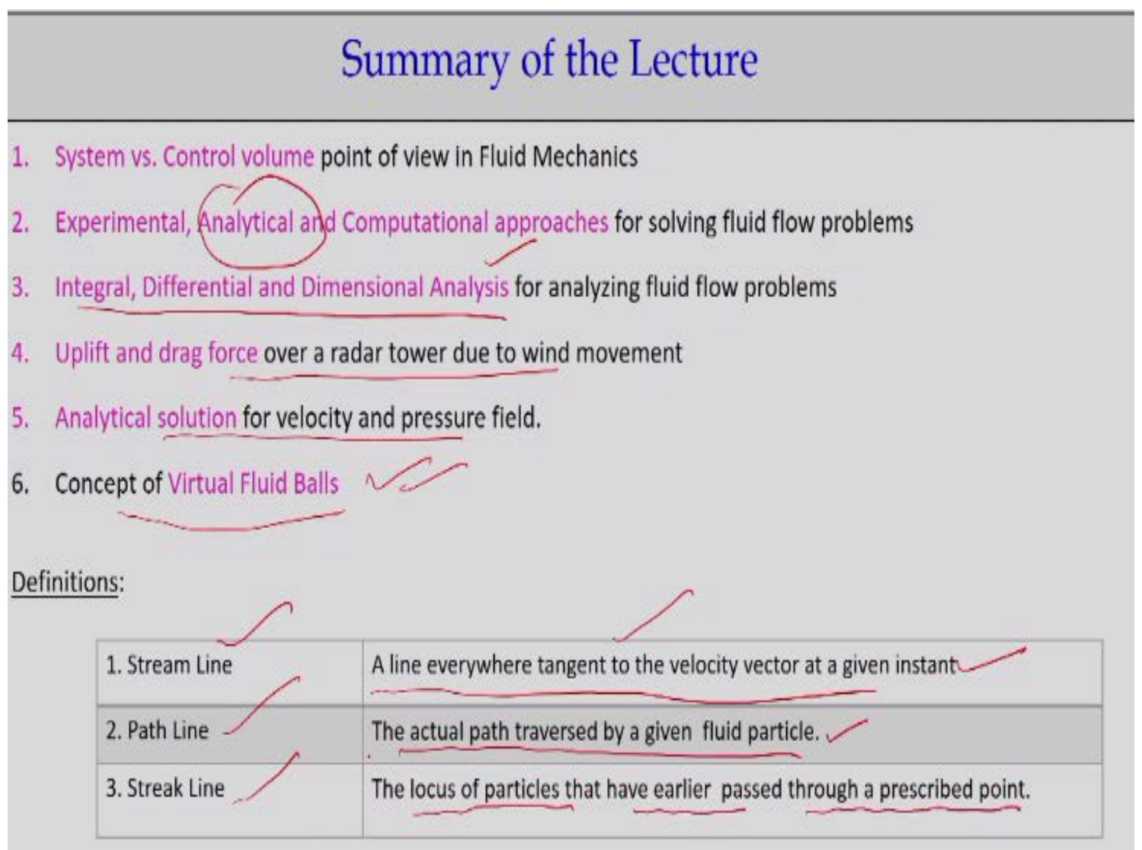

With this let me summarize today's lectures that we define what is the systems and the control volumes and the fluid mechanics problems. There are three tools are available to us, the experimental, analytical and computational approach. The last two decades' people have been using the computational methods more extensively solve very complex fluid flow problems.

Because of that, we have fuel efficient aircraft, the fuel efficient spacecraft. So all these are possible because of the use of the computational fluid dynamics. The use of the computational fluid dynamics helps us to predict the weather which is also a fluid flow and heat transfer problems.

Also the parallely as I say that there are a lot of experimental facility has developed in the world that can not necessarily will we do in a scaled model can do a full prototype of models, which is used in automobile industries or the aerospace industry. They try to use the full scale models and try to look into what is space technology centers they use the full scale models to test it.

So these are not is possible. But before that as you know these analytical methods is give us a basic knowledge how the fluid flow problems happen it with the help of a control volumes with the basic energy conservation equations and mass conservation movement. And these are the three approaches. Next is integral, differential and the dimensional analysis.

As we have talked about that radar problems and the bird problems. Then very simple way I just define it the again the virtual fluid balls concept what we should try to understand it. Then we can visualize the flow and once you visualize the flow then you solve the problems very systematic way. At the end we have learned also the three lines. One is streamline, pathline, and streakline.

The streamline the line everywhere tangent to velocity vector gives at a particular instant. That means it talks about the tangents is a parallel to the directions of velocity vectors. And the actual path traversed by the fluid particle is pathline. And the locus of the particles that have the passed through the prescribed point is called the streak lines. With these definitions let me conclude this class. Thank you.