Fluid Mechanics
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Lecture - 01
Basic Concepts of Fluid

Welcome you to this MOOC course on fluid mechanics. This course is designed for undergraduate students in civil engineering, chemical engineering, mechanical engineering and other disciplines. This course is going to cover within a 20 lectures in eight weeks. I am Subashisa Dutta, Professor in Department of Civil Engineering, IIT Guwahati.

I going to take this lectures in very conceptual wise so that the student can understand the fluid flow problems. By understanding the fluid flow problems, they can visualize or conceptualize very complex fluid problems, which is challenging task in present era.

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I will cover these lectures in 20 hours, considering that it has been designed to give in eight weeks. The first week we will discuss about the introductions, the basic concept and properties of the fluid. The second one will go for the fluid at the rest. That means fluid statistics and the pressure distributions concept. Then we will go forward in the third week when fluid in motions not considering the force component which is called as fluid kinematics.

We will talk about more detail about the fluid kinematics. Then we will go in a fluid flow systems if we are applying the physical equations, conservation principles like the mass conservations, the energy conservations and momentum conservations in mass, Bernoulli, and energy equations which we will cover in two weeks of six lectures.

Then we will go for the application sides. In the applications we will talk about how we can use the momentum analysis of the flow systems. Then we will go for in case of the physical modeling concept for a very complex process how we can use a dimensional analysis to design the physical. Dimensional analysis and modeling we will talk about how we can do the physical laboratory experiment to address very complex flow problems.

In the next we will go for the applications of flow in pipes where we will discuss about the complex flow like the turbulent flow, the laminar flow, how we can approximate it for designing the pipe networks for an industrial use or domestic sewage. With this concept, let me start the very basic concept today about introductions and the basic concept.

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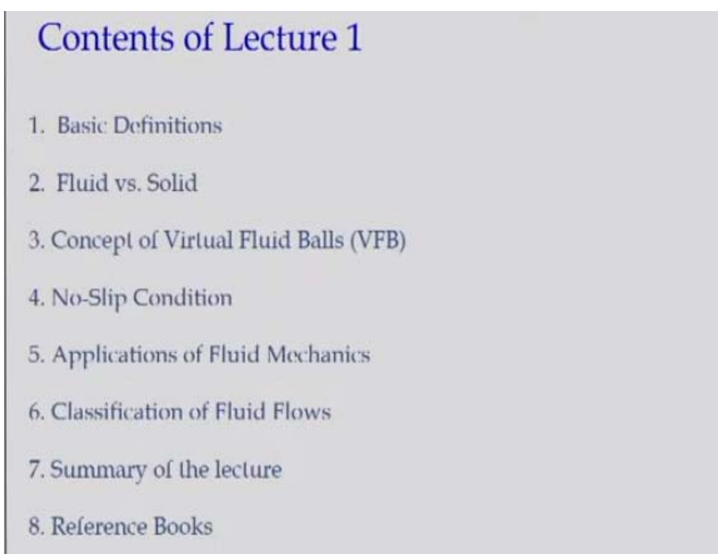

In that we will start with very basics that the fluid versus solid. Then the new concept of the virtual fluid balls I will introduced to you, which is not given any text books, so that you can visualize the flow process very easily if you have a virtual fluid ball concept. Then we will talk about no-slip conditions. Then applications of the fluid mechanics for engineering point of view. Classification of fluid flow. Then we will have a summary and the reference books, which is we are following.

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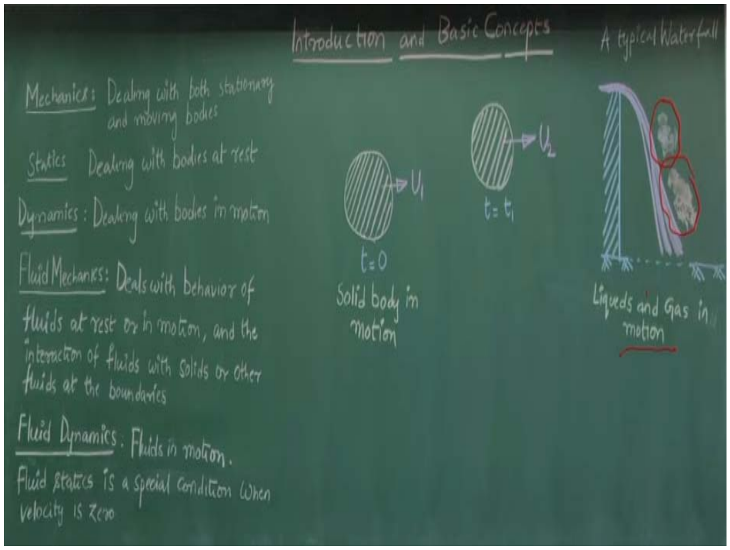

Now let us talk about the introductions and the basic concept. As you know it when you talk about the mechanics we talk about the flow of dealing with the both stationary and the moving object. So like for examples what is given here you can have a solid body is translation rotation, the rotation position can have a shear stress, shear strain all you know it in solid mechanics.

Here also we talk about when the solid body is in a rest we have a statics and when a solid body is moving conditions we call it the dynamics. But when talk about the fluid mechanics which will deals about the behavior of the fluids at rest or in a motions, so that besides that, it also have interactions. When you have a fluid flow you have a interactions with a either another fluid mediums or with a solid interface.

So the fluid mechanics when we talk about that, I talk about the fluids, either in at rest or in a motion, and also the interactions of the fluid with the solids or other fluid at the boundaries. Now if you take it this examples, is a very simple examples is given here. That is what is clearly indicates is that for examples, a waterfall is there. So you can understand it, there is a change of potential energy to kinetic energy.

But if you go beyond that, that how these the water vapors are generating at these points at the down of the of a hill of a waterfalls, that what is they create have a slight bit complexity is that there is a change of the kinetic energy to the heat energy and the heat energy is responsible for changing the water from the liquid to the gas phase.

And if you go beyond that topic that because of the change of the heat, the pattern, the temperature patterns, how the ecology of a river system changes it then it has a more complex problems. So we will try to conceptually do that very complex problems like the waterfalls, where these the energy changing from the potential energy to kinetic energy, kinetic energy to heat energy.

The fluid is changing from liquid to the vapors. All this process we can conceptualize, we can understand it, when we can have a better understanding of the fluid mechanics. Very simple way we can classify is a fluid dynamics that means we talk about the fluid when in a motions, but when if we does not have motions, that means very simple things that the velocity is equal to zero. That means is a fluid at the rest, which is very simplified versions of the fluid dynamics.

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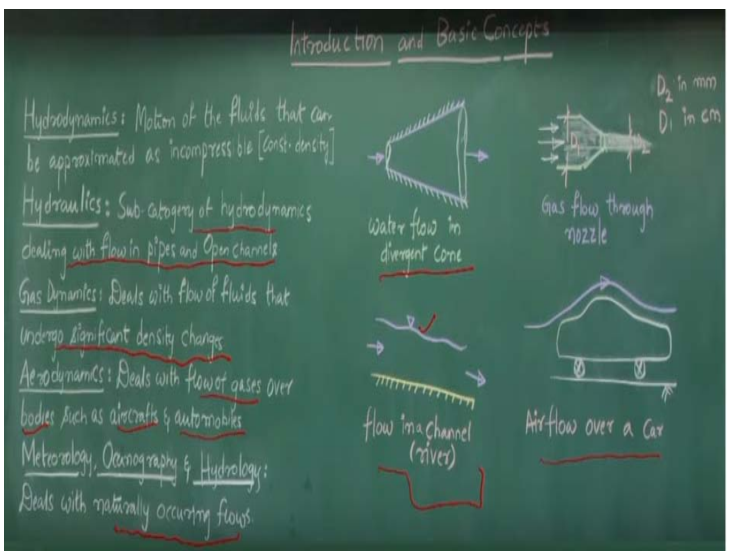

Considering that let us go to we also classified the problems the based on a different conditions like the compressibility, like the fluid properties that is what one of the basic properties is fluid density, the mass per unit volume. If it is the density changes, then we call it fluid is compressible. If density does not change then we call fluid is incompressible.

Now if you look at the topics you relate it to motion of the fluid when it can be approximated as incompressible flow. That means the fluid, the density of the fluid does not change or if it changes it, that does not change that significant order as compared to the other flow variables. So the flow problems which consider that type of problems we call the hydrodynamics problems.

Like for examples, the water flow in a divergent cone where the flow is coming one side is going outside the flow process that happening it in this case there is no change of fluid density in very considerable. So we can approximate it the fluid density is constant and flow is incompressible. But if you look it the other problems like the gas dynamics that deals the flow of the fluids undergo of significant density changes like for example, you have a gas flow through nozzles.

That means, if you talk about two nozzles are there. One is in centimeters and other may be lesser than millimeter levels. As you have a very high speed flow is goes on through these nozzles, the fluid may go through a change in its density. As it change through the density then flow is compressible flow.

So we talk about that type of problems when you handle it, we talk about the gas dynamics problems we are handling which most likely the mechanical engineering, the chemical engineering students they focus on that. If you look at these very simple category in a hydrodynamics is that the hydraulics which dealings with the flow in pipes and open channel flow which is very simplifications versions of the hydrodynamic flow that you have the flow through in a flow in a channels where you have the free surface and you have the boundaries.

And as the flow goes through this, this flow can be simplified it as compared to the hydrodynamic. So hydrodynamics, the hydraulics, gas dynamics, then let us talk about the aerodynamics. The aerodynamics talks about the flow of gases over a bodies like the aircraft the automobiles. Like the examples what is given here that the air flow over a car.

So the basically we are talking about how the air flow is going over a aircraft, the spacecraft, aerodynamic things, we try to look at how these the force components are going to act it. How we can design a aerodynamically streamline the car safe those are things we generally discuss in aerodynamics. Besides that, there are topics like in a natural sciences like natural occurring flows, which talk about methodology, oceanography in hydrology.

So the basically we divide the fluid flow problems, hydrodynamic, hydraulics, gas dynamics, aerodynamics and the metrology. Okay let us start it engineering perspectively I have to define it what is the solid what is the fluid okay.

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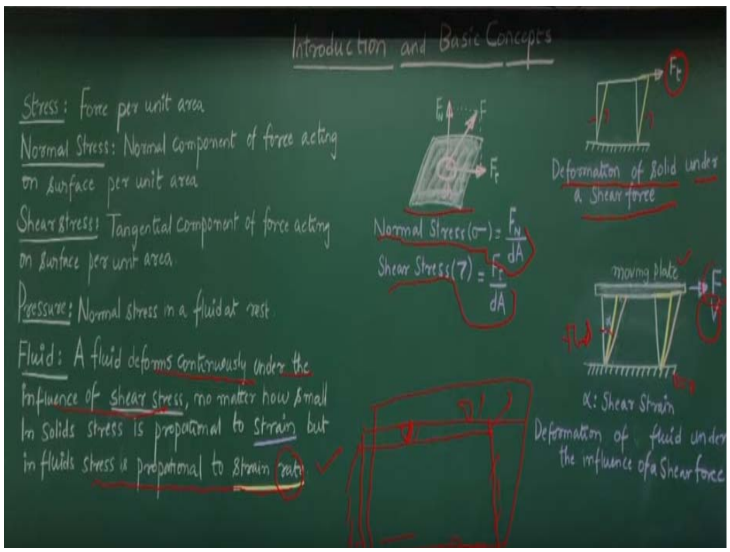

You as know it when you apply a force then you will have a stress concentrations on that. For example as is given here there is a surface in which we have applied the force component which has a tangential component also the normal component. Because of this normal component, you will have the normal stress components acting on that. Then you will have the shear stress component on that.

So whenever you have a surface and you apply a oblique force on that, which has two components of normal force and the tangential force component we will have the two stress will be built up. One will be the normal stress another will be shear stress. The force per unit area, that is the stress component what you talk about.

When you talk about the difference between the fluid mechanics and the solid mechanics, here we any engineering point of view, we talk about how the fluid and solids when you apply the shear stress how do they behave. So for example, if you look at that, if we take a solid body as given it here under a shear force, the solid body will deform it, the shear deformations will happen it as we are applying the shear force acting on this.

But as soon as we release that ones if it is within the elastic limit, it can come back it. So there will be a deformations, the shear deformations will take place it but it can come back into if it is within the elastic limit. But if we talk about the fluid mechanics, for example, as we have given a sketch here, the fluids are within this two plates. One is velocity is equal to zero.

That means it is a rest conditions and another is a plate is moving with a force F acting on that and moving velocity V and I have the fluid within that the two plates. When you apply the shear stress on the moving plate as moving plate is moving on, it has the shear stress is generated at the surface. Because of that the fluid element which presented here that what will be on the shear deformations.

But as we are applying the shear deformations, the shear strain rate will go, the shear strain is going on increasing and increasing. Even if you release this force, the fluid will not come back to the original position. So here we talk about not the shear strain, the shear strain rate, the shear strain changing with respect to time.

How does it changes? So when you talk about the shear stress which will be proportional to the shear strain, that is where the fluid mechanics where we will talk about the solid, we will talk about the shear stress proportional to the shear strain. That the basic difference is come with a rate, which we will explain more details when we talk about we will talk about the Newton's laws of viscosity in the next class.

So if you talk about any fluid, the basic definitions is that it starts continuous deformations under a influence of a shear stress, no matter how small the shear force acting on that fluid elements. For examples, let me talk about that. I have the fluid is there in a containers and if I just tilted this once, if I tilted this once then this free surface will change it. The free surface will change it.

So this is what it says that whenever you applied a small shear stress, the fluid starts deforming it the and that deformations changes the free surface, that changes the shape of the fluid thing. So, but in case of the molecular levels if I talk about that which is you know it very basics in the school's levels that the molecules are having a inter molecular forces in the solid is much more stronger as compared to the fluid.

And within the fluid the liquid has the stronger intermolecular forces as compared to the gas. So if you look in that the molecular levels as it has the stronger forces in the solids and the fluids does not have that much of intermolecular forces, it goes for the shear strain deformations rate as we apply shear stress on any fluid mass.

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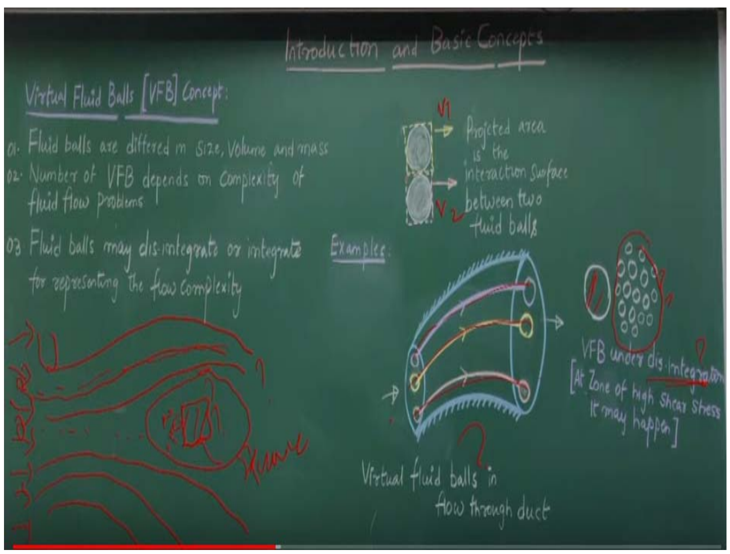

Now let you introduce a very interesting concept what I introduce for you, that is called the virtual fluid ball concepts. Like many of you do not have the accessibility to very sophisticated fluid mechanics labs in our country. And many also cannot visualize the fluid flow problems very easily. If you follow many of the textbooks where they describe the fluid mechanics as a part of mathematics components.

So considering that fact, I am just introducing a very new concept is virtual fluid balls. What does mean that, that let you have a 100 balls or 1000 balls with you and you have the flow problems. And you try to just rolling the balls and try to understand it that what could be the fluid flow patterns in that the flow problems. So you are looking it, it is a virtually if I am to flow a balls instead of the fluids, what could be the flow patterns.

So if I understand the flow pattern then I can understand the many problems, the complex problem or the simpler problems very easily. That what the concept. This concept when you are talk about that I am not talking about the molecules okay I am not talking about the atomic labels of the molecules levels. I am considering a representative a virtual fluid balls, which are moving it and which you can visualize it to understand the flow patterns the understand the fluid flow problems very easily.

So I will give you a lot of illustrations using this concept. So if you have a doubt over this concept you can always write to us and then we can modify it and can relook the concept one. So we you talk about the fluid balls the virtual fluid balls, it can be different size, it can be different volume, it can be different mass. Like if you have a two fluids that can have a two different fluid balls can be considered with a different mass.

Like I have a oil, I have a water. I can define as the fluids are the different, balls are the different. One is for the water and for the oils. Not only that, if I am to solve a very complex problem or you are visualizing it that problem is very complex, then you may need a larger number of balls to solve it. If a very simple problems like this, if I look at these problems, which is very simple problems that the fluids are coming in a duct and going out.

So you can visualize very easily there is a inflow, there is a outflow. And if I consider as is given here is a different color of the balls, this ball can move it like this, move like this. So ball will move like this, ball will move like this, ball will move like this. The balls which are closest to this solid surface, they will have either the resistance because of the boundary.

So we can understand using these flow, with this simple flow that how the flow patterns occur it. Let me give a simple example. Before going to give a simple example, these balls are the virtual balls. That means, this ball can disintegrate like what I am giving it here very easily that these balls the mass are not fixed. If these balls go through a, any drastic velocity variations or the shear stress variations, stress variations, they can disintegrate into a smaller and the smaller numbers.

So the ball is very dynamic, they can change, they can disintegrate, they can expand it, they can deform it, they can have the properties as this. So we can look at that disintegrating behavior or the integrated behavior. Now if I take a simple example, see here that I have a square object and I am considering that what could be the flow field. If I put a square object and I have the uniform flow is coming from this side, which is velocity let be the U. Now let I consider the ball.

So as I consider this one ball, which is directly hitting over this part. So as it directly hits at this point the velocity will be zero as the object at the fixed conditions and this ball can go for disintegrations, this ball can go for disintegration. The balls which is just far away that can follow the path. Similar way we can follow this the path like this, the path like this, the path like this, the path like this.

So we can understand now, very simple way that if I have 100 balls, I am just rolling that 100 balls and try to look it conceptually, the how far these balls are effected and where there will be potentially the ball will be disintegrated because of impact of the ball on that structures. If I try to understand that, I can understand it that I can draw the flow path networks and the different zone of influence very synoptic way as I go for more details like what I my point to tell it, we look it the problem from whole to part.

The first we look at what could be the gross the flow patterns. Then as we go for a detailed near to the structures this square so we can try to look it if this is a disintegrated then how the movement will change it whether the boundary effect how will you commit all we will try to understand when you go to close to that.

So we will try I will try to explain you through this concept of virtual fluid flow in this 20 lectures what is that so that you can try to understand it the fluid flow problems as conceptualize in the flow pattern, flow flowing of a rolling balls. Now if you talk about other concept when you talk about that, if the two balls are moving it, let V and V_1, V_2 velocities the definitely this balls will be axis the interactions between these two balls will be there.

So that interaction of the two balls will not define as a point of contact. We will consider a projected area. That the projected area under that there will be exchange of the momentum flux or the fluid balls will be disintegrated and can go up and go down. All that what we will talk about when we talk about at the interference at interference the surface levels. How the fluid particles are moving. So these are virtual balls.

The ball we have considered because it is in motions. But it can have a potential to disintegrated when you have tried to look it a detailed flow patterns in a near the structures or a very complex flow patterns near that. And when you talk about the computing of the force component, the shear stress component will consider as a projected area to defining that.

So these are concept what we are, I am just introducing that. You can always visualize the flow as the considering there are n number of balls I have, as it is they follow it, what could be the flow patterns, what could be zone of influence. And if you do understand that, then you can solve many real life problems. Okay.

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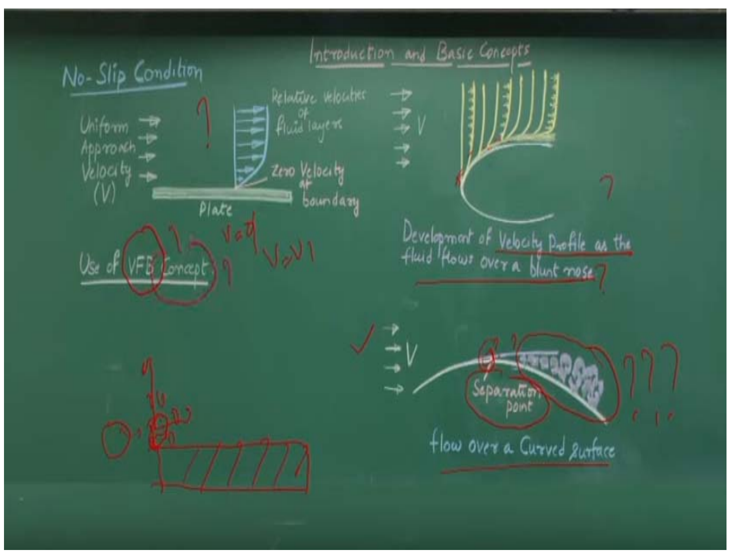

Let have talk about a very interesting concept which is called no-slip conditions. When a fluid flow through a having a interface with a solid surface, what is the conditions prevails it. For examples, if I have the plate, which is at the rest conditions the velocity is zero and I have the uniform flow is coming from the left side. As the fluid flow touches over that of the surface is the condition is called is no-slip conditions.

That means, the fluid particles which is stick on the surface will have the same velocity. So the fluid particles in this case will come to the zero velocity. As it is the fluid particles, which is close to the surface will be zero velocities. And as you go away from the surface, your velocity will going to increase it as the effect of these the boundary conditions is nullified as go far away from the solid surface.

So if you can look it very theoretically, the velocity will be zero, then it will be increase it, then you may have the velocity which is closer to the uniform velocity. So this concept is called a no-slip conditions. If I considers this the plate is moving with let V be the V_1 velocity. If it is that is the conditions then the fluid which is stick on that at that surface, the velocity of the fluid will be the V_1.

So that is the reasons the fluid will not be in slip-in conditions. No slip conditions. That means these are the same velocity will remain to each other. So that is what we have to consider it when you apply real life fluid flow problems, you will have the velocity which is equal to the velocity of the solid surface. Now take it another examples, which is very interesting examples and we can try to know these when you have a higher level of the fluid mechanics, but let us talk about that.

I am not going more details how the velocity distributions take place and all. But if you look at these ones, if I have a blunt nose like the part of aerofoil wing, so as the fluid velocity is coming over that as you know it, their velocity distributions will change as we proceed from this point to more downstream. And as go far away from the surface the velocity distributions also going to change it.

So velocity distributions are going to change it because of the no-slip conditions, because all these points here the velocity will be the zero. So you will have a velocity distribution changes along these, the away from these and on the surface of that. So this way we can understand it. This is a very basic concept no doubt. If you change the velocity you change this shape of the nose you can have a different velocity distributions.

But try to understand it is because of no-slip conditions, the velocity distribution changes near a solid surface like a nose here. Now if you go further like I have a curved surface and the flow velocity V is as a uniform flow velocity is coming up. And if you look at that, if you have the surface is very larger surface and it may come a particular locations when the fluid particles will detach from the surface.

Okay, this is very conditions what is called it is called the flow separations occurs it. The fluid particles will not attach to the as we call the no-slip conditions. That does not prevail here. The fluid is separated from that. That does not mean it creates a vacuum. There are will the flow patterns will be there. But the flow streams which are coming from the up streams they separated from this locations.

And here it create the different flow patterns, which are more or less we are going to discuss when we talk about the complex flow when talk about in turbulent flow and all. Just likely talk about again coming back to virtual fluid ball concepts. If I consider this plate problems, which I have the plate I have just giving a more zooming to that and I have the balls which is coming it that as this balls comes here and it experience that the there is a force component acting on that ball because of interaction on this.

This is what is going to go to disintegrate it. And very smaller part the part of the disintegrated can be have a velocity zero. So as it disintegrated you can say that the fluid will try to like a dispersing this the mass of momentum along this direction. So as it does that, the definitely that is what going to change the fluid flow patterns in terms of the velocity distributions and all.

So if you try to understand is that there are the virtual balls is this. The virtual balls are coming closer to a solid surface. As it touches there as the force acting on that it disintegrates. As it disintegrated there could be a mass transformations and momentum transformations are going on in different directions. As a totality this what will be change the velocity distribution from these the interface between the fluid to structures as you go above.

That is what you can show this velocity distribution. So how does it disintegrate and all that what let us not go to that level. But try to understand that we can also define the no-slip conditions using this the virtual fluid ball the concept which you can try to understand how no-slip conditions prevails it and understanding of the no-slip conditions can tell us that what would be the velocity distributions when flow passed on a solid surface maybe horizontal surface like this, the curved surface like this, or we have a nose surface like this.

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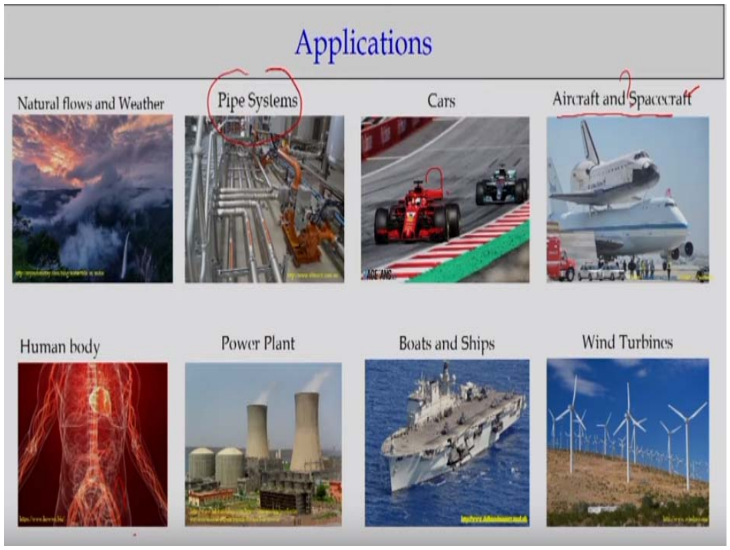

Let's talk about this applications of the fluid mechanics. Almost all you are experienced this application of fluid mechanics when you starting from your day activities, opening water basins to just switch on a electric fan, living in AC rooms all where we have the fluid mechanics problems okay. And some of the problems we can understand very easily and some of the problems we do not understand it.

If you look it that the series of applications of the fluid mechanics, it is caught across the many problems. okay. And many of the problems we have also the solve it, the because of that, if you look at this, the aerospace condition the spacecraft and all the very advance the fluid mechanics problems, fluid flow problems we have solved it using advanced techniques like these.

We can design the racing cars based on the fluid mechanics. You can have the if you understand the fluid, how does it flow it the heat transports how it happens it. If you go to any industry, you can see the series of the pipe networks and that pipe systems, the controls the mass transport, the heat transport and all. So if you understand the fluid mechanics, you can solve the pipe system problem.

The similar way if you talk about when you talk about the biological science, where you can see these figures which is looks like very complex flow problems, when you talk about the fluid flow through a human body. And no doubt there are the studies has been going on to understand this fluid, very complex flow problems in a human body.

And if you look at the engineering applications like with based on the advance the fluid mechanics understandings, we design the wind turbine such a way that if any, for a very low velocity winds, it can generate the electricity. So the renewable energy what concept we have, that is a major application of the fluid mechanics, which the harvest of wind energy and that is what is possible because of advanced fluid mechanics, the understanding with that.

The same way you can talk about when you talk about the natural science the weathers and all the today's which is possible to predict the weathers very accurately. That what is possible because our understanding of the fluid mechanics. Let me talk about this natural flow and weather systems which are very complex systems that what we also try to understand because of the fluid flow and by understanding fluid in a different scale levels, which he gives us to predict the weather's in a different time period.

Maybe within hours within a week or within a seasons we can predict the weather patterns. So the fluid mechanics has a lot of applications in different field. And it looks like a very complex process, but the last two or five decades, the application of the fluid mechanics has made it a very systematic analysis of the complex flow to find out the engineering solutions, starting from aircraft, spacecraft to human bodies, the natural flow, the wind turbines, pipe networks and the power plant and the boat and ships.

Let us not go more detail what could be the applications of the fluid mechanics in real life. That is enormous numbers, but let us talk about very basic concept wise.

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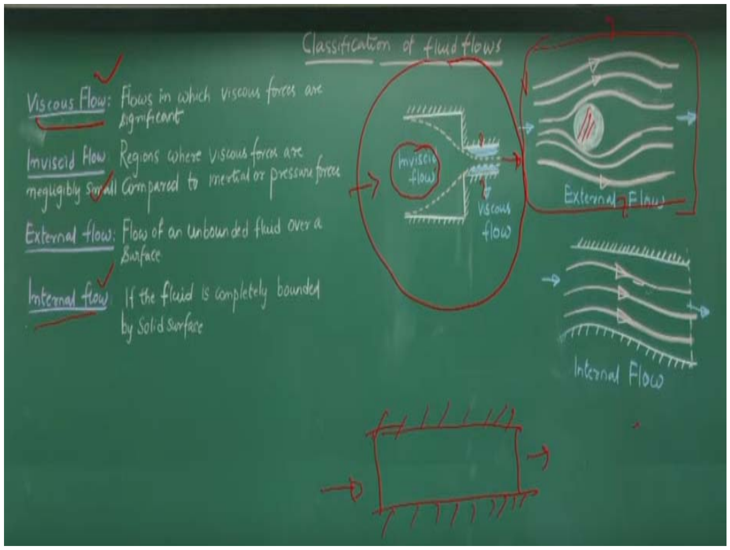

Now if you talk about when do I get a problems of the fluid flow problems, first it comes it that we should classify it. The classification means you will try to understand that we are simplifying or categorizing the fluid flow in that category. So we can solve that particular category class of the fluid flow problems. Like first let me talk about that. When the as you know in a solid mechanics when two objects are moving it there will be the resistance force okay.

And exact same way the resistance in a fluid flow we call the viscous. So that viscosity, viscous flow when we have the flow resistance are dominated, are significant then we call the viscous flow. But there are the reasons where you may not have the viscous is going to dominated or comparatively it is a less as compared to other force component, those reasons we can talk about the inviscid flow.

Now you take it this example. This is very interesting examples here, okay. If you look at a two pipes are there. One is a bigger pipe, another is a smaller pipe, okay. And the fluid is coming from the form the left side and going from the right side. As the fluid is coming from this, the left to rights, if I follow the basic concepts that there will be the viscous force in dominating these regions.

But the fluid particles at these fluid locations, they may not have that significant the viscous force acting on that. So there are these regions where the flow can be considered is inviscid. That means the viscous force is comparably the orderly less as compared to the other force component. So we can within a flow to pipe flow, you can see regions where the flow is inviscid and there is a reasons which is viscous force is dominant.

So this is what clearly difference we are showing it in a very simple to pipe flow, there will be regions where the viscous force is dominated. There is reasons there is no viscous force is not dominated as compared to other force component and we define as inviscid flow. The second component what we will talk it now is the internal flow external flow. Here I am talking about the boundary.

That means, if a fluid flow is happening, okay, whether I can define the boundaries like external flow. Like for examples I have a pipe flow. That means I know there is inlet, there is outlet and these are the boundary is defined by this the pipe boundary. So these are internal flow. So I know the boundaries defined by the solid surface there is an inflow, there is an outflow.

I know the boundary of the domain where the fluid is coming and going out. So if that is the conditions we can say is the internal flow. Is very simple problems can be we can define can get it where we know the boundaries where the solid surface is there where the flow is coming in where is a flow is going out. If you look at other type of problems like I am talking about a flow over a tennis ball. okay?

So as you know it is okay the tennis ball when you have the flow that means you may consider a tennis ball is moving with the velocity V or you can consider the wind is moving with velocity V. Both are the same conditions can prevail it. In this case, we are considering the other conditions that let be the wind is moving it the tennis ball is at the rest conditions.

As the wind is moving with the velocity V, you can see that the flow patterns will happen like this. That is what I have given you earlier the examples, if I have a square how the fluid flow will happen it using virtual fluid ball concept. But in this case, what you see that is an external flow. Because there is no boundary we have defined it here or here, where we can know with any solid surface there or the in flow is there.

So in that type of flow we call external flow, the internal flow viscous inviscid. So whenever you take a fluid flow problem, you have to find out what type of flow there, either internal flow or external flow depending on the boundary conditions or you will look it that where the viscous force is dominated. That what need to be visualized by your experience in the fluid mechanics, understanding other flow process what could be happen it.

So you can define it there will be regions where the viscous force will be dominated. There will be regions, there will be viscous force will not be dominated, which will be inviscid flow. So we can simple way categorize viscous flow, inviscid flow, external flow and the internal flow. Now if you look it very interesting things that when you I have talked about the balls okay as I talk about a virtual fluid balls.

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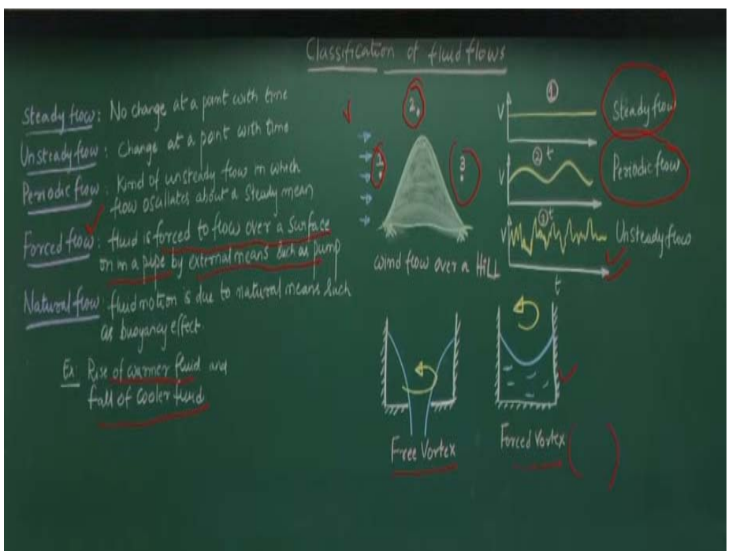

Let me consider that I have the wind movements of the velocity V, there is a hill and the flow is coming over that and going out okay. So let it assume it that the uniform flow velocity is coming it and as the uniform wind flow is coming it which is a simplification but still that simplifications is okay for solving very complex fluid flow problems like the wind movement over a hill.

So if you look at that problems, if I take a point one if I just look at how the velocity varies with respect to time, I will see that velocity may not change that significant with the time which is more or less constant. Okay, I can repeat it. It is more or less constant.

May not have exactly same value, okay. So if you would that conditions, then we can say it, it is a steady flow.

That means, the time does not matter for us the flow, the velocity or other flow variables they are independent to the time. But there are, let me consider the particles at the two which is just above the hills okay. I am not telling what could be the flow pattern here, but most expected is that the velocity will is going to fluctuate here. okay.

And that velocity if fluctuates like a very periodic functions like a sine curve or cosine curve okay then we can say this fluid is just accelerating with the velocity field. So we can have a periodic flow. But if you take it the point three which is just behind that you can as you expect that as the fluid flow is coming the fluid structures will change it here.

Then the, the velocity at these points will not have a very as the constant does not change with the time or can have the period it can have this type of unsteady behavior in these three points if you look at that the flow velocity can fluctuates like this. So we have an unsteady. So the fluid flow problem based on it variations the fluid flow variables variations with time we can classify them steady flow, periodic flow and unsteady flow.

Now the second part what we have, like if you look at that if I flow through a turbine okay. There is a force component is working on that. So that is a forced flow. That means, in this the flow you have a surface in a flow in a pipe whether there are, there is a extra means of the pumping turbine flow all the external force, external energy driving the flow systems then we call the forced flow systems.

Like another flow system which is very simple the gravity based or buoyancy based fluid systems like for examples of this vortex patterns what I am showing it here that one case I have the tank and I am rotating with a uniform angular velocity of omega and another one I have a tank, I just have a slit to fall up the waters just like a wash basin sink.

If I have that, if you look at that you as you seen it that in a sink there are the vortex formations will be there okay that is the flow will make a round and round okay. That vortex flow will happen into here, which are not having additional force acting on that. This case we are applying additional forces the rotating this tank. In this case there is no additional forces. So this what we can call a natural flow system.

The free vortex can happen it and others you can know it that when you have warmer fluids which will be having a lesser density that what is going to off it, going to raise it and if are the cooler fluid means the density is higher that is what is going to settle it and falling that. So with this concept what I am talking about that one is the flow varies with the time and another one is that whether we are visualizing there is external forces acting on that flow systems or not.

If there is no force acting on that, then we call natural flow. If there is a force is acting on that we call the forced flow and the flow what we are dividing steady, unsteady and periodic. Try to understand it how the flow varies with respect to time. That will vary from the locations to location like the examples what I have given it the wind flow over a hill. There are the locations can have the flow is steady. There is a location can have the fluids periodic. There is a location can have a flow is unsteady.

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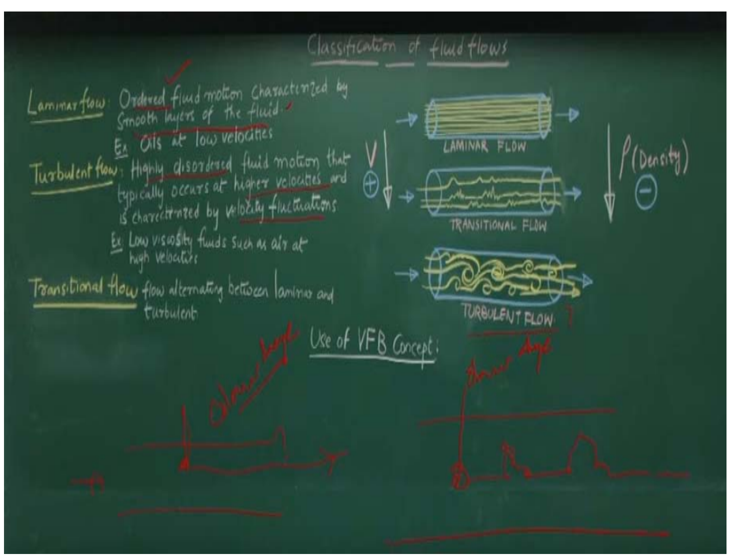

So let come to the rest of the classifications. We talk about the flow, laminar flow, the turbulent flow, and transitional flow. In this case, we consider whenever flow is laminar that means the flow is moving in a smooth layers and they follow very orderly fluid motions. But when talk about the turbulence, the flow will be chaotic, highly disordered and the typically it will have this higher velocity and the fluid the velocity will fluctuate.

Now that I will try to understand it there will be the flow where the flow will go very orderly as a layer wise layer. Like understanding this pipe flow where is we have just drawn the four paths. It shows that the flow goes like a layer by layers. And they follow very systematic order to flow from one layer to another layer. That the flow we call the laminar flow.

The second flow what we call it the turbulent flow, which is a disorder like for example, see if you look at this flow, visualize this flow that the flow can coming in that and they can have a very much fluctuation of the velocity, there could be a formations of eddies. So this type of very complex flow can happen it. And that the flow we call turbulence okay. So laminar and the turbulence.

But if you talk about that, if I am just using a virtual fluid ball concept okay, here I will consider it the fluid flow is coming it here and I have the pipe and I am just putting a color dye here. The I putting color dye on this. So I just dye a virtual fluid balls and track on that. If you are tracking that, it just moves with very smooth surface, then I will call it laminar flow okay.

That is what the Reynolds experiments, we will discuss that later on. That if you look it very visual ways, you can see that when the fluid flow is going on, and very systematic order and if you take a virtual fluid balls and dye that ones, color it and track the how it is moving it, if it is very smooth, then you can talk about is a laminar flow.

Similar way, if we consider it the turbulent flow and I try to do a color dye to a particular virtual fluid balls as is a turbulent flow as a disorder message coming it. That means you can expect it, there are lot of disintegrations are going to happen it. That means ball will be as soon as this ball bigger ball can have n number of smaller balls. There exists n number of smaller balls.

They are trying to disperse it, they trying to spread it from this direction, that directions. As if they are spreading it so this color patterns what we will see that what will be the spread through it or dispersion through this one. And that what we will have the turbulent flow. So we are not talking about what is the momentum flux and all, but as very simple way we can visualize it.

Just thinking that flow patterns whether it will be a highly order flow. In case of you have a high density, the flow like with a low velocity like oil in a flow or that can be a laminar flow. But if you talk about the river flow, where you can see that a lot of turbulence activities happening and the flow patterns are changing it that what we can say it the turbulent flow.

But, there is transitions between the laminar turbulent that is what is the transitional flow which is in between. When the flow changes from the laminar to turbulence you will have a certain range will have a transitional flow. So when you have the transitional flow, if I try to look it again same virtual fluid ball concepts, which is we just introduced to you to understand it that there is the virtual fluid balls is coming it and I am doing a color dye on the surface.

As I do the color dye on the surface, the balls here that can go it disintegrate it again can join it and disintegrate and going away. So it can have disintegrate, integrate, disintegrate, integrated. So the you can see that the balls will come go and disintegrate there. So that would be the transitional flow. So if I have a simple color dye just have a ball throw into a flow system I can we can visualize it whether the flow is laminar, transitional, or the turbulent.

More detail we will go it when your turbulent flow and all but we can classify it by common sense using a simple color dye and the virtual fluid ball concept that what could be whether the flow is laminar or the turbulent or the transitional zones where very details are given here and more details will have in other classes when we go more detail on laminar, turbulent and the transitional flow.

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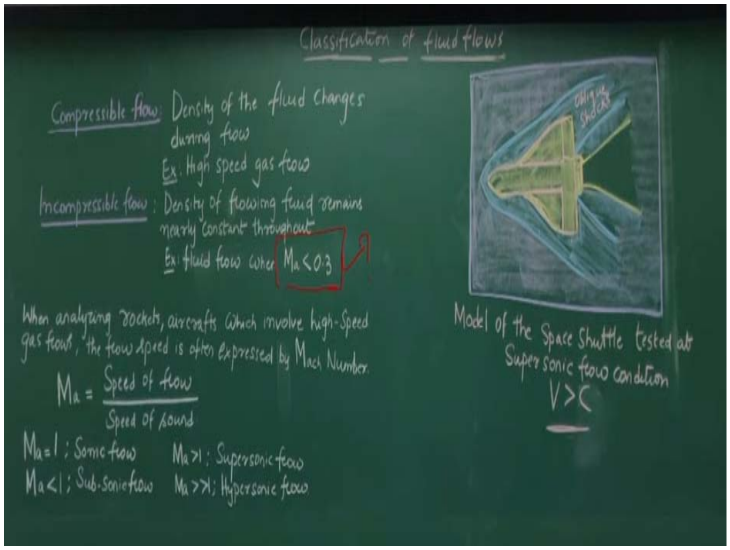

The next concept is that when you talk about a fluid flow systems and as I talk about that density is a mass of the fluid per unit volume. And as you go for a very high pressure zones, high velocity zones okay, there could be a change of the density, either the mass or either the volume will change it so that the density will change it. If it is the density changes, we call the compressible flow.

If density does not change it or does not change that appreciable way density variation is much lesser than like lesser than 1% or the 0.5% of this fluid flow, we can assume it that fluid is close to the incompressible. The most of the fluid flow problems what we consider it when you talk about the flow Mach numbers okay. We will discuss of that is a less than 0.3 then we can assume it or we can solve that problems as incompressible flow.

The basically which is a Mach numbers? The Mach numbers give a ratio between the speed of the flow and the speed of the sound. So as the speed of flow is close to the as equal to the speed of the sound, then we call the sonic flow okay Mach number equal to 1. So sonic flow, if it is more than 1 then supersonic, less than 1 is sub-sonic. If Mach number is much larger than the 1 value, then we can say that this is what it happens it very different flow process.

What happens you will have a spacecraft is moving with the speed which much higher than the speed of the sound okay. If that is the conditions, you can have an oblique shock. So let not we discuss about oblique shock. Please you try to understand the oblique shock in any materials available to that. So there will be a shock formation will happen it which is a different than what we are talking about laminar, turbulent flow process what is there.

So we can define the flow between the compressible and incompressible. Most of the engineering problems what we solve as a civil engineering or as a mechanical or the electrical, chemical engineering the most of the flow falls under the incompressible flow. In case of the aerospace engineering the sometimes they consider flow is the compressible flow systems.

That is what very simple way to know it whether flow is compressible or incompressible. Just try to find out what could be your maximum velocity in a flow field. And the ratio between the maximum velocity divided by the speed of sound will tell us that whether the flow is compressible or we can consider as incompressible flow concept. Now let have a very interesting concept is that how we simplify it.

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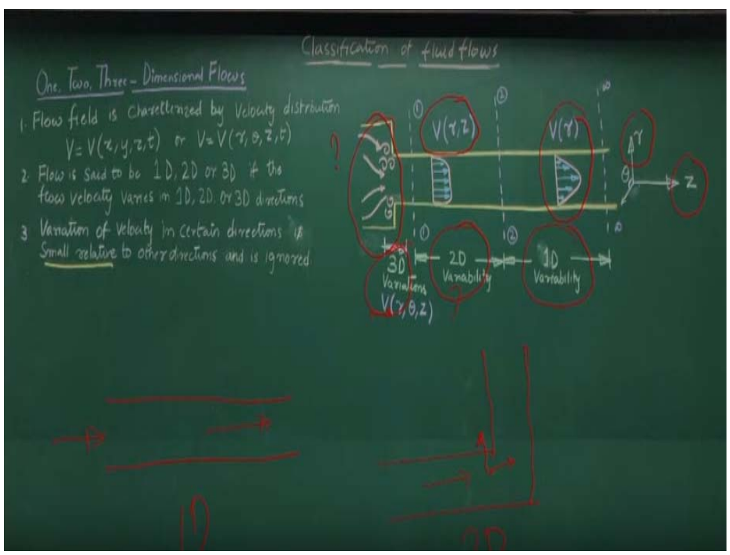

When you talk about any flow systems that flow is having a three dimensions okay. Like as you know it the any velocity, it will have the three components what will come it the V_x, V_y, and the V_z. It will have the time components in a Cartesian coordinate system. In case of cylindrical coordinate systems, you will have a velocity will vary in a with respect to radius, θ, and the z.

So when you talk about this velocity variation can have a complex, can have a three dimensional velocity components anywhere in the flow field. Now many of the times we have to approximate that flow or we can understand that what type of flow assumptions we can do it to represent that flow process. Like for example if I go it give a simple example here is what is given it here that what I will come it later on.

Like let I have a pipe flow which is straight ones I have the pipe flow is coming in. So I can consider it as the flow is going it you can see it the more or less this is the one dimensional flow is happening. But the same pipe if I just use the turn like this, then definitely I cannot say that this velocity distribution at this point it will have the two components. One in this directions, another in this directions.

So here there are three velocity components in the pipe flow. But the major dominated force will be much larger as compared to the other velocity components. Like it could be the velocity in major direction one meter per seconds velocity in other direction maybe 0.05 meter per second, 0.03 meter per second. If that is the order so we can neglect that two velocity component.

We can assume it that major velocity is good. But when you have this, the two pipe having a curve that what is giving the two velocity components. So the problem here is a two dimensional. The problem here is one dimensional. Same way if you look at that, where you can expect it that velocity could have a three component and the three component of the velocity will have a more or less similar magnitudes.

Then we have to consider as a three dimensional problems. Now if you look at that how the velocity variations going on again a bigger pipe and the smaller pipes okay. And looking it the fluid is coming from the left to right. I have the bigger pipe and the smaller pipes. The at the interactions locations you can see that, that the velocities will have a three dimensional component.

And three dimensional, all the three dimensional component could have the similar magnitude range. But when coming to this velocity in this directions, varies the velocity will vary with r and z, the r is a radius here and the z is the directions, okay? So you can see that because in a pipe flow the velocity may not vary along this theta directions okay?

That what will be the nullified but velocity will vary in radially and elevates the z directions. That means the velocity will change it as you are changing the positions. But that flow if you go bit longer way and you will see that velocity does not depend upon now the z component. The velocity is more or less varies with respect to r. So the problems now, which is because the three dimensional here became a two dimensional flow here, the one dimensional flow is here.

So depending of the problems what we are considering, we have to visualize it that what is the magnitudes of the velocity components and which direction it dominates it and whether it is one direction or two direction or the three direction. Based on that we simplify it with one dimensional problems or two dimensional problems or the three dimensional problems.

As you simplify the problems that means you can solve this problem easily. If you consider three dimensional, the unsteady problems, that what you can solve it, but it will have a more complex way to solve it as compared to the simplify the problem to the one dimensional or two dimensional and the solve the problems.

Here the idea comes it that to understand it whether it is one dimensional, two dimensional or three dimensional, the flow field understanding from the experimental data or the flow field given by any computational techniques like computational fluid dynamics, we can understand what type of flow is happening it. What type of velocity components are happening it and then we can simplify this is a one dimensional, two dimensional or the three dimensional flow.

As you simplified it, we are simplifying the problems from complex to the simpler way and we can solve the problems in simpler way as compared to the going for a three dimensional way. Now before going to the next levels what I have to say that whenever as an engineers if you get a fluid flow problem, first you try to understand it, these classifications. That whether these fluids steady or unsteady.

That means, flow does it varies with time or does not vary with time. So first you talk about the time varies, this is steady or non-steady. The second what we will commit? Do we expect that flow Mach number will be more than 3.3 then incompressible or compressible will come. So similar way when you talk about whether the fluids external or internal or the flow is can consider one dimensional, two dimensional, three dimensional.

I just encourage the students before solving any problems please write the classification of the flow problems what you are writing it. If you write it I am solving a problem a pipe flow steady one dimensional incompressible flow, if you write it that it gives a very clear cut representation is that the students has assumed it the flow does not vary with the time. Second, the density does not vary with within the domain.

Third it considers is the flow is dominated in one direction. So whenever you solve the problems, please classify the problem in the first. As you classify the problems then whoever try to understand it okay these are the assumptions, these are the conceptualizations student has taken to the solve the problems. So the classification of the fluid problems I have instructed here to give you instruction that first you visualize the problems based on your fluid mechanics or the virtual ball concept.

After understanding then you clearly write it what type of flow problems you are solving it. Like if I am solving it unsteady, incompressible, three dimensional problems, okay. That means I am talking about the flow problems which is the time variabilities. It has the density variabilities; it is having unbound flow problems.

So that what it will be the students to be write it very clearly that what type of problems you solving it. So as you given that problems as I cited that this is the type of the problems we have, then it gives us the understanding the problems, simplified it to this category.

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Summary of the lecture

1. FLUID MECHANICS is the science that deals with behavior of fluids at rest or in motion and the interaction of fluids with solids or other fluids at the boundaries

2. A fluid in direct contact with a solid surface sticks to the surface and there is no slip. This condition is called as NO-SLIP CONDITION

Classification of Fluid Flows:

1. Flow of unbounded fluid over surface 2. Flow of fluid in pipe or duct	External flow Internal flow
3. Density of fluid flow is constant 4. Density variability in fluid flow	Incompressible flow Compressible flow
5. No change in flow with time 6. Change in flow with time	Steady flow Unsteady flow
7. Depending on flow properties changing in directions	1D, 2D, 3D flows
8. Smooth layered flow 9. Rough flow with eddies and mixing between the layers	Laminar flow Turbulent flows

With this note, let I give the summary of today lectures as I try to give you illustrations and the definitions of the fluid flow problems as you know it. When you talk about the fluid flow problems we do not talk about only the fluid in motions and rest. But please remember there is a boundary which is defined the interaction of fluid with other fluids or the boundary. That also the major concept what you consider it.

The second thing is that you know it the no-slip conditions what we in a real life fluid problem, the fluid will have a no-slip conditions when a fluid and any solid surface interacts it. That what we consider it. Then we talk about all the classifications of fluids as I told that depending on the boundaries we define is external or internal. Depending upon the flow density we define it incompressible, compressible.

Depending upon the time we define it unsteady and steady or depending upon the flow whether it is one dimensional, two dimensional, three dimensional we define it and very basic way I just introduce that is a laminar and the turbulent flow which smooth orderly flow then laminar flow. If it is a disorder, then chaotic flows happen as you observed in the river flow and any other flow you can visualize that can have either turbulent flow. So with this let me conclude today, this first lecture.