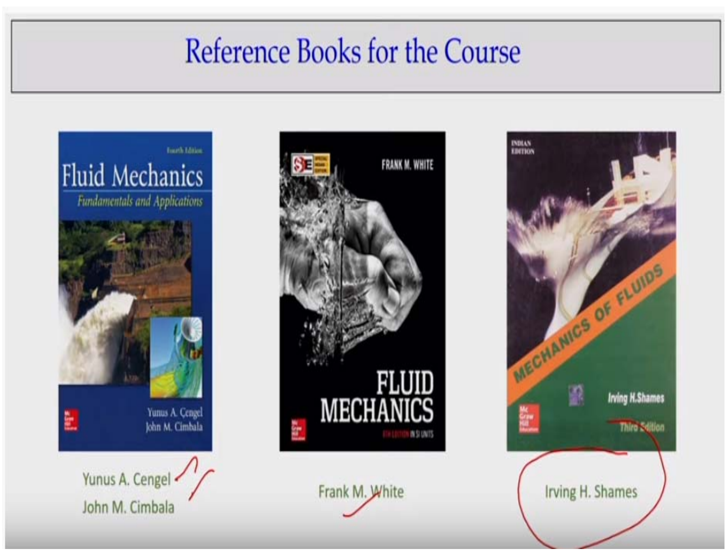
Fluid Mechanics
Prof. Subashisa Dutta
Department of Civil Engineering
Indian Institute of Technology-Guwahati

Lecture - 22
Losses in Pipe Fittings

Welcome all of you again for the second lectures on viscous flow through pipes, which is quite interesting for you if you are preparing for GATE or engineering service. So this part of the lectures if you see that is quite interesting in the sense that it has the applications of Bernoulli's equations.

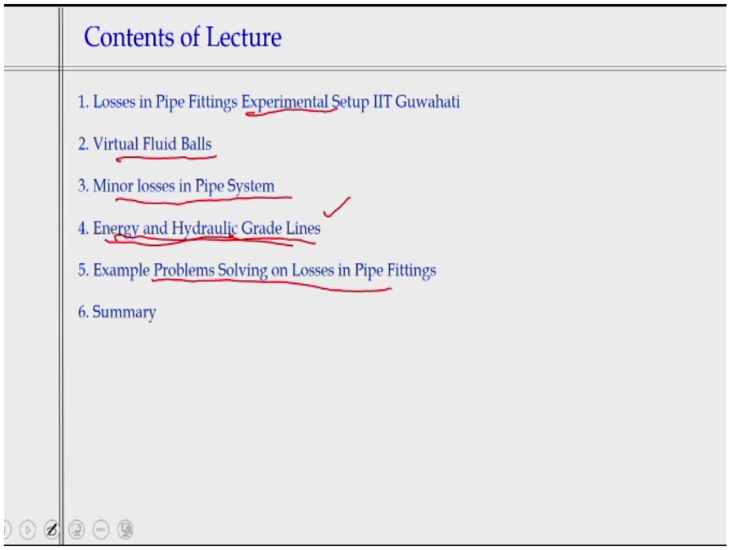
It has a applications of momentum equations. Also it has that how to approximate a complex flow through the pipe systems. So that way I designed this course for you so that you can have the feeling of application studies how we can do it with knowledge of the fluid mechanics.

(Refer Slide Time: 01:16)



So I can see that this the books what I am following more details in for these chapters. But you certainly can have these two books which F. M. White and Cengel Cimbala. They are the books at the higher levels as you know we discussed earlier.

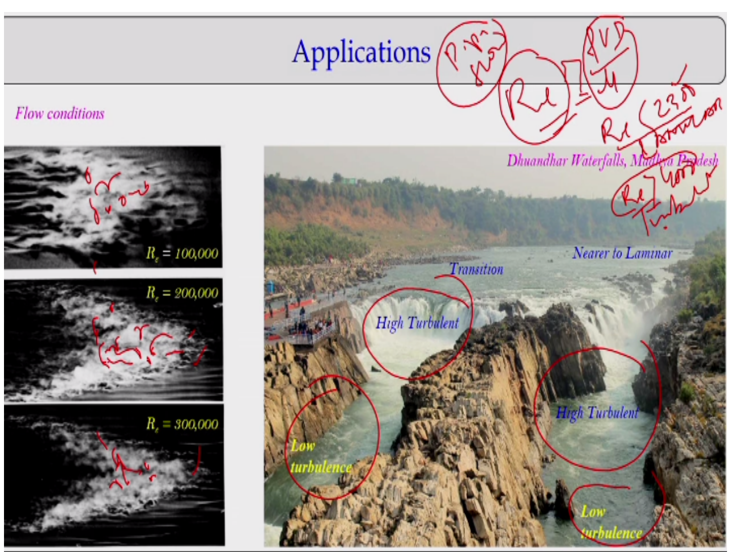
(Refer Slide Time: 01:31)



So today what I am talking about that we are going for a demonstrations of the pipe fitting experimental setups which is there in IIT Guwahati. Again, I will revisit the virtual fluid balls. Then we will talk about the minor losses in the pipe systems. And again, I have to revisit it what is called energy gradient lines or the hydraulic gradient line which is more important when you are solving this pipe network problems.

Then followed by I will solve the few problems on pipe networks using Bernoulli's equations, linear momentum equations, and the pipe loss equations. That is the example problems what we will solve, solving the losses in the pipe fittings and all. Let us go for the next level slide.

(Refer Slide Time: 02:30)



Again I am repeating these slides to just to energize to you that when you have the pipe flow, most of the times we have the turbulent flow okay. So whatever the pipe flow you consider it always we have the turbulent flow as you can visualize the turbulent flow of high turbulence, low turbulence zones, high turbulence, and the low turbulence zones.

When you talk about the turbulence, do not look at the figures like these type of vortex phenomena and all. Always we quantify the turbulence with respect to Reynolds numbers. The Reynolds numbers, if it is a greater than some threshold values then we call the turbulent flow. That means, the Reynolds numbers when you talk about that, it is a ratio between inertia forces and the viscous forces.

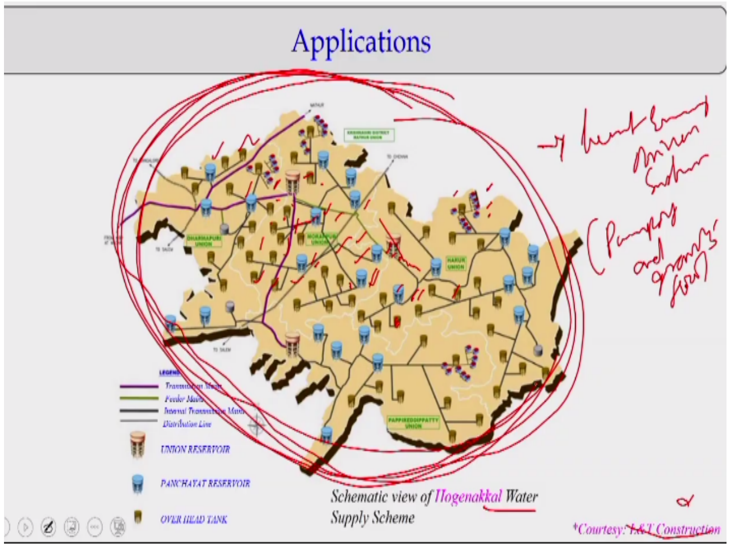
For pipe flow what we have the Reynolds number which is

$$Re = \frac{\rho V D}{\mu}$$

The inertia force by viscous force. These values if less than 2300 the flow is laminar. If Reynolds numbers, greater than 4000 the flow is turbulent, okay? So please remember this threshold for the pipe flows. But for other flows, you can have the higher studies to look it that. So if it is a Reynolds number less than 2300 and Reynolds number greater than 4000 we have a laminar and the turbulent flow.

In between you have a transitions flow systems. And you can see here the photograph of showing how turbulence vortices are there or eddies formations are there. So we can visualize that and today many of the best fluid mechanics labs they have the facilities to measure this type of turbulent structures, they quantify it that how much of energy dissipated, because this turbulence structures.

(Refer Slide Time: 04:48)



So looking, this is just a introductory to start our things. Just I am taking one of the example of water supply schemes from L&T constructions were fetched. You can see this the planning of water supply systems, you just look it. So there is a source, there is the supply systems. There is a source points and there is a supplied at the individuals the house level.

But for that if you look it that it will be a series of the tanks. What is it dedicate? The series of locations where you will have a augmenting the additional energy in terms of pumping the waters. The additional energy you want to give to the flow systems and store these waters. Then you have a second line of again you have the tank systems. So if you look at these systems which look at the water supply system, is like a power grids.

So when you plan these type of water supply systems, we need to know how much of loss is happening it. How much of pumping is the requirement is there. How many overhead tanks are we should design it. What should be the network of these pipes? What could be the diameter of this pipe and what type of pipes would be there?

All these things these complex systems what we design it to make it so that this totally should have a the least energy driven system Okay. That means it is a combinations of pumping and the gravity flow system. So you will have a certain systems. You will have a pumping systems. Then you have also the gravity flow from that. So all these components of these water supply systems, we need to find out how much of energy loss is happening it and what will be the available discharge at different points.

Like considering this point what will be available discharge at this point. So these analysis if you look it that what we are discussing it those are very preliminary levels. But when you design this type of water supply systems that are commercial softwares or the free softwares are available so that you can design these systems to know it at each point what will be the available energy, what is the amount of discharge will be available, all these things you can quantify under different scenarios.

Like you have a summer water supply system, winter water supply system where you need different amount of the waters. So all the things we consider it considering this basic the pipe flow what we are discussing it that. So with this note, let us go for the next slide.

(Refer Slide Time: 07:56)

On the next slides what I am showing it that how we conduct the experiments to quantify the how much of losses are happening, energy losses is happening it. So one if you look it, we call major losses. Major losses, that is the losses due to the frictions. So that way if you look it there are the two pipes are there. And in these two different pipes there are the manometers are attached to determine what is the pressure difference at the two points, you just closely look it.

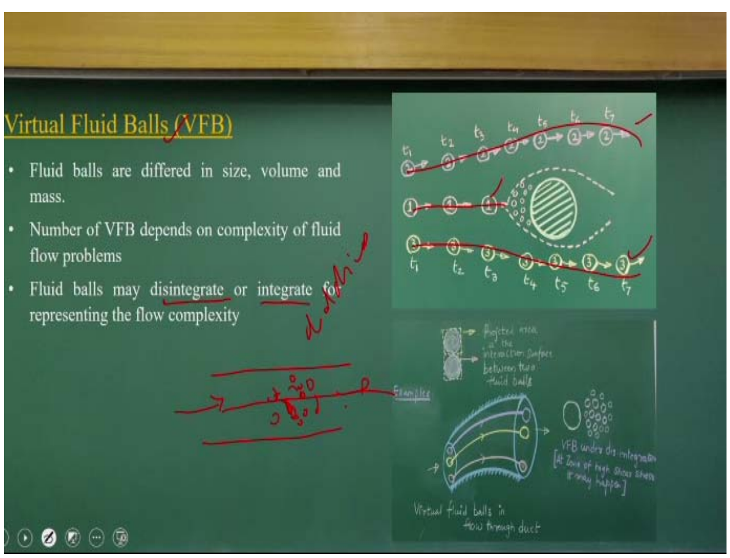
So as we will measure the pressure difference, and as you know the how much of discharge is going through this pipe systems for a steady flow conditions, we can compute the velocity, we can know the pressure difference, then we can quantify the energy losses just following Bernoulli’s equation with some modifications. That what we will discuss.

So the basically these type of systems we have to quantify what is the amount of major losses. But there are minor losses like this is the band is there. There are loss will be there. The band is here, there will be loss. Here also we have the band and there are the valves are there. So all these are called minor losses, as well as there will be the exit loss or contractions loss.

All these loss components which are called the minor losses that what in terms of energy, how much of energy losses when flow is going through that. So those things also today we will discuss it. So these are the experiment setups, the students conduct the experiment with a different research and find out, measure the pressure difference.

And with a simple calculations they quantify it how much of energy losses or the head losses happens for minor component as well as the major components like the pipe due to the frictions and the fitting, the elbow, the bends, the exit, the valves all we consider it to find out how much of energy losses are happening it.

(Refer Slide Time: 10:21)



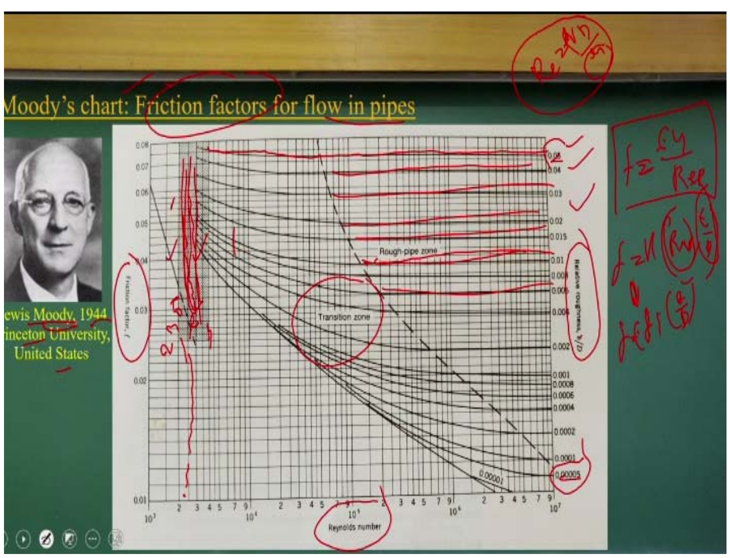
Now let us go for the next slides which is again I will talk about virtual fluid balls. Here again I have to repeat it to tell it the virtual fluid balls to understand how the vortex formations happens within a pipe flow systems, okay. Like the last class I discussed about the pipe flow systems, when I am considering it, the pipe, a horizontal pipes and because of the turbulence how the eddies formations happen.

These are eddies, these are eddies formations happening it and those what we try to understand because if there is a horizontal flow is coming going out and we quantify in terms of the balls moving with disintegrated, integrated concept. But for to define the streamlines for a complex fluid flow problems, today we will use to same virtual fluid ball concept to define the flow streamlines.

Because, as you know it when you try to apply the Bernoulli's equations the first assumption is that you should apply along a streamline. Or if you consider the flow is irrotational. So it is very difficult to quantify the flow is irrotational, but always we can draw a streamlines, draw a streamline like this cases and I can apply the Bernoulli's equations.

That is what today we will discuss more when I will give the applications and also the some few example problems.

(Refer Slide Time: 12:13)



Now let us go back to the Lewis Moody 1944 Princeton University, USA. What he has developed is from the experimental data. If you try to look it, he has not pulled out only his experimental data, but long back the data from others researchers. All the data he combined it for the developing this Moody's charts to compute friction factors, compute the friction factor, the flow through the pipes.

Mostly this commercial pipes, what is use it. So now, if you try to interestingly look at these things, which is, I can say that is a knowledge of the fluid mechanics. If you try to understand these curves is the representing the knowledge of the fluid mechanics in a just compute the friction factors. If you look at the friction factors, here we have a Reynolds numbers.

$$Re = \frac{\rho V D}{\mu}$$

The x axis is Reynolds numbers in a logarithmic scales and the y axis we have the friction factors, which is normal scale. If you look at this part, what it is indicating for us the first condition is laminar flow. This is a laminar zone as I repeatedly showed that this is up to 2300. So the relationship between the friction factors and Reynolds numbers you have

$$f = \frac{64}{Re_t}$$

So it is a linear functions you can see it that. But when you have a transition zone which is 2300 to 4000s in those regions, we cannot compute this friction factors because so fluctuation behaviors are there. We cannot compute it. If you compute it there will be a lot of erroneous will be there as the experimental data is showing it. So most often when you design the pipe systems we ever to have laminar flow and the transition zones.

Because in the transition zones, the frequency factors can fluctuate very wide range from this to this. And most of the times we design the flow which is a turbulent flow, okay. Then it can start from smooth pipe to rough pipe. That means, it can start with a relative roughness, which is $\frac{e}{D}$. That means roughness by the D values can have very very small to 0.05. Each lines are representing for you the 0.05, 0.4.

So this is the turbulent zone spot. Now if you look it try to understand it as you know it the friction factors for the turbulent flow is a function of Reynolds numbers and relative roughness value. But it is there if you look it that function dependency is there still at this point after the pipe we call rough pipe zone. That means, after that the friction factors as a single functions of only the relative roughness.

Not, it does not depend upon the Reynolds numbers. Now if you try to understand the physics wise, what it happens it as we increase the roughness, then the Reynolds numbers which represent you the $\frac{\rho VD}{\mu}$, this part does not have a much significant. The viscous effects are not significant, more the effect of the roughness is comes it.

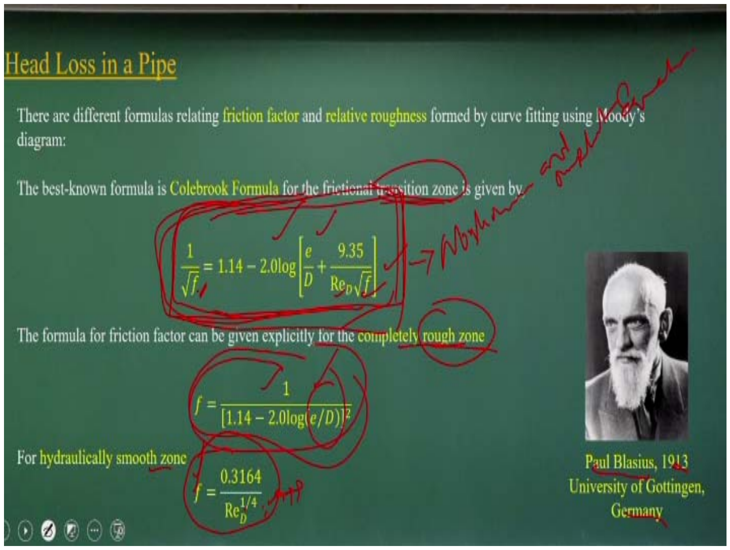
The mu components, not much significance as you are going more the roughness, it becomes independent to the Reynolds numbers. That is the reason it is a constant, independent to the Reynolds numbers. It is just depend upon the roughness factor. So we divide into two zone. One is a transition zone, where the fiction factors is depends upon the Reynolds numbers and the relative roughness.

Now you try to understand it that if you have a increase the relative roughness of and the higher Reynolds numbers, you it depends upon the friction factors. Only these relative roughness, not the Reynolds numbers. These things you can conceptually just think it that how the process happens it. I am just leaving to you.

So these diagrams what is prepared from the experimental data not from only from his data set also the data set what were prepared from the artificially glued the roughness pipes in Germany, the combining the all the data Europe data and the USA data he prepared this map which still date mostly used or we have been using this the chart to determine their friction factors.

Because once you the friction factors it is easy to compute energy losses. So once you know the energy losses then you can quantify it that what type of pipes we need it. What type of diameter pipe you need it, all we can link with the energy losses.

(Refer Slide Time: 17:55)



Now if you look it if you do not have a this chart okay then there are two parts as I say that for the transition zone there is a developed equations like this okay. You can see that it is called implicit equations because the friction factors also here, okay. So it we cannot directly compute the frictions factor because this is a implicit equations which is there in the both the sides and is also nonlinear and implicit equations okay.

Because of that, nowadays we can estimate these ones because there are a lot of mathematical tools are available like the Microsoft Excels and all we can iterate it and compute it what will be the f value if I know the e, you know the D and if I know the Reynolds numbers. So we can compute it. It is not that difficult today when you have a good computation facility with us.

$$\frac{1}{\sqrt{f}} = 1.14 - 2.0\log\left[\frac{e}{D} + \frac{9.35}{\mathrm{Re}_D\sqrt{f}}\right]$$

But when you go for the rough zones, which is as I had already said that it has a function of only the relative roughness factors. That is what is defined it here. So you can use for this part for the transition zones, this is a part you can use for the roughness zones. But earlier for the smooth zones also we can approximate like this which is explicit equations.

That means you just substitute the Reynolds numbers you can get the f value okay. You can always debate it what is the difference between these two? This is approximations of this part. It is valid for certain regions, but the exact equation is that this is the one okay. So that is what is the Paul Blasius in 1915 from Germany that is what he develop it.

The formula for friction factor can be given explicitly for the completely rough zone

$$f = \frac{1}{[1.14 - 2.0\log(e/D)]^2}$$

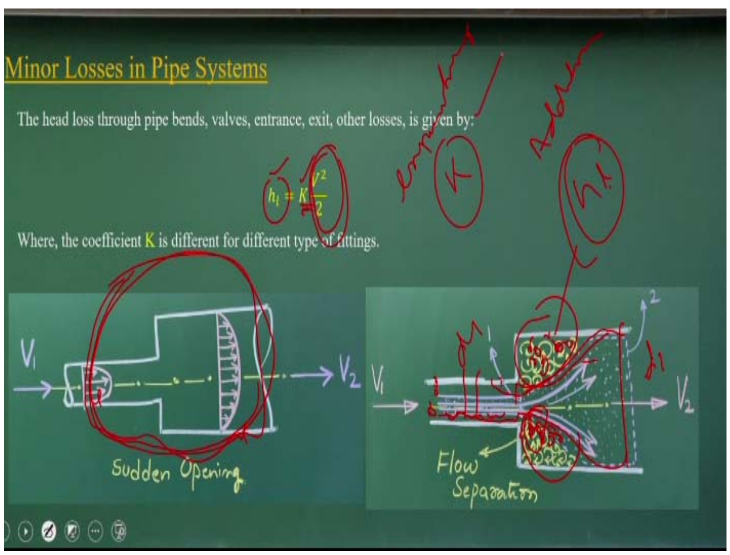
We can explicit equations you can develop it, which is just substitute the Reynolds numbers you will get the f factors. But for getting the accurate f vectors for the transitions zones, we can use these equations which is nothing else the fitting of the Moody's charts and similar way you can get it for the rough regions the equations. This is also is derived from the Moody's charts.

For hydraulically smooth zone

$$f = \frac{0.3164}{\mathrm{Re}_D^{1/4}}$$

So if you do not have the chart, you use these equations. If you have a chart you do not need to compute these equations. Directly you can get it the values from the chart itself.

(Refer Slide Time: 20:33)



Now let us go to the minor losses in the pipe systems. As I told it when you have the pipes, it can have a regions you have a smaller pipe to bigger pipe or bigger pipe to the smaller pipe. When you have a these conditions that means the flow is coming it here and going out, the smaller diameters and the larger diameter. If you have these conditions, what we do it that when you compute the energy losses, for this total regions, we compute the analysis this.

You can understand it energy losses will have a functions of e square by 2 which is kinetic energy per unit mass into a vectors, which will be responsible for how the flow patterns, how the streamline patterns, how the vortex patterns are (()) (21:31). If you know that, you can quantify it or you conduct the experiments. It is very easy to conduct the experiment of different pipe diameters, different configurations you can compute it.

You just measure the pressure at these two point and you know the velocities like the manometers you can put it then you can measure the pressure difference and you can easily quantify that how much of K value from experimentally. That is what it was done so far to compute this K value from experimentally. But for your point of view, I am just explaining it how the flow process happens within the pipes.

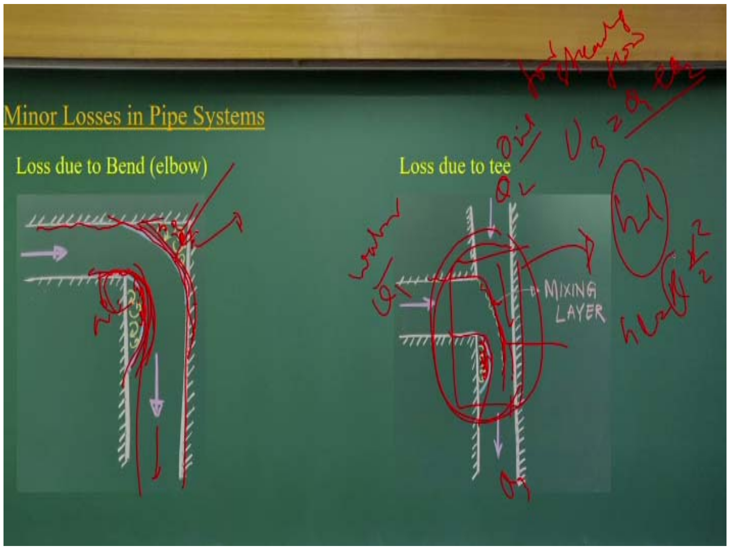
Now let us look it how would it happens it. That again I am considering virtual fluid balls okay. If I consider the virtual fluid balls, the balls which is going very close to the wall, which will go straight and inject here as a tangential and go like this, okay. What will happen to this? Here also we have the particular liquid, but that liquid will have a vortex formation. They will start rotating it, start rotating it.

So immediately your flow will pass this, these regions will have a vortex formations. Because of these vortex formations, you will have a energy losses. You will have the energy loss, the additional energy loss you will have because of this vortex formations are there. And this the quantity of the vortex formations, quantity of the energy losses happens it depends upon the d_1, d_2, V_1, V_2 what type of flow is happening it.

Because your streamline patterns will change depending upon the V_1, V_2 the flow Reynolds number energy, what is the energy is coming this. So from the experimentally for different d_1, d_2 we can compute it how these things are changing it. From experimental data, we can get it the energy losses in terms of,

$$h_l = K\frac{V^2}{2}$$

(Refer Slide Time: 24:06)



Now we go to the next ones, it is quite interesting. You have a bend. Most of the times we avoid the bend, but it is okay looking the topography and all we need to have a bend, the pipes. So when you have the bend the pipes okay the flow is coming like this and it is going like this. You can easily draw the streamlines okay considering this, the balls virtual balls. Similar way, this is like this.

In this and these regions the vortex will be there. This is for energy loss. This is because of this vortex process are there, that is what is additional energy losses will be there. Those energy losses depend upon what is the angle of this one. This is case is 90 degree. So if you have a different angles this the zone where the vertex is happening, that is what will be the different.

So you**,** the angle of this part also depends upon what is the flow is coming, that also depends upon. But on average we consider it even if you have this case. But if you looking these figures what it showing, how to avoid these vortex. It is easy you make a instead of straight 90 degree elbow, you give a curvatures here which will fit it exactly this part.

If you do that the pipe systems with a then there will be less energy losses. So instead of having just 90 degree bend of the elbow, we can have a curve at this point. You can give a bend pipe. So that what will be the lesser energy loss as compared to these ones. That is what most often in industries they use it. But if you look it that we have the T joint.

That means I have the discharge is coming Q 1 here and the Q 2 is here okay. And this is the Q 3 which is going out okay. Looking these figures you can say that Q 3 is equal to Q 1 + Q 2, it is not a big issue, for steady flow, okay. But let us look it that inside what it happens it. It depending upon if this you look it if flow is coming like this, the flow will follow this and will go like this.

This flow will come like and here this vortex also will be there. And this flow what is coming it they will come like this. And this is what the mixing zones. This is a very interesting phenomena if you can look it that many of the times if you look it that if there is a two fluids are there if you just put a two fluids okay, fluids like maybe this is waters, this may be the oil or something, you can see how the mixing zones is happening. How the vortex zones is happening. It can easily quantify it.

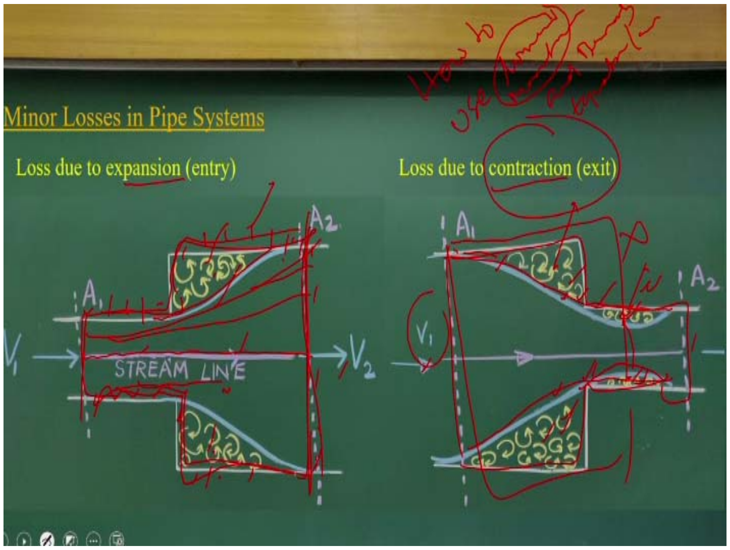
So now if you visualize that, so now if you look it that the because of this mixing layers, because of the vortex formations, and the presence of the vortex formations you can feel it if you are engineers just touch these pipes, you can see this heat is generating it. You can see the temperature difference. So that means, indirectly it indicates for us there is a vortex formations are happening it.

The energy dissipations are happening it So we can identify which are the regions are the heat generating it or it is so those regions you can identify and also we can measure this vortex phenomena and but more of the times we just try to look it that how much of energy loss is happening to this case h l part okay. So we can define in terms

$$h_l = K\frac{1^2}{2}$$

This K we compute it with a different configuration. That is already experimental done it. So there are the table, we just follow it.

(Refer Slide Time: 28:21)



But interestingly let us go for that is two systems okay, which I intentionally putting to you that just look at these figures. One is expansions another is contractions. The flow is comes from this side and goes like this side. In this case also flow goes like this. Now if you look at the steamlines, which is just closer to the wall, in this case, it happens like this. We already discuss it, but if you have a contractions, then what it happens it. There will be vortex zones here. There will be vortex zones here.

So you can understand it that more energy losses will happen when you will have a contractions okay, when you will have the contractions. But in case of expansions the vortex zones are the less. So energy losses in this case which will be much higher as compared to the expansion zones because of the vortex formations.

But if you can make it a the shape of like this okay gradually variations or gradually expanding it then you can avoid the energy losses what is going to happen because of this vortex in a similar way like this. But exactly to have this shape is very difficult okay and as this in a pipe flow we do not get a constant velocity there is a fluctuating velocity there is like the flow varies it.

Because water demand is varies from the winter to monsoon to the summer season. So we vary the waters to design exactly the face of what will be the shape of the outer streamlines are very difficult the mostly we take a trade off between that and you try to make it as closer as possible to have a less energy losses because of this part. I just highlighting here to show you streamlines okay to tell it.

Now if you look it I am just talking about how to use linear momentum and Bernoulli's equations which is energy equations. So to apply this energy equations what I should do it, I take a streamline. Along the streamline I should apply the Bernoulli's. So most appropriate streamline is this ones, you take it this. Because this is a horizontal streamlines so we can just know the pressure and velocity, pressure and the velocity and modify the Bernoulli's equations, apply over this ones.

Not here are there okay. Similar way if I am to apply the linear momentum equations or other mass of conservations I should consider the control volume is much bigger than affected area so that I can get it, this effect should not be there. So I can use this control volume to apply the mass conservation equations or linear momentum. Exactly same way I can use this control volume still up to this spot, apply it.

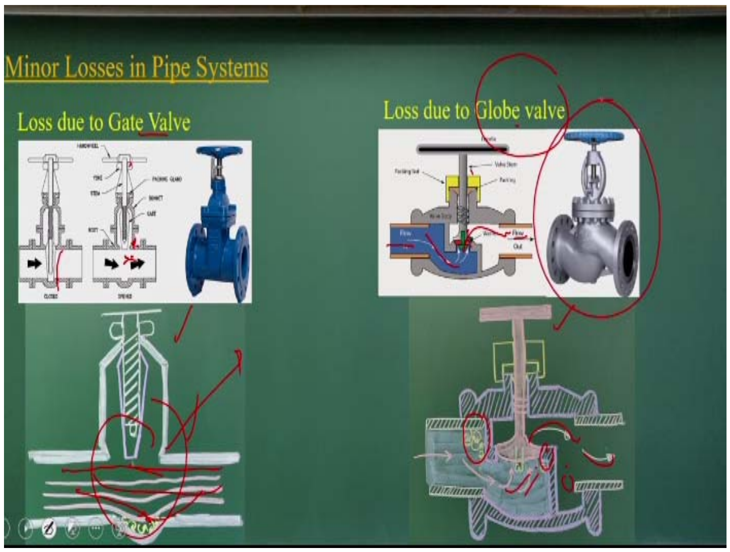
Please do not take the control volume like this, which is totally wrong. Because you do not know it this zone what is happened it. So when you take the appropriate control volume we should take it. That means you should look it the control volume, where the streamlines are the parallel, streamlines are parallel. In this region the streamlines are not the parallels.

So you try to avoid to draw the outward streamlines, find out the reasons where there are not supposed to have the streamlines having any curvatures, the more or less the parallels. Like this case I draw the streamlines all will be the parallel by the time we reach it here. These regions I can consider this part and this part anyway, it is not a difficult for us, because there is no flow boundary conditions.

So to take a appropriate the control volumes, we should have a knowledge of how the flow happens it, how the flow behaviors are happens it, where the vortex is happening, where the flow lines the streamlines are parallel, you consider that by visualizing this flow like this or this. Then you try to look it. So what I do encourage you to that whenever you get a problems you try to draw the streamlines and find out where is the locations we can have a vortex formations.

If you try to understand that or try to draw that sketch you solve the 20% of the problems, another 20 I can say not the 20% maybe 50% of problems. Another 50% is that how to apply mass conservations equations, linear momentum equations and the Bernoulli's equations which it is not that difficult to apply it. So the basically the strategy is that you should try to understand these ones.

(Refer Slide Time: 34:18)



If you look it that most of the times also we have a valve to control the flow okay which is a gate valve okay, it is a gate type of systems. If you rotate it this valve closes the waters okay. And it can have a total open or half closed and all these conditions to regulate the flow to regulate the flow we have a these systems. Now if you look it if I am to draw the streamlines, how it happens it.

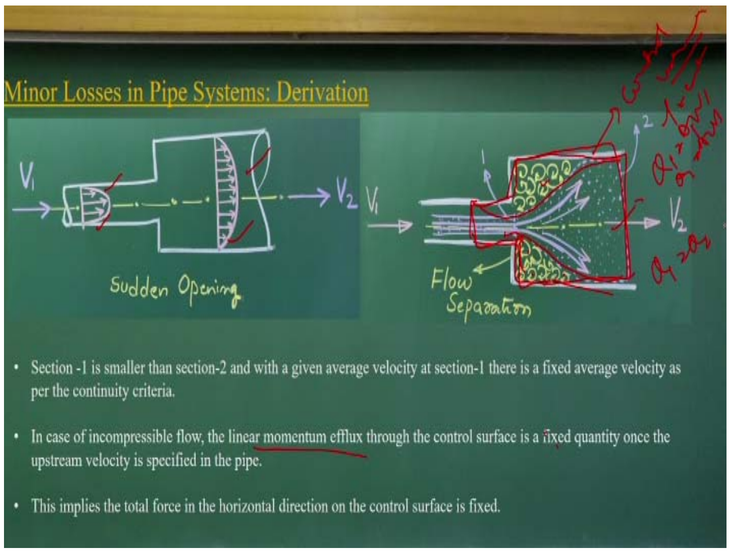
So streamlines will come like this okay. There could be the vortex formations. And if you try to understand it, that I have not this open or the totally close, if the half open your flow distributions you can understand it how the streamlines patterns will come, how the vortex formations will have. Either you open it or close it, but half close half open will make it us the flow process at these process difficult or the more energy will dissipate as compared to the other conditions.

Now if you look it similar way we have a the globe valve which is more control valve systems. The flow comes here, then rotate it and this valve it goes off and flow goes like this. So we can look it now in terms of vortex formations here, the vortex formations here, and once flow goes it also could have the vortex formations also here.

If you look it that way and just compare to valves one is globe valve and the gate valve this require for different type of discharge conditions.

So if you look at these conditions you can easily interpret it we will have a more energy losses for this case as compared to this ones. But we need sometimes this type of valve to control the flow systems.

(Refer Slide Time: 36:18)



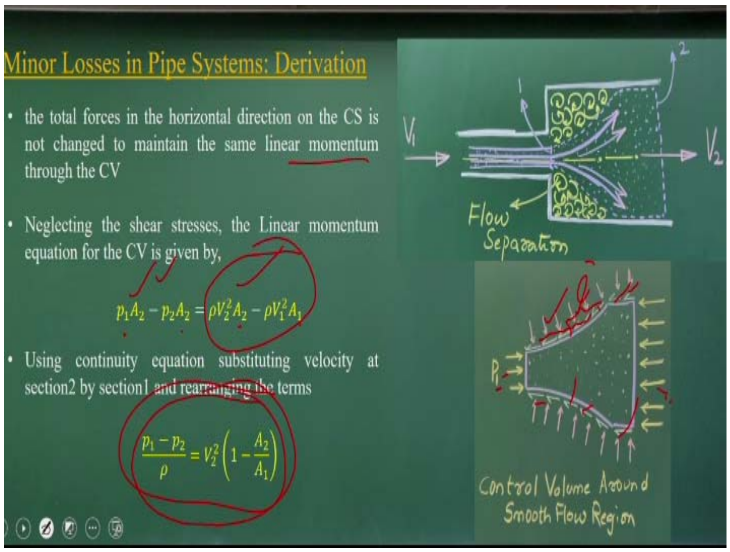
Let us come for derivations of energy losses and the pressure and velocity distributions of having a systems where two pipes we are enlarging it from the smaller diameter to bigger diameters. If you have that conditions and you can draw the velocity distributions. The velocity distribution it depends upon the type of the flow. If I have a laminar flow, the velocity distribution is different.

If I have a turbulent flow velocity distributions is different. That part we will discuss in the next class. So we will have a velocity distributions here depending upon the type of the flow. And then I try to understand it to draw the streamlines the flow separations point and the vortex formations. So I will consider the control volume as I said it earlier where I have a streamlines or this part.

Or I can consider the outer this one is my control volume part. I can consider it that or I can consider this is the control volume. The most of that we will use the linear momentum efflux that way we will apply it to compute it. So the basically what I am talking about here, this is what is our control volume. And we will apply mass conservations equations since this is a incompressible flow, density is a constant.

So mass conservations will be the A_1V_1 and Q_2 will be A_2V_2 and Q_1 will be the Q_2. The two locations will have the discharge is the same because of mass is constant.

(Refer Slide Time: 38:03)



Now coming to this, I am just applying the linear momentum equations for these control volumes okay. So if you have this is the control volumes. So you may have the shear stress is acting on this okay, this the shear stress part, okay. But we are neglecting this part, we are neglecting the shear stress part. Just we are assuming the pressure different between these is equate with a momentum flux.

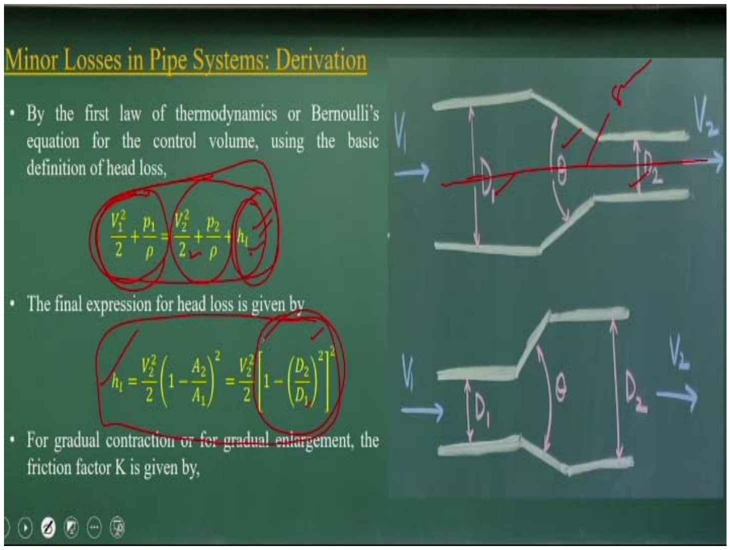
$$p_1A_2 - p_2A_2 = \rho V_2^2 A_2 - \rho V_1^2 A_1$$

This is what we have derived lot. So this is a rate of change of the momentum flux is equal to the, the pressure difference between the, the pressure force difference between this p_1 and p_2 and that what if you rearrange it you will get it this part okay. So it is very simple equations that we are using this. The linear momentum equations applying over these control volumes along this line and neglecting the shear stress components, okay. Because this is a very start reach okay.

That is because of shear stress whatever the force component will come it much smaller as compared to the pressure force and the momentum flux components. This is the momentum flux component what we are equating it V_2 and V_1 directions. If we that you get it this part. Okay, this is very simple just to rearrange the part and you will get it that.

$$\frac{p_1 - p_2}{\rho} = V_2^2\left(1 - \frac{A_2}{A_1}\right)$$

(Refer Slide Time: 39:36)



Now I will applying Bernoulli's equations along the straight line, okay I am just applying the Bernoulli's equation along the straight line. When you apply the Bernoulli's equations, this line is horizontal. This streamline is horizontal, so you do not have a z components. You have pressure head component and the velocity head component. That is what you equate,

$$\frac{V_1^2}{2} + \frac{p_1}{\rho} = \frac{V_2^2}{2} + \frac{p_2}{\rho} + h_l$$

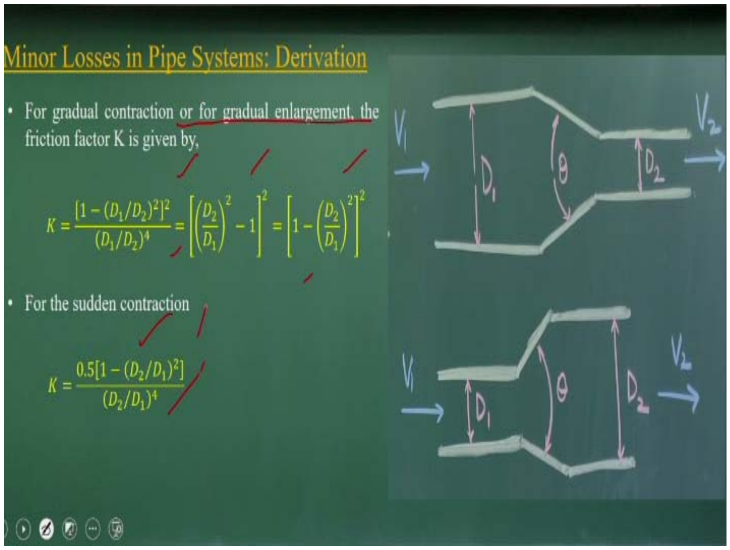
So the flow is come from the one section to sections two where through the flow there is energy losses, that is what we quantify. So because of that we call it is a modified Bernoulli's equation which is nothing else. You are equating the energy, you know that how much of energy losses has happened. So you are just incorporating the energy losses at the sections two. That should be equal to the energy at the section one.

So that is very basic equations, but we are incorporating directly this energy losses, what we compute from major loss or the minor loss. If we substitute that, finally you get energy losses or the head losses in terms of the velocity.

$$h_l = \frac{V_2^2}{2}\left(1 - \frac{A_2}{A_1}\right)^2 = \frac{V_2^2}{2}\left[1 - \left(\frac{D_2}{D_1}\right)^2\right]^2$$

So the K varies with this parameters, which is very easy to quantify it, which is a functions of D 2 and the D 1.

(Refer Slide Time: 41:10)



The same way if you have a gradually contractions happening it or gradual enlargement that you can compute this values, okay? And sudden contractions happening it you can have this type of calculations, we can get it with a simple applying this momentum equations.

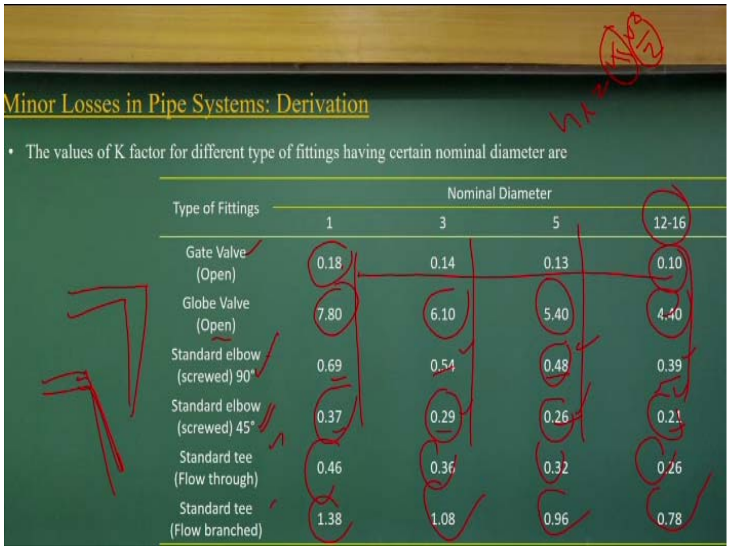
For gradual contraction or for gradual enlargement, the friction factor K is given by,

$$K = \frac{[1-(D_1/D_2)^2]^2}{(D_1/D_2)^4} = \left[\left(\frac{D_2}{D_1}\right)^2 - 1\right]^2 = \left[1 - \left(\frac{D_2}{D_1}\right)^2\right]^2$$

For the sudden contraction

$$K = \frac{0.5[1-(D_2/D_1)^2]}{(D_2/D_1)^4}$$

(Refer Slide Time: 41:31)



Now if you look at the tabular values what we have and here I am talking about the head loss is equal to

$$h_l = K\frac{V^2}{2}$$

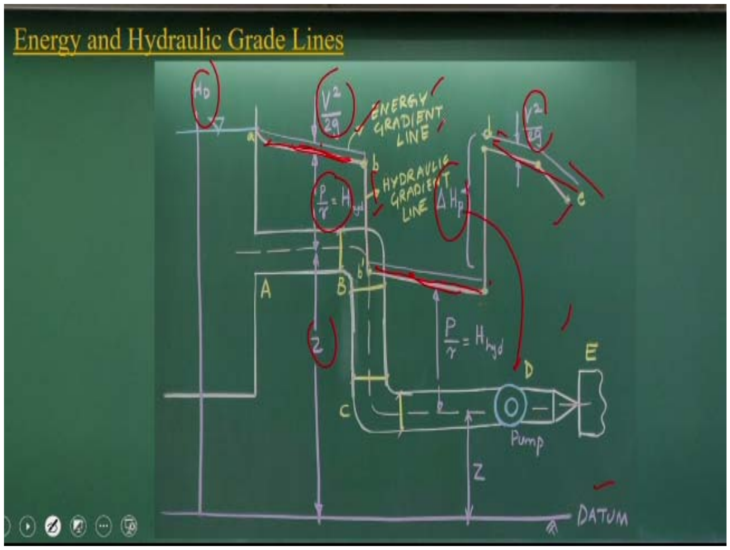
So this K value. How does they value it. First is gate conditions which is 0.18 can varies up to 0.10 as the diameters increases. Same way, if you look it that, gate valve is 0.18, 7.80. So we can understand it, how much the globe valve and the gate valve the energy losses will be there.

Is much larger. But as you increase the diameters, it can be reduced it. Similar way, we can have 90 degree 45 degree, the elbow will have different quantity of energy losses. The 45 degree, we can understand it, it should have a less energy losses as compared to the this is 90 degree. So if you have a 45 degrees, you can draw the flow, the streamlines vortex zones you can understand it, the vortex zones will be the lesser as compared to the 90 degree. So this is less as compared to this one.

This is this to this one. So what I am highlighting is these are things you should understand from the tables. Do not look at the table you just data we should use it to other things. But these tables give a knowledge to us how the flow patterns are happenings. Similar way if you have a tee joint, you will have a different type of the energy losses is happening.

So these are the experimental data to get it this energy losses coefficient of K and if you know the velocities, you can compute it what is the minor loss or minus energy losses.

(Refer Slide Time: 43:35)



Again I am repeating it this energy gradient line and hydraulic gradient line what we discussed just after the Bernoulli's equations. Now let us I have the reservoir, okay. This is the datum. From the reservoirs I have the pipe systems okay and there is a pumping system. So you can draw hydraulic gradient line, also we can draw the energy gradient line.

The hydraulic gradient lines will have the z plus the pressure head, okay. Plus if you look at the velocity head we will get it the energy gradient lines. So now if you look it that as the pipe flows goes down you will have this drop of the potential head, that is what drop is there. Similar way if we look it that there is a pump systems which is increasing the energy.

This is the increase of energy because of the pumping systems and increase of the velocity, that is what will be making this energy gradient line. And if we can see there is a slope ,that is the major losses what is happens it, the frictional losses that will represent to us the slope components. The major losses will be there. So any pipe flow system you can sketch it tentatively what is the energy gradient line, what is the hydraulic gradient line.

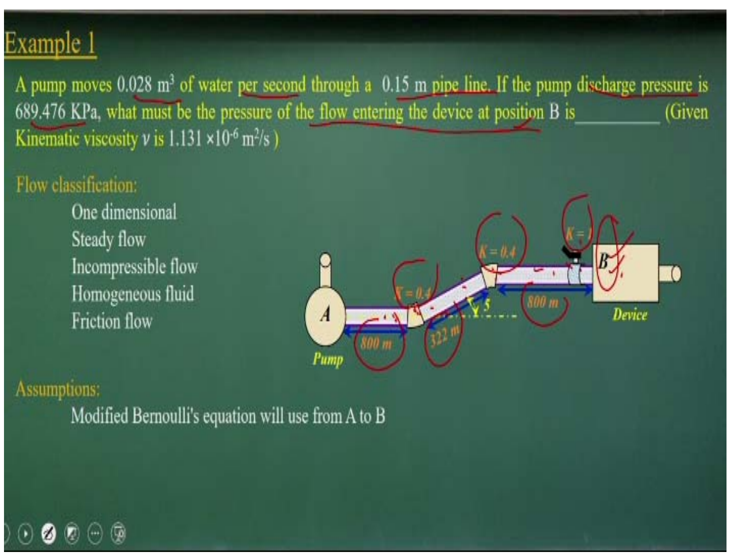
This energy and hydraulic gradient line stock us that how the flow how the flow patterns are happening it with is how much of the velocity of the flow and what is the amount of energy is available at different points, okay. So we try to understand the sketching this energy gradient line and the hydraulic gradient lines.

That is what is important. As I said it earlier, today pipe designs and all the things are necessary, but there are lot of softwares are there, mathematical models are there you can compute this the design a pipe networks. But as a engineers always you should look into the hydraulic gradient line, energy gradient line. Then you try to interpret it, how much of velocity is there, how much of energy available for different conditions.

$$H_{hyd} = \frac{P}{\gamma}$$

So that interpretations we should do it and we should always try to sketch this energy gradient line, the hydraulic gradient lines and if we are good faster in how to draw the energy gradient line and the hydraulic gradient lines you could be a good designer, pipeline designers and all.

(Refer Slide Time: 46:19)



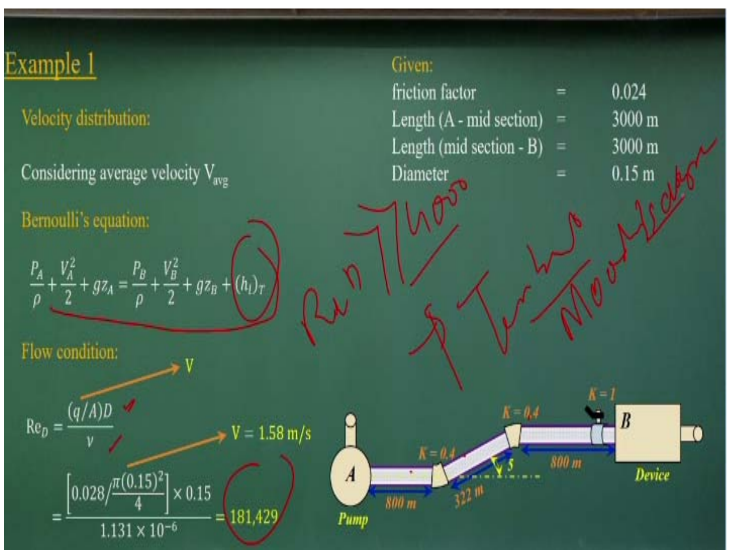
So now let us come to the questions okay, the examples what we have. Okay, so the first example is very simple is there is a pump okay and which moves this amount of the waters per second. That means, this is given to us, through a pipe diameter is given is a pump discharge pressure is this much okay kilo Pascals. What must be the pressure of the flow entering the device at the position B, okay.

That is need to be computed it that and there are pipe dimension of 800 meters 322 meters 800 meters is connected with a two junctions where you have the energy losses, the K factor is given to us with a valve also K factor is given to us. So we will apply the basically we will apply modified Bernoulli's equations and the energy loss equations or using the Moody's chart.

Based on these two we can find out if you know this pressure at this point you know this total energy available at this point, if you compute the energy losses through this pipe, this pipe because of frictions also the because of the junctions and because of the valve, if I know the total energy of losses on this, I know energy at this point, then I can compute energy at this point.

Once I know what is the available energy at these three point, then we can easily find out what could be the pressure. That is not a big deal, okay.

(Refer Slide Time: 48:01)



So first I say that we should have a modified Bernoulli's equations with the head loss components okay, modified Bernoulli's equations with the head loss components. First what you do it we should compute the flow Reynolds numbers okay. So here we are substituting with in terms of diameters and we are computing the flow Reynolds numbers which is coming out to be so large numbers okay.

Given:

friction factor = 0.024

Length (A - mid section) = 3000 m

Length (mid section - B) = 3000 m

Diameter = 0.15 m

$$\frac{P_A}{\rho}+\frac{V_A^2}{2}+gz_A=\frac{P_B}{\rho}+\frac{V_B^2}{2}+gz_B+(h_l)_T$$

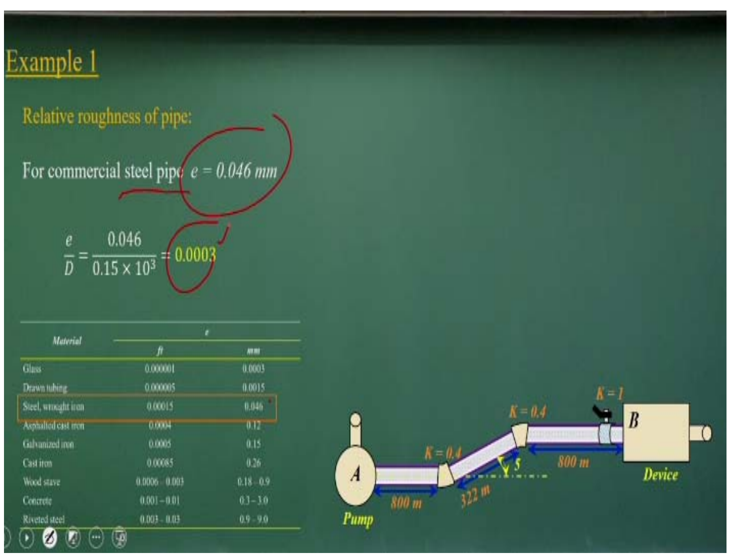
Flow condition:

$$\mathrm{Re}_D=\frac{(q/A)D}{\nu}$$

$$=\frac{\left[0.028/\frac{\pi(0.15)^2}{4}\right]\times 0.15}{1.131\times 10^{-6}}=181{,}429$$

This Reynolds numbers is much larger than 4000. So the flow is turbulent. Okay, so you can multiply it what is happening the flow at this. This value is much larger, this flow is turbulent. So we can use Moody's diagram for solving the problems okay. So that is the, this is the Reynolds numbers and we are confirming it that the flow is turbulent. Also we are trying to we will use the Moody's diagram to computing that.

(Refer Slide Time: 49:06)



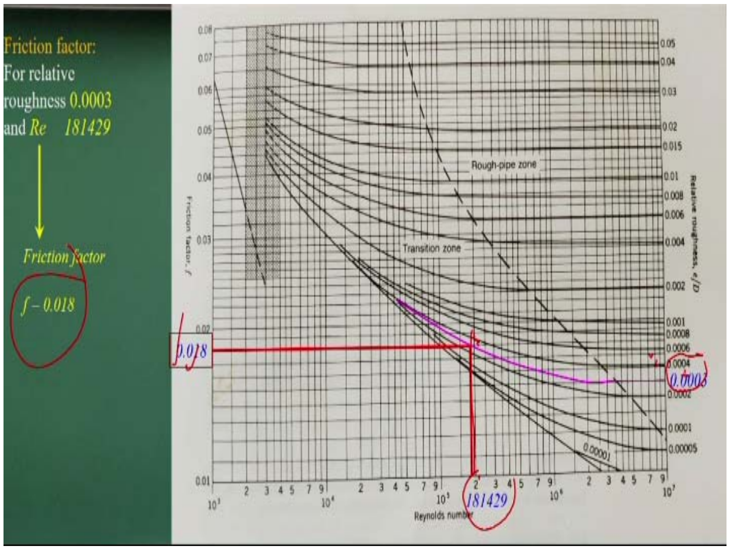
So this is a commercial steel pipe. So roughness value is given to here. The relative roughness value is know it. And once you know the relative roughness value, we are getting it this value and we are computing the relative roughness values.

For commercial steel pipe e = *0.046 mm*

$$\frac{e}{D}=\frac{0.046}{0.15\times 10^3}=0.0003$$

If I know Reynolds numbers and the relative roughness value, I can compute it what will be the friction factors from Moody's chart. It is very easy.

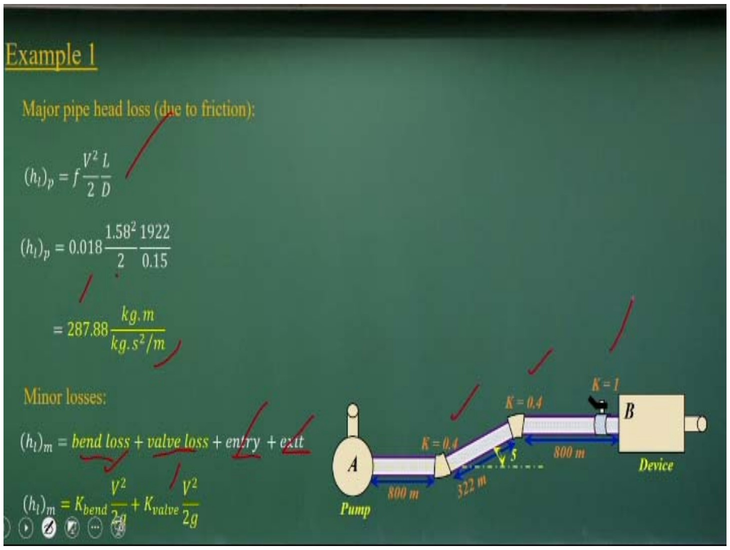
(Refer Slide Time: 49:30)



Identify this approximately which the curve will come there. You know, these Reynolds number, compute it that. Draw the lines with matching that then compute this friction factors, okay? It is very easy. Using this Moody's diagrams, you can first identify with respect to the relative which curve we should follow it. But if curve is not there exactly we can interpolate it that curve and know the Reynolds numbers, interpolate it this.

Then you get it the f factor which is the friction factors we are getting it. So once you know the friction factor then the problems I believe is quite easy okay.

(Refer Slide Time: 50:12)



So that means I know the head losses that is what is computed here by substituting this value. There will be minor losses like bend losses, valve losses, the entry and exit losses all the components, this entry and exit loss we do not consider it here only the bend loss and valve loss we compute it which we have these values.

Major pipe head loss (due to friction):

$$(h_l)_p = f\frac{V^2}{2}\frac{L}{D}$$

$$(h_l)_p = 0.018\frac{1.58^2}{2}\frac{1922}{0.15}$$

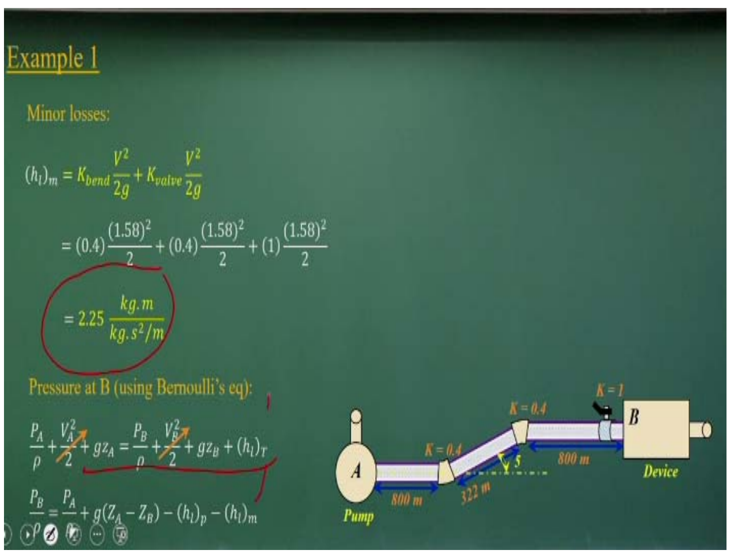
$$= 287.88\frac{kg.m}{kg.s^2/m}$$

Minor losses:

$$(h_l)_m = bend\ loss + valve\ loss + entry\ + exit$$

$$(h_l)_m = K_{bend}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g}$$

(Refer Slide Time: 50:39)



If are considering that the loss components will get it this much is the minor losses. Now we are substituting Bernoulli's equations, the modified Bernoulli's equations to compute what could be the pressure. So I am not going more detail as you can read this ppt to get these details.

Minor losses:

$$(h_l)_m = K_{bend}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g}$$

$$= (0.4)\frac{(1.58)^2}{2} + (0.4)\frac{(1.58)^2}{2} + (1)\frac{(1.58)^2}{2}$$

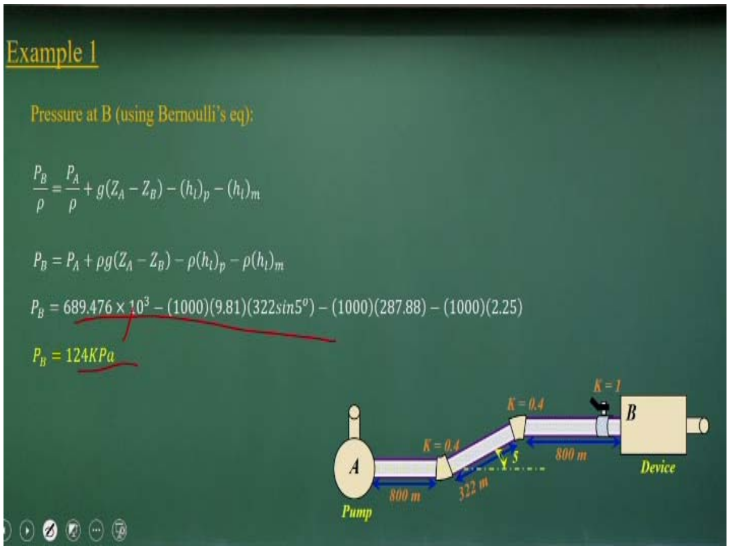
$$= 2.25\ \frac{kg.m}{kg.s^2/m}$$

Pressure at B (using Bernoulli's eq):

$$\frac{P_A}{\rho} + \frac{V_A^2}{2} + gz_A = \frac{P_B}{\rho} + \frac{V_B^2}{2} + gz_B + (h_l)_T$$

$$\frac{P_B}{\rho} = \frac{P_A}{\rho} + g(Z_A - Z_B) - (h_l)_p - (h_l)_m$$

(Refer Slide Time: 50:57)



So once know it then you can compute the pressure. Just substitute the value then compute the pressures. So it is quite easy job now once you know that.

Pressure at B (using Bernoulli's eq):

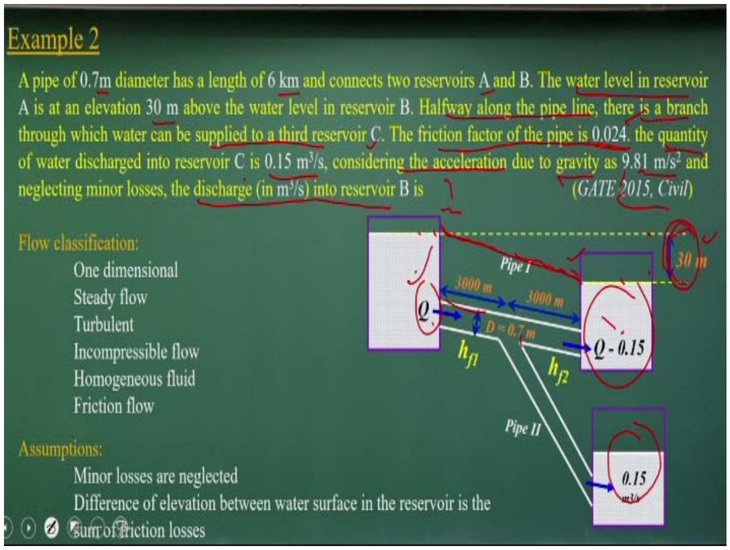
$$\frac{P_B}{\rho} = \frac{P_A}{\rho} + g(Z_A - Z_B) - (h_l)_p - (h_l)_m$$

$$P_B = P_A + \rho g(Z_A - Z_B) - \rho(h_l)_p - \rho(h_l)_m$$

$$P_B = 689.476 \times 10^3 - (1000)(9.81)(322 sin 5^o) - (1000)(287.88) - (1000)(2.25)$$

$$P_B = 124KPa$$

(Refer Slide Time: 51:09)



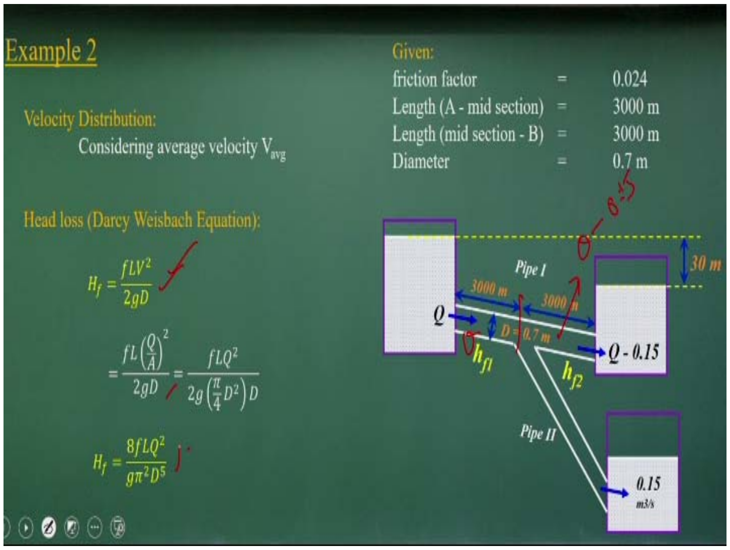
Now you take it the second problems which has the GATE 2015 problems is that the pipe of 0.7 meter diameter has a length of 6 kilometer connects the two reservoirs okay and the water level in the reservoirs is 30 meter above the water level of reservoir B okay. Halfway along this pipeline there is a branch. Water is supplied to the third reservoir C. Then friction factors of the pipe is given.

The quantity of the water discharged into reservoir C is given it. Considering this accelerations due to the gravity this value neglecting the minor loss the discharge into reservoir is what, okay? That is what is the questions. If you look it that you draw the sketches that is the 6 kilometer, this D is given and you have a 0.15 this the discharge what is coming.

If this is a Q amount of discharge this will be Q minus this point okay. So you know this part. You also know these two reservoirs having the elevation difference of 30 meters. That means, this much of energy loss has to be there. Otherwise, these two levels cannot be maintain it. So when flow comes from this pipe of a Q amount of the waters which is passing through this point one pipe on this, but total head losses, total energy losses from through these pipes would be the 30 meters.

Then this too have a 30 meters elevation difference will be there, because velocity at this point and this point will be the zero. So the total these values will be there or I can say it, it will have a some sort of the hydraulic gradient or energy gradient like this. So we need to try to know it that how what could be the Q value such way that we will have the energy losses of 30 meters when passing through these 6 kilometer long pipe. For that f is given to us okay. We know this the length, we know the f factors value is given.

(Refer Slide Time: 53:36)



So we just substitutes to compute head loss because this amount is a Q amount of waters and this pipe will be Q minus 0.15 okay. So you will compute the head loss. That is what we have derived it and you compute this head loss components. Sometimes we write in terms of Q or you can write in terms of V, that is not a big issue.

Given:

friction factor = 0.024

Length (A - mid section) = 3000 m

Length (mid section - B) = 3000 m

Diameter = 0.7 m

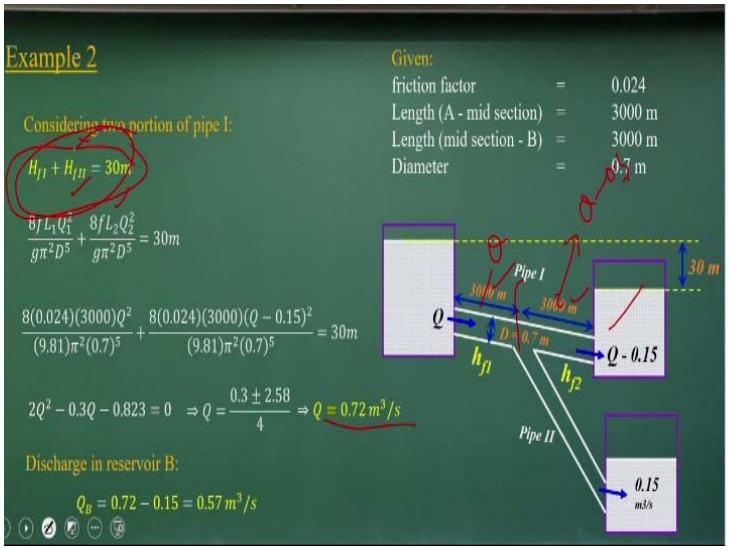
Head loss (Darcy Weisbach Equation):

$$H_f = \frac{fLV^2}{2gD}$$

$$= \frac{fL\left(\frac{Q}{A}\right)^2}{2gD} = \frac{fLQ^2}{2g\left(\frac{\pi}{4}D^2\right)D}$$

$$H_f = \frac{8fLQ^2}{g\pi^2 D^5}$$

(Refer Slide Time: 54:02)



Considering two portion of pipe I:

$$H_{fI} + H_{fII} = 30m$$

$$\frac{8fL_1Q_1^2}{g\pi^2D^5} + \frac{8fL_2Q_2^2}{g\pi^2D^5} = 30m$$

$$\frac{8(0.024)(3000)Q^2}{(9.81)\pi^2(0.7)^5} + \frac{8(0.024)(3000)(Q-0.15)^2}{(9.81)\pi^2(0.7)^5} = 30m$$

$$2Q^2 - 0.3Q - 0.823 = 0$$

$$\Rightarrow Q = \frac{0.3 \pm 2.58}{4}$$

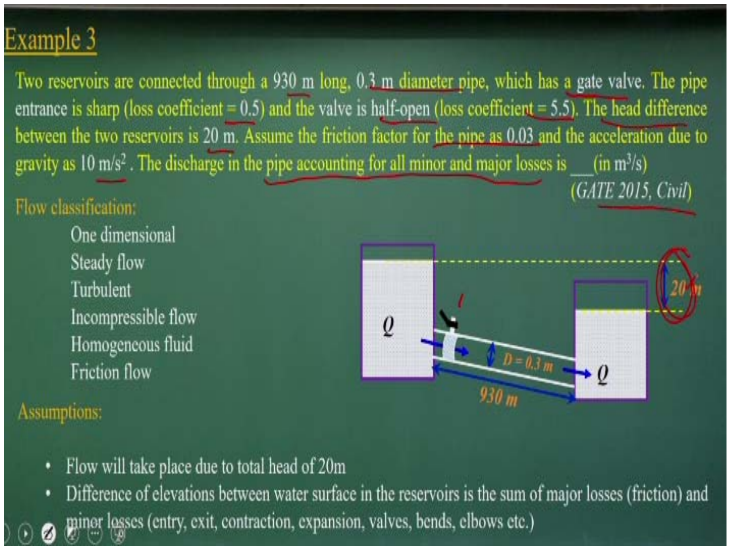
$$\Rightarrow Q = 0.72\,m^3/s$$

Discharge in reservoir B:

$$Q_B = 0.72 - 0.15 = 0.57\,m^3/s$$

And you can compute the energy losses and this should be equal to 30. That is what I was discussing. That is the key point of these problems, okay? The energy losses of this factor and this part should have. This is Q amount of discharge is going. This is Q minus 0.15. So you get this value. If you solve it, you will get the Q value and if know this Q value you can compute the Q. The tricky of these problems, the hints of the problems is only this ones nothing else.

(Refer Slide Time: 54:36)

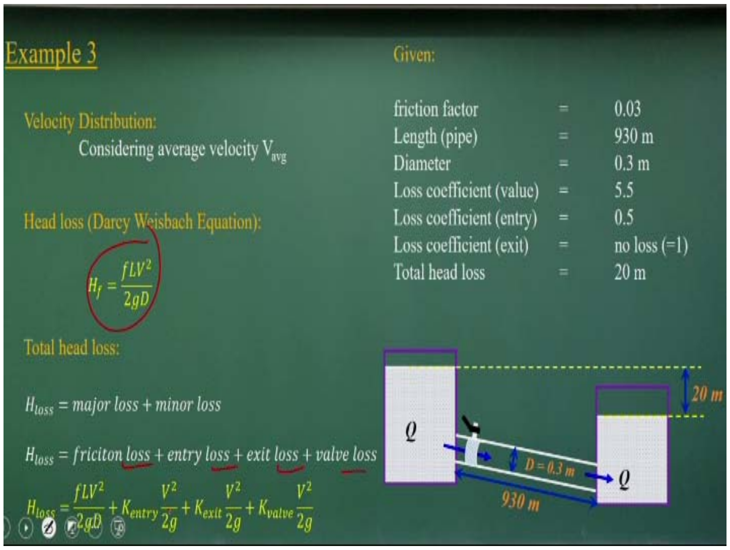


Another the third examples. Okay, two reservoirs are connected with a 930 meters. That is the GATE, again this 2015 paper. The diameter pipe which has a gate valve, okay it is having the valve here, okay. The pipe entrance is sharp. The loss coefficient is given it. The valve is half open. Loss coefficient also is given there. K is given here. Here also K is given. The head difference between two reservoirs is given it.

Again same problems, okay. Assuming the friction factor is given. Acceleration due to gravity is given. It is approximated here and you have to find the discharge accounting all the major and minor losses. If you look at these problems is exactly for the problems what we discussed it, nothing else, okay. Here we have a major losses and minor losses.

All these losses we will equate it to compute, find the total energy losses which will be the 20 meters, that is the problem. The f is given, the K values are given. So you will write in terms of this and compute it what will be the.

(Refer Slide Time: 55:48)



We will use this energy losses, frictions losses, entry losses, exit losses, valve losses, all components are there.

Given:

friction factor	=	0.03
Length (pipe)	=	930 m
Diameter	=	0.3 m
Loss coefficient (value)	=	5.5
Loss coefficient (entry)	=	0.5
Loss coefficient (exit)	=	no loss (=1)
Total head loss	=	20 m

Velocity Distribution:

Considering average velocity V_{avg}

Head loss (Darcy Weisbach Equation):

$$H_f = \frac{fLV^2}{2gD}$$

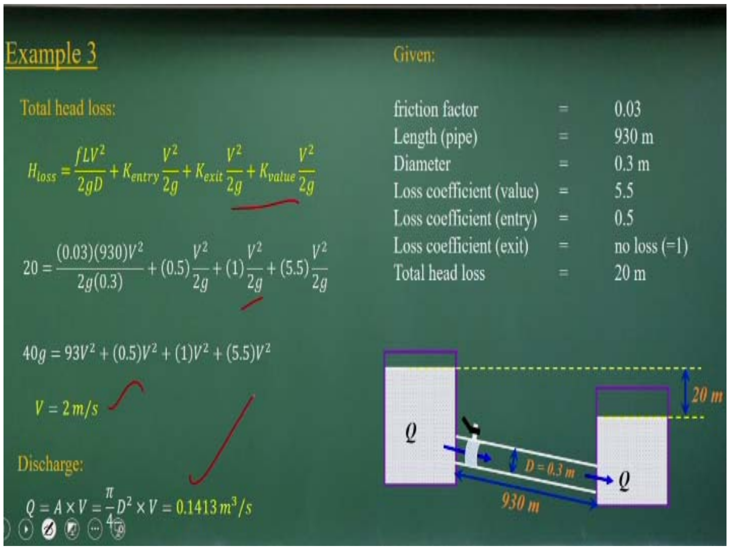
Total head loss:

$$H_{loss} = major\ loss + minor\ loss$$

$$H_{loss} = friciton\ loss + entry\ loss + exit\ loss + valve\ loss$$

$$H_{loss} = \frac{fLV^2}{2gD} + K_{entry}\frac{V^2}{2g} + K_{exit}\frac{V^2}{2g} + K_{valve}\frac{V^2}{2g}$$

(Refer Slide Time: 55:58)



And if you substitute it you will get the velocity and you will get the discharge. So the substituting this value and all you try to understand it. It is okay, it is not a very difficult task for you.

Given:

friction factor	=	0.03
Length (pipe)	=	930 m
Diameter	=	0.3 m
Loss coefficient (value)	=	5.5
Loss coefficient (entry)	=	0.5
Loss coefficient (exit)	=	no loss (=1)
Total head loss	=	20 m

Total head loss:

$$H_{loss} = \frac{fLV^2}{2gD} + K_{entry}\frac{V^2}{2g} + K_{exit}\frac{V^2}{2g} + K_{value}\frac{V^2}{2g}$$

$$20 = \frac{(0.03)(930)V^2}{2g(0.3)} + (0.5)\frac{V^2}{2g} + (1)\frac{V^2}{2g} + (5.5)\frac{V^2}{2g}$$

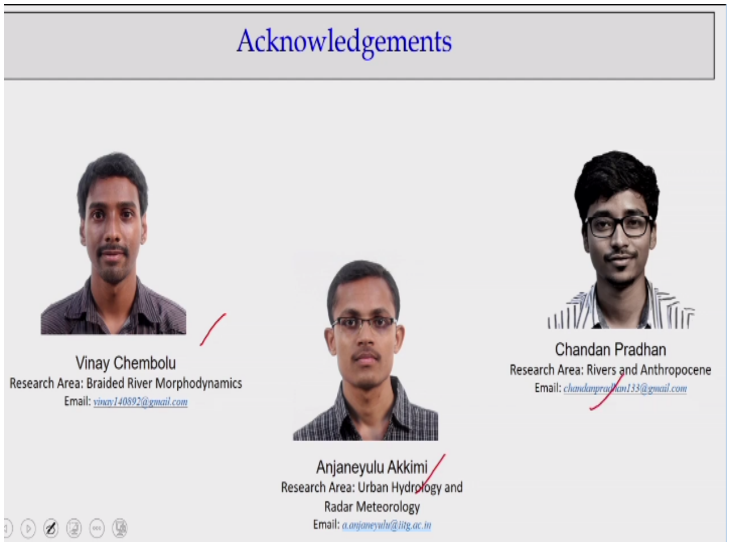
$$40g = 93V^2 + (0.5)V^2 + (1)V^2 + (5.5)V^2$$

$$V = 2\, m/s$$

Discharge:

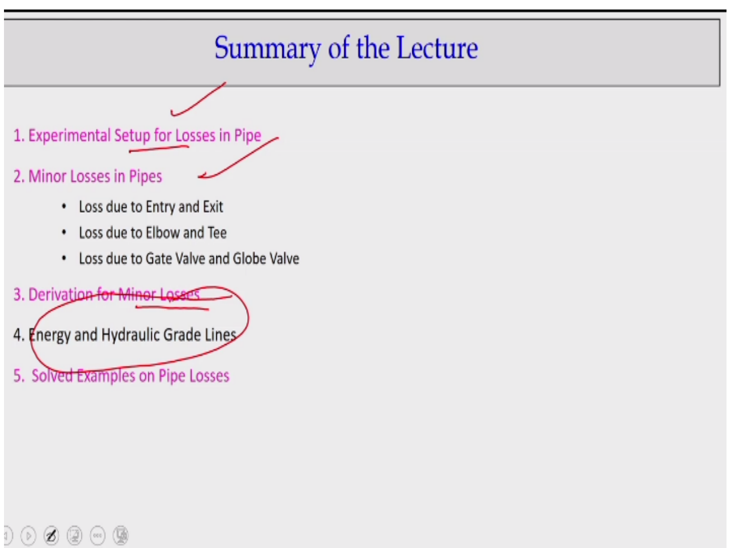
$$Q = A \times V = \frac{\pi}{4}D^2 \times V = 0.1413\, m^3/s$$

(Refer Slide Time: 56:11)



And with this let me finish this lectures with giving acknowledging their contributions having so beautiful ppt and illustrations for you delivering this lectures of fluid mechanics. Really I enjoyed lots delivering the lectures because it has a lot of illustrations, lot of examples and all. And then this there are the summary.

(Refer Slide Time: 56:42)



As you know it we discussed about the minor losses of the pipe. We also showed you the experimental setup. We also derived the minor losses how to these more importantly the energy and hydraulic gradient lines which need to be drawn it and also you can use the control volume concept and you try to understand the flow. It is not microscopically also the gross characteristics wise. With this let me thank all of you for this attention. Thank you.