Upstream LNG Technology
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Lecture – 21
Tutorial on fluid mechanics

Welcome, today we shall see some tutorial on the Fluid Mechanics which we learnt earlier. In that if you recall we learnt about the pressure drop in pipe lines and how to estimate them. We will learn some formally today in the Tutorial.

We shall be using those formula and look into how we calculate the pressure drop for single phase flow as well as for two phase vapor liquid flow in natural gas pipelines and as you recall that these knowledge are required for calculation of the various types of power requirement during the design of the pumping systems.

So, today we shall be looking into the tutorial on fluid mechanics. Now, in this what we shall learn?

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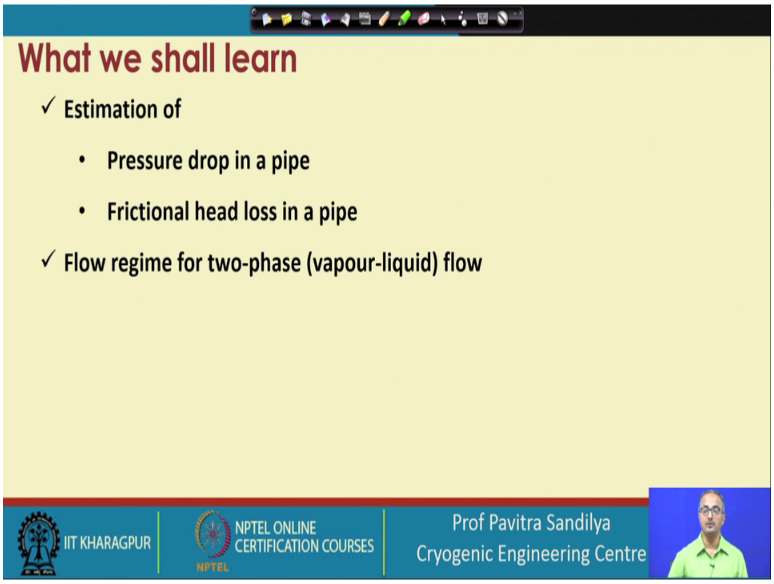

We shall learn how to estimate the pressure drop in a pipeline, the frictional head loss in a pipeline and then, we shall be going to the two phase vapor liquid flow in a natural gas pipeline.

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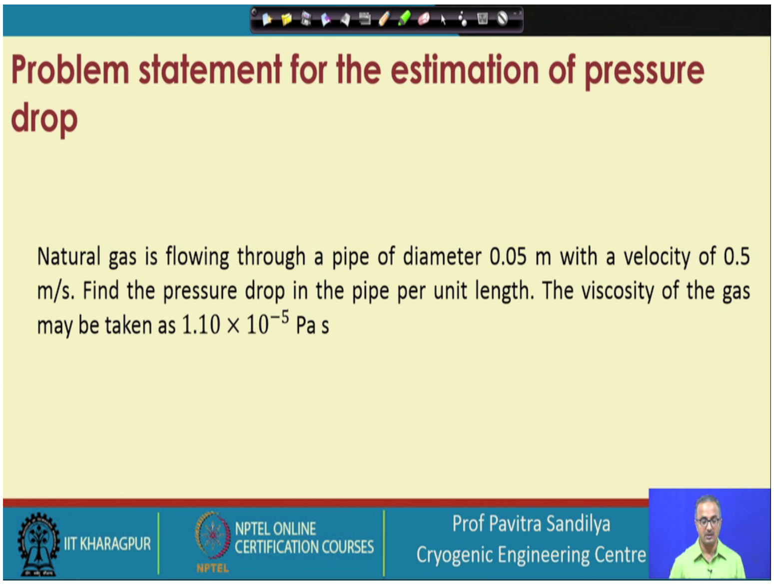

So, first let us look into the estimation of pressure drop in a pipeline. Here we have the problem statement like this. Natural gas is flowing through a pipe of diameter about 0.05 meter, that is 5 centimeter approximately about 2 inches with a velocity of 0.5 meter per second. We have been asked to find out the pressure drop per unit length of the pipeline. The viscosity of the gas has been given as 1.1 into 10 to the power minus 5 Pascal second.

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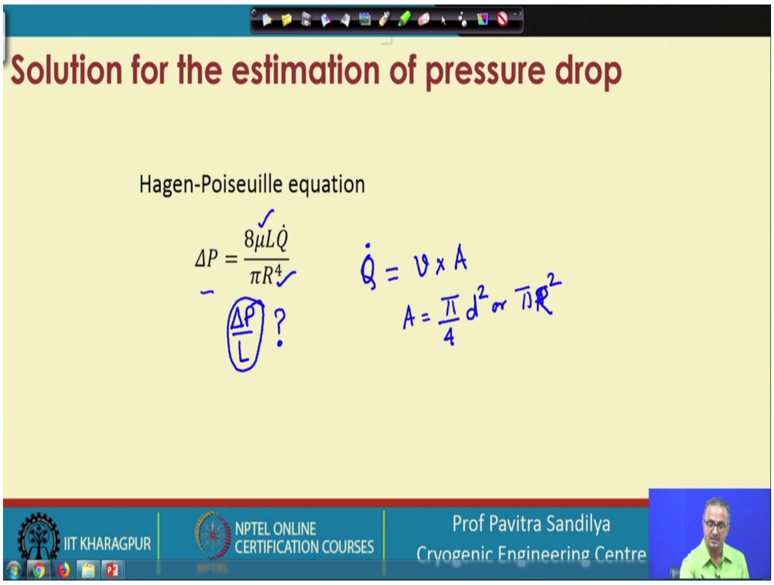

Now, let us go to the solution of this particular problem and for this straight line flow, we shall be using the Hagen-Poiseuille equation which is given like this that the pressure drop is equal to 8 mu LQ dot where mu is the viscosity L is the length of the pipeline, Q dot is the volumetric flow rate and R is the radius of the pipeline. So, here what we shall do now? We can see that we have been asked to find out the pressure drop per unit length, that is we have to basically find out delta P by L; this we have to find out.

Now, mu has been given and mu has been given, the radius of the pipe has been given and how to find out the volumetric flow rate. Volumetric flow rate is nothing, but the velocity into the cross-sectional area and this cross-sectional area is equal to pi by 4 D square or pi R square. So, we shall be using any of this formula. Let me just correct it. This is capital R. So, this is R square. We shall be using to find out the volumetric flow rate and then, we shall be plugging in these values in this for particular formula to get the value of delta P by L. So, that is how we can make use of Hagen-Poiseuille equation to find out the pressure drop per unit length of a pipeline.

Next we shall go to another problem.

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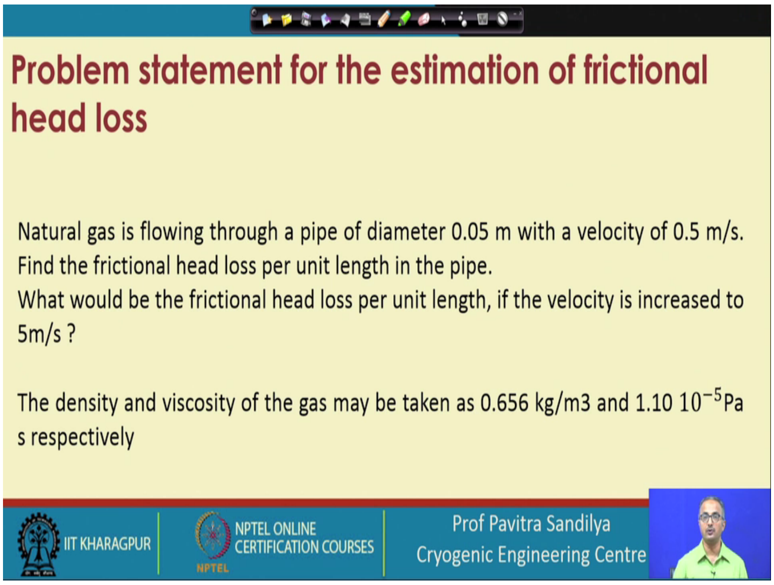

This problem is on this natural gas is flowing through a pipe of diameter 0.5 meter with a velocity of 0.5 meter per second. Here we have to find out the frictional head loss per unit length in the pipe. This is a first part of the question and second part is that what would be the frictional head loss per unit length if the velocity is increased to 5 meter per second? Now, in this case as we learnt earlier that Hagen-Poiseuille equation was used for sort of laminar flow. Here also we have a same thing that we have been given initially some velocity that is 0.5 meter per second and later the velocity increases 10 times to 5 meter per second. Now, due to the change in the velocity what happens? The nature of the flow might change. That means, it may go from laminar flow to turbulent flow.

So, when the nature of the flow changes, so will the pressure drop? So, first we have to figure out what is the type of the flow. For that we have to find out the Reynolds number.

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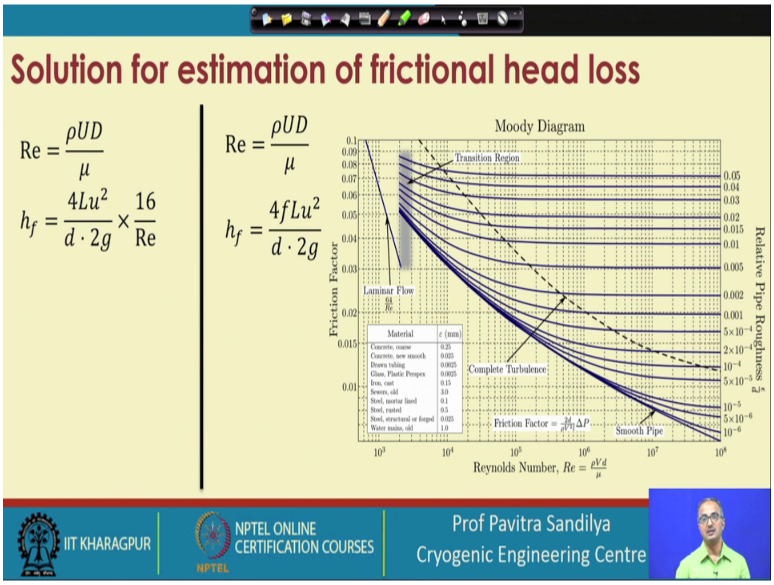

So, the Reynolds number as you know that it is the formula is the rho UD by mu rho is a density, mu is a viscosity, U is the velocity and D is the diameter of the pipeline. So, all these values have been given in the problem and if you calculate the Reynolds number, you might find that it is coming below to say 2000 which is the critical Reynolds number for turbul laminar to turbulent transformation in a circular pipe.

So, if you calculate the Reynolds number and if you find it is less than 2000, then you can use this particular formula to find out the h f that is the head loss. Please mind it this head loss is given in terms of length dimension,. So, this head loss will be in terms of some meters.

So, this is the one and then, to go for the next one again you find the Reynolds number because the velocity now increases 10 times. So, you will find the Reynolds number will also increase 10 times. Now, if Reynolds number increase by 10 times, you might find it goes to a turbulent region.

So, if it goes to turbulent region, then instead of this 16 by R e, the 16 by R e represents the frictional factor in laminar flow whereas, for turbulent flow you have to have some frictional factor that is f which can come from Moody's diagram which we saw earlier and in this Moody's diagram, you can see that there are many lines over here which are given for different types of pipe roughness and here in this type particular table you find that we have the various types of materials because the type of material, the smoothness of the pipe will be depending on the type of material.

So, depending on what kind of material of pipe you have, you have to choose appropriate value of the epsilon from here and from epsilon by d on in this particular thing, you have epsilon by d. So, this d is the diameter of the pipe line. So, the epsilon by d we locate on the y axis and you will locate the Reynolds number on the x axis and then, you go straight straight up from Reynolds number and go on the horizontal axis you see where is the roughness factor and then, wherever they intersect you have to get the value of the friction factor and that friction factor value you can plug in this particular formula to get the head loss for that particular flow.

So, in this particular problem we have shown you that either for laminar flow or for turbulent flow, how we can estimate the head loss due to friction.

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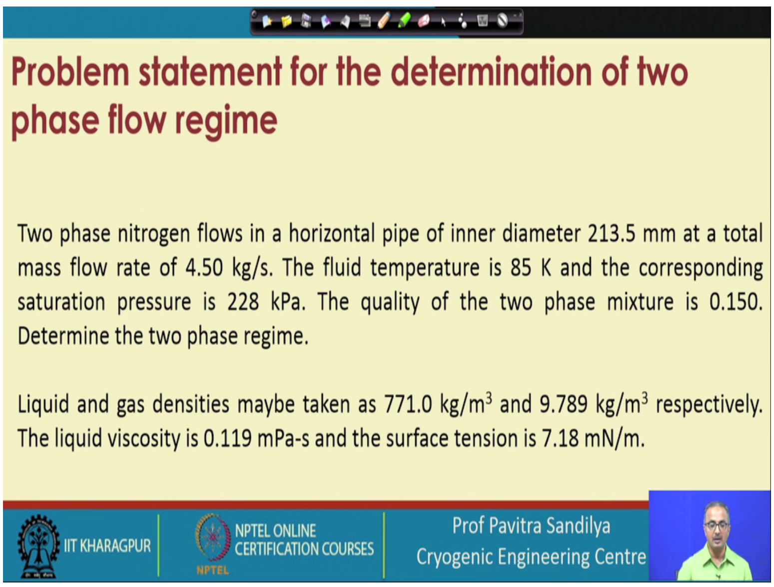

Next problem we come to pertains to a two phase flow. Now, in this two phase flow as we learnt earlier that while natural gas is flowing, it might get condensed or when we have liquefied natural gas that may get evaporated during its flow. So, these situations generate two phases; liquid and vapor and in that case we can have different types of flow regimes like bubbly flow, slug flow, churn flow etcetera and depending on the type of the two phase flow, we shall be having different types of pressure drop.

So, it is needed to understand that what kind of flow regime we are in; so, here is the problem. We have a two phase nitrogen which flows through a horizontal pipe of inner diameter 213.5 mm at a total mass flow rate of 4.5 kg per second. The temperature of nitrogen is given as 85 k and the corresponding section pressure is given as 228 kPa that is kilo Pascal. Now, please understand why it is needed for us to know the saturation pressure? It is because it is a pressure at which the nitrogen or any kind of fluid will try to go from the liquid phase to the vapor phase or vice versa at a given temperature.

So, this is very important for us to know that whether evaporation will occur or not and the quality of the two phase mixture is 0.150 and by quality what we mean there is a fraction of the vapor in the total mixture that is the quality. So, the quality is given as 0.15, that is 15 percent is vapor and rest of it is liquid and we have to figure out what is the type of flow regime that is whether it is bubbly, whether it is slug, what kind of flow regime we are in with this kind of information and we have been given the liquid and gas densities here that 771 kg per meter cube is the liquid density and 9.789 kg per meter cube is the gas density and liquid viscosity is given 0.119 milli Pascal second and surface tension is given as 7.18 milli newton per meter.

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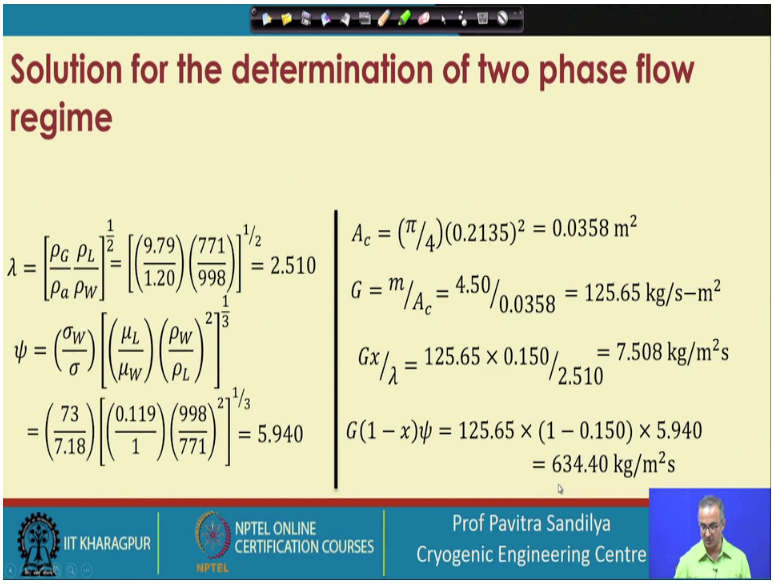

So, with this information we have to figure out the type of flow regime. So, for this what we do, we first again please recall we learnt about the beakers diagram for the two phase flow regime. So, in that beakers diagram, we have some parameters which will now be calculated. So, first is the lambda. This lambda is this particular factor which depends on the densities of this flow and here we find the value of lambda like this that we plug in the values of water and other liquid and we find the value of lambda and this lambda is obtained as 2.510.

Similarly, there is another parameter psi which depends on the viscosity density and the surface tension, and here we in this particular equation we plug in the values and we get the value of the psi. So, after plugging the values, we get the value of psi as this. After obtaining lambda and psi, then what we do that we find the area of cross-section that is pi by 4 d square. So, with this thing we find the area of cross-section as this value 0.0358 meter square.

Then, we find out the mass flux that is the mass flow rate divided by the cross-sectional area. This is the mass flux that is kg per meter square per second. So, here we find the mass flux as 125.65 kg per meter square per second. After this again we find this value G x by lambda which is necessary for use of the beakers diagram. So, x is given as 0.15 that is the vapor fraction and lambda has been obtained from this particular, earlier from this particular equation and we plug in the values and we get the value of G x by lambda and then, we also find out the value of G 1 minus x into psi. This one minus x represents the liquid fraction in the mixture. So, here we get the value of this particular whole parameter and this comes out to be this 634.40.

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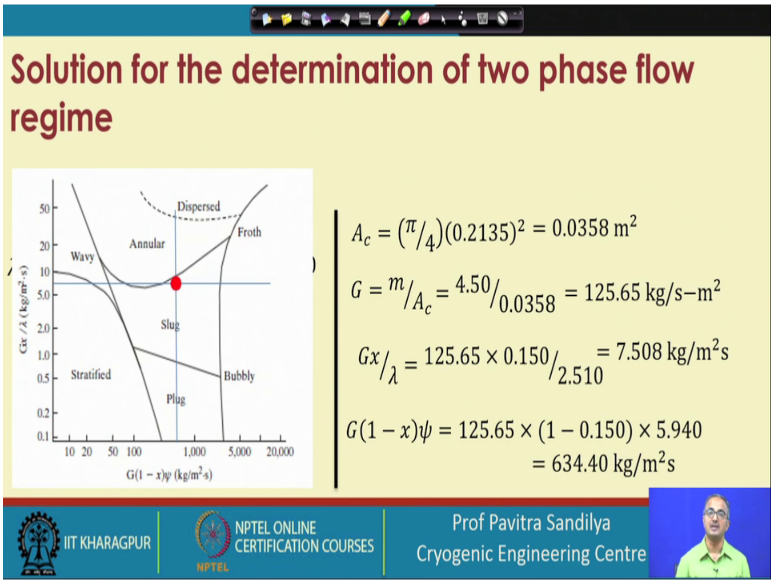

Now, with these values now we refer to the beakers diagram. Now, you can see that on the y axis of beakers diagram we have G x by lambda whereas, on the x axis we have G my into 1 minus x into psi. Both these values we have just calculated. After this what we do, first with this G x by lambda, this horizontal line represents the G x by lambda value, and then, what we do, we G my into 1 minus x psi this. We also go with the vertical line.

Now, wherever this vertical line and the horizontal line intersects, that tells us about the type of flow regime. So, here we find the intersection falls within the slug flow regime. So, we can say for the given conditions, we have a slug flow of the natural gas nitrogen system, sorry nitrogen system. So, nitrogen will be now having both liquid and the vapor which will be in slug flow regime. So, that is how we solve for the two phase flow.

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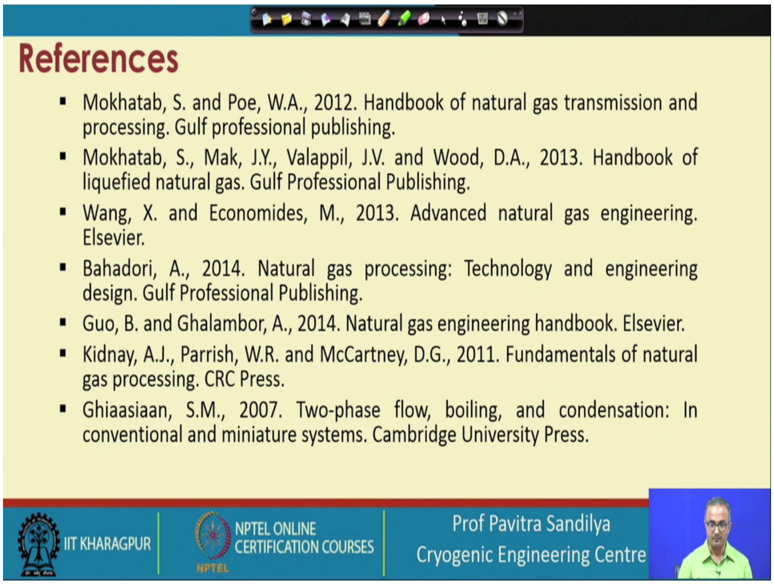

These are some of the references you can refer to for this kind of problem.

Thank you.