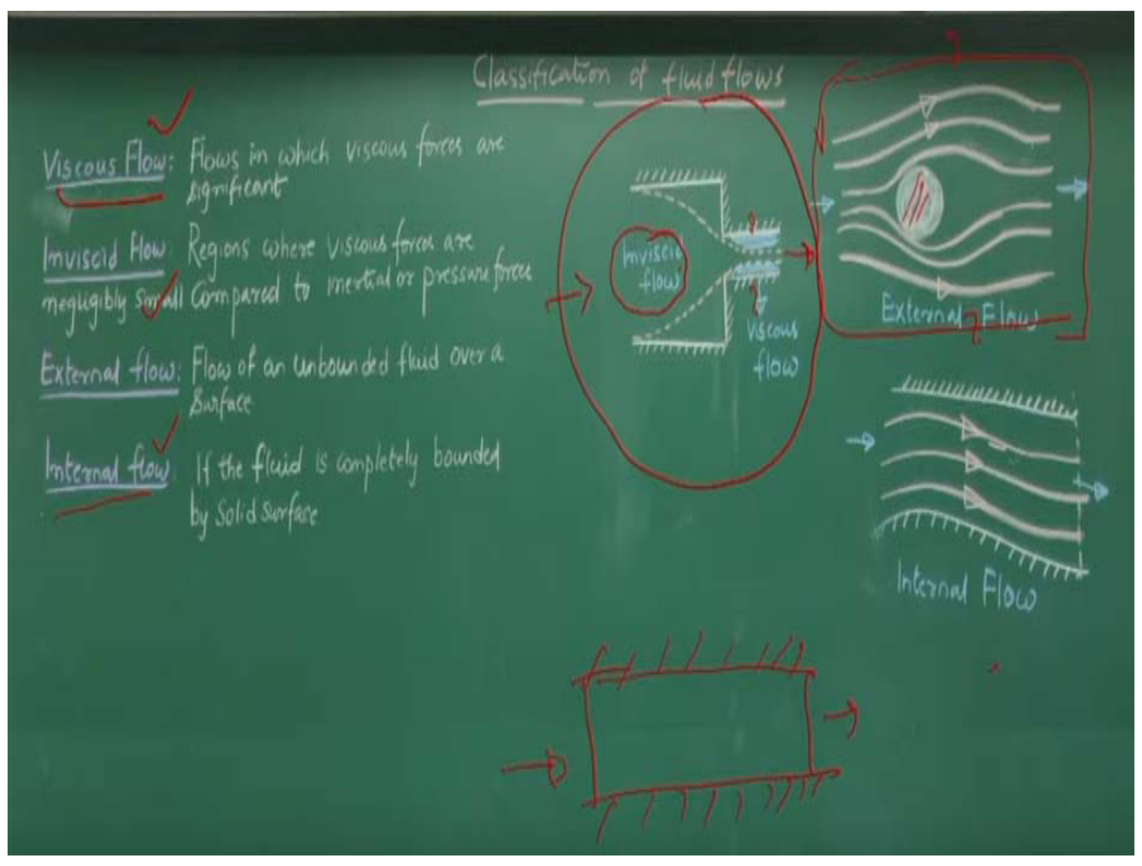


Now if you talk about when do I get a problems of the fluid flow problems, first it comes it that we should classify it. The classification means you will try to understand that we are simplifying or categorizing the fluid flow in that category. So we can solve that particular category class of the fluid 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?

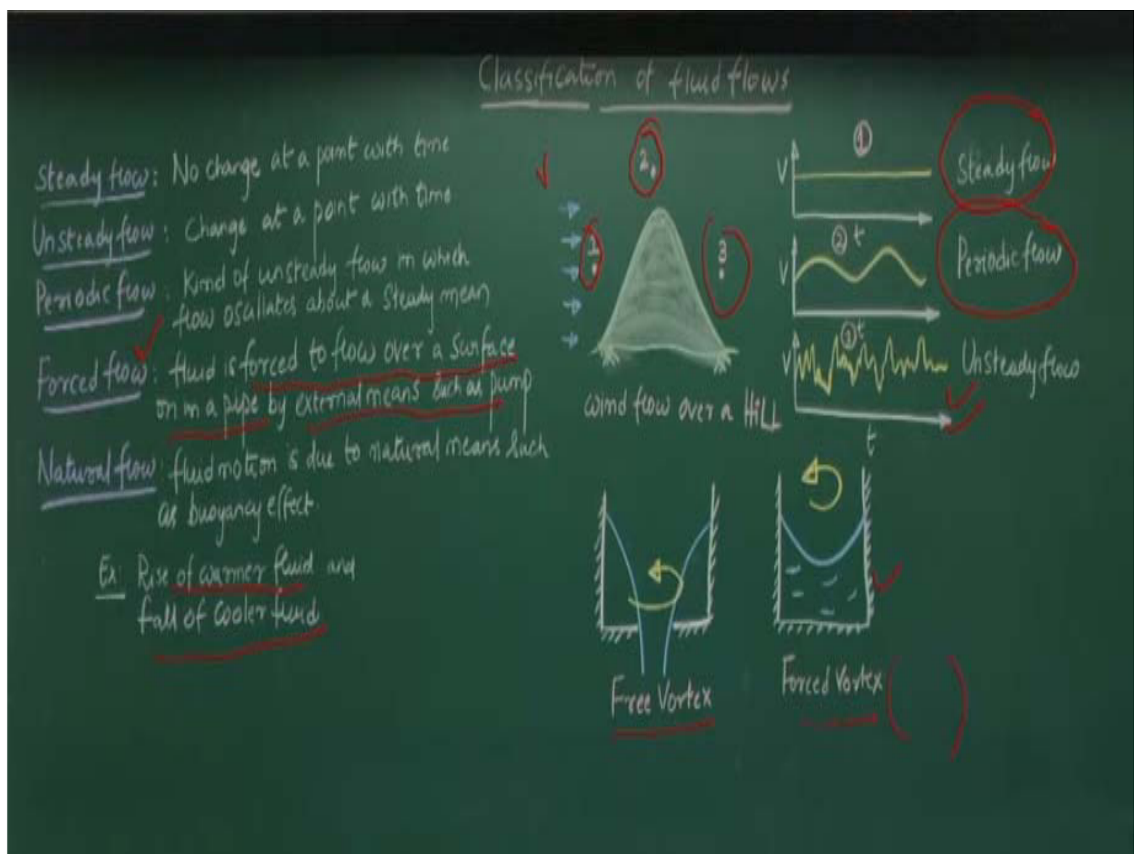
So as you know it is okay the tennis ball when you have the flow that means you may consider a tennis ball is moving with the velocity V or you can consider the wind is moving with velocity V. Both are the same conditions can prevail it. In this case, we are considering the other conditions that let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

(Refer Slide Time: 42:55)



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.

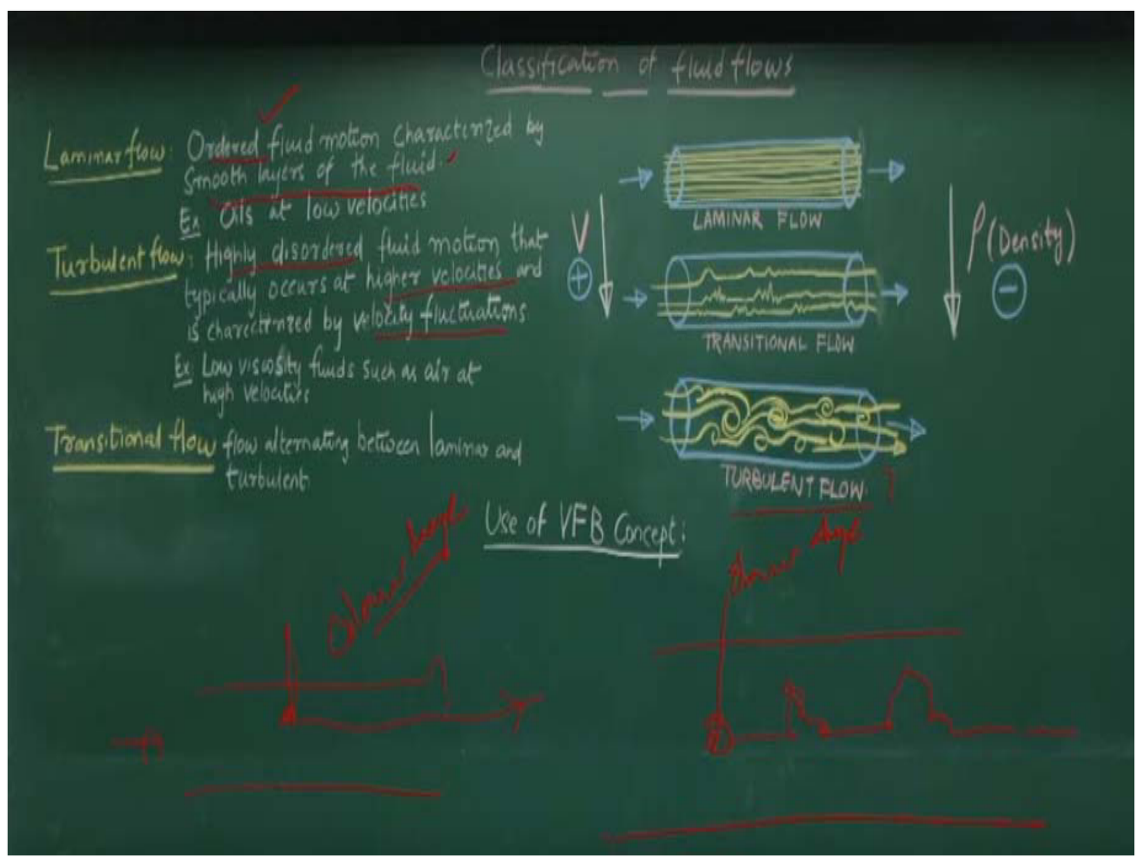
Like another flow system which is very simple the gravity based or buoyancy based fluid systems like for examples of this vortex patterns what I am showing it here that one case I have the tank and I am rotating with a uniform angular velocity of omega and another one I have a tank, I just have a slit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

(Refer Slide Time: 48:06)



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.

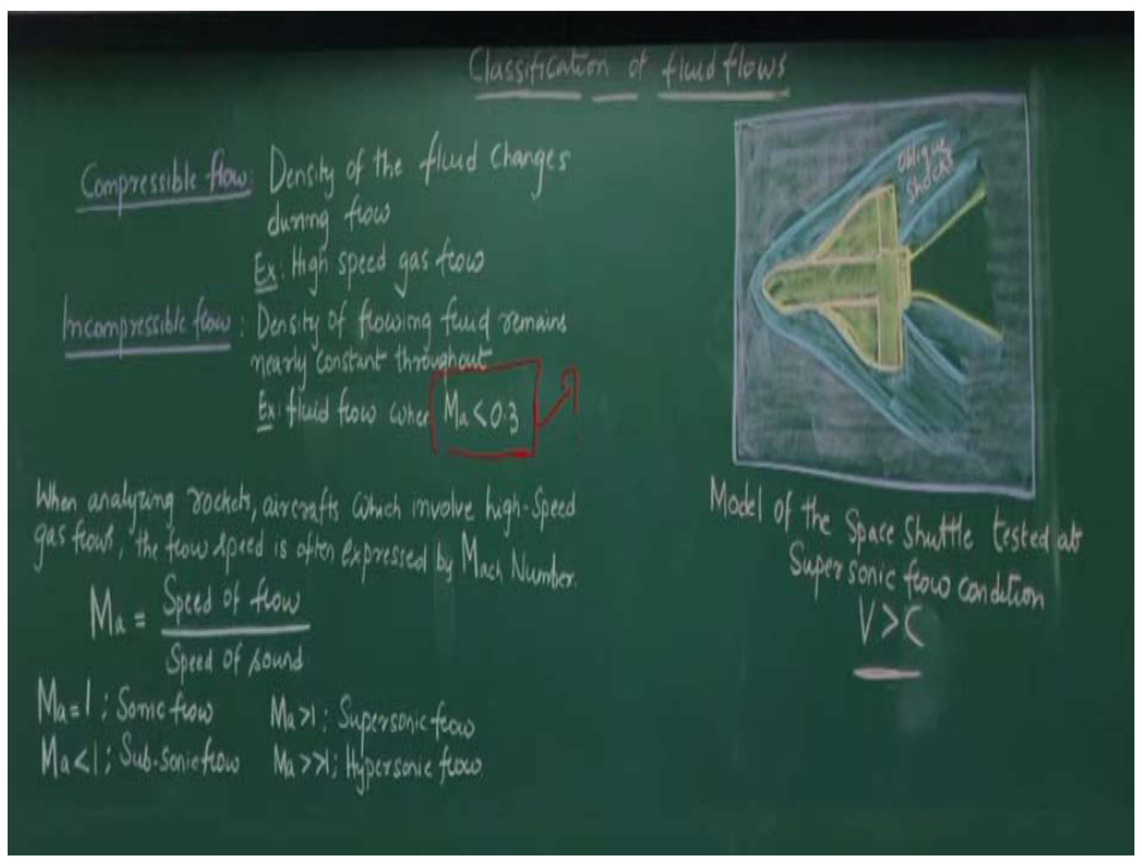
Just thinking that flow patterns whether it will be a highly order flow. In case of you have a high density, the flow like with a low velocity like oil in a flow or that can be a laminar flow. But if you talk about the river flow, where you can see that a lot of turbulence activities happening and the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

(Refer Slide Time: 54:10)



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.

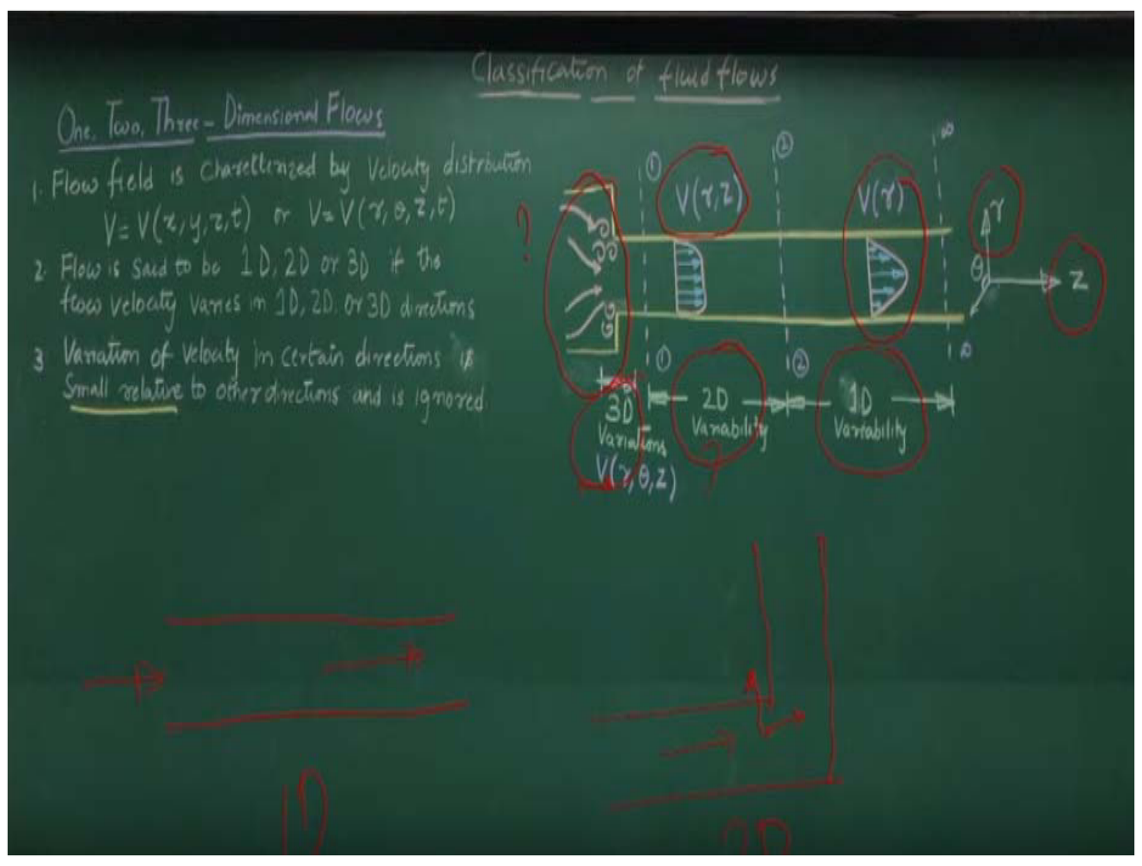
The basically which is a Mach numbers? The Mach numbers give a ratio between the speed of the flow and the speed of the sound. So as the speed of flow is close to the as equal to the speed of the sound, then we call the sonic flow okay Mach number equal to 1. So sonic flow, if it is more than 1 then 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.

(Refer Slide Time: 57:31)



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.

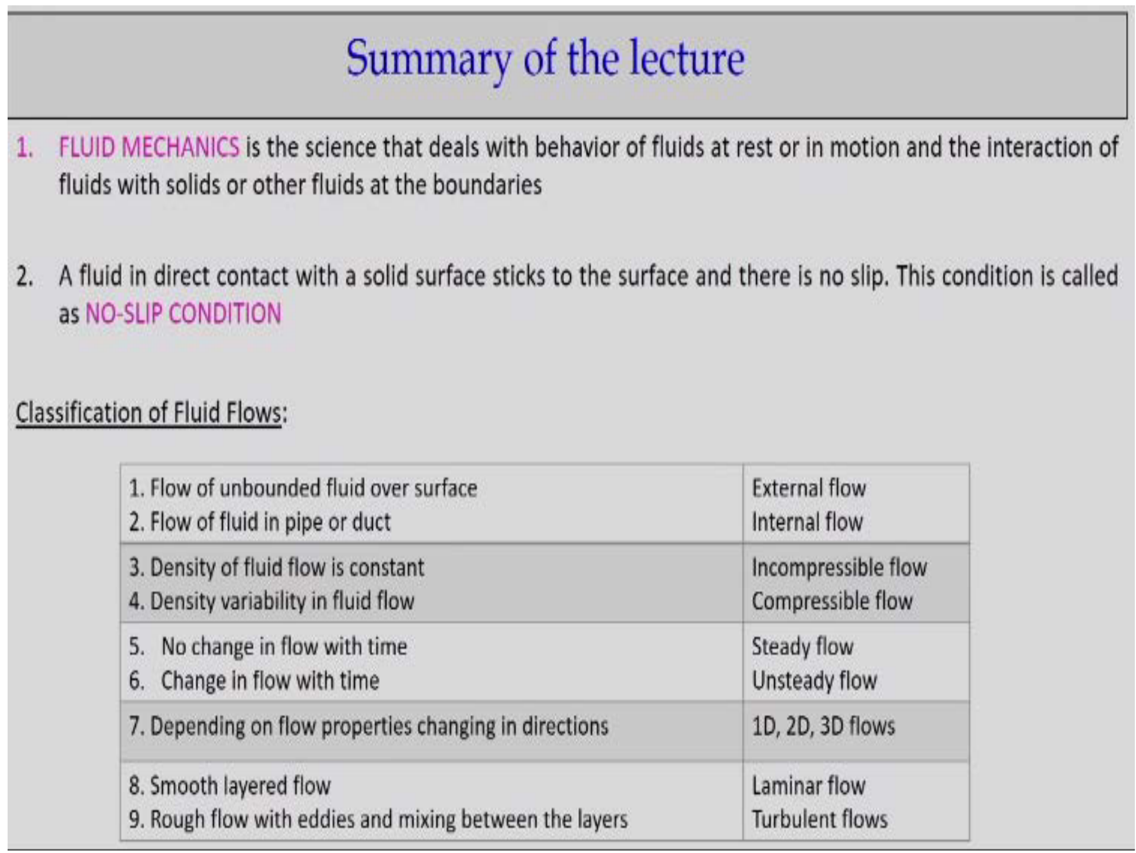
I just encourage the students before solving any problems please write the classification of the flow problems what you are writing it. If you write it I am solving a problem a pipe flow steady one dimensional incompressible flow, if you write it that it gives a very clear cut representation is that 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.

(Refer Slide Time: 1:05:48)



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.