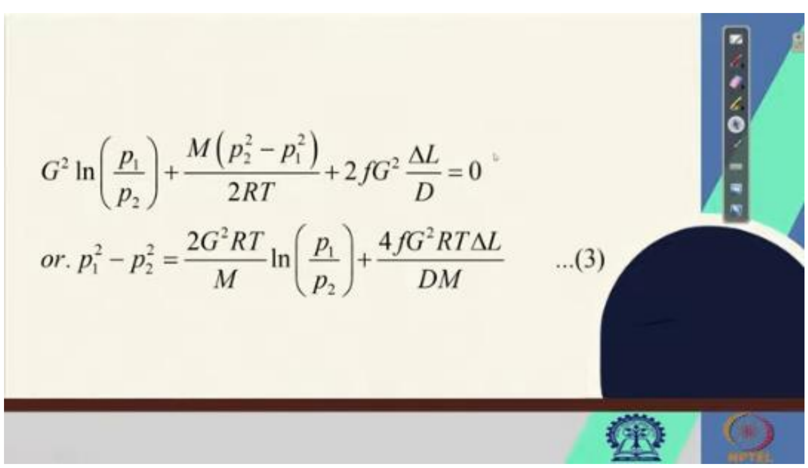
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

Lecture34

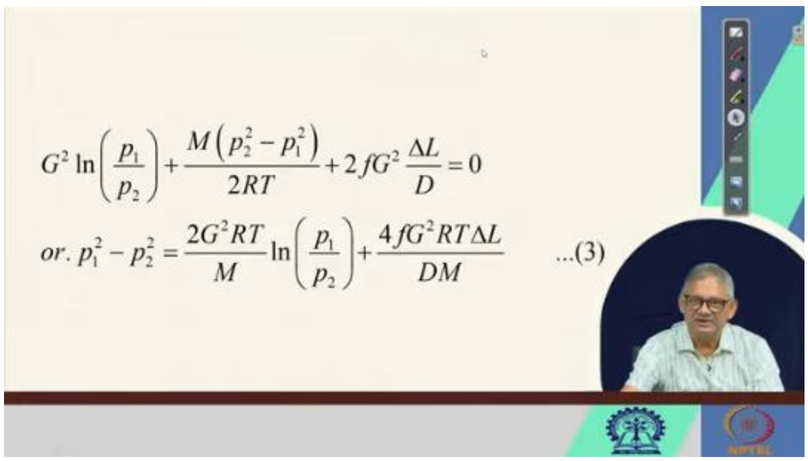
LECTURE 34 : PROBLEM AND ITS SOLUTIONS OF PRESSURE DROP FOR COMPRESSIBLE GAS FLOW

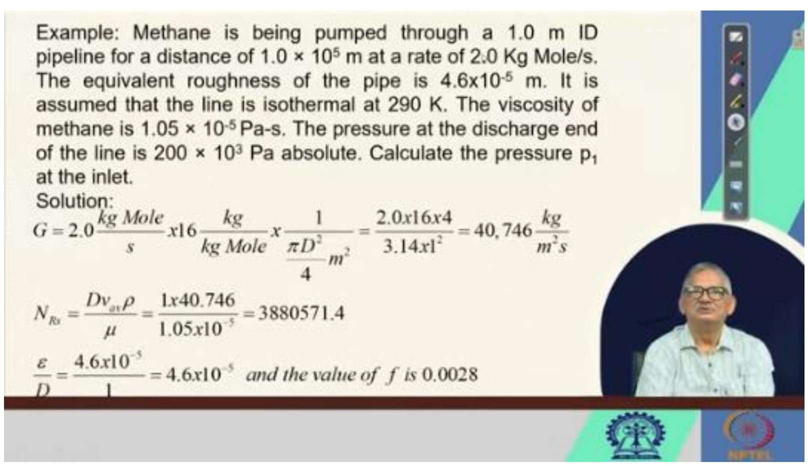
Good morning my dear boys and girls and students and friends. We are doing with compressible fluid flow right. So, it is a continued class because we have developed the relation to find out the pressure drop right. This pressure how to find out we have determined,



right. We have rather developed a relation that p_1 square minus p_2 square equals to 2 G square R T by M ln of p_1 by p_2 plus 4 f G square R T delta L by D M. We said that this relation most of the parameters are known, most of the variables are known. It is used to find out generally the pressure drop, but since there is a term in between ln of p_1 by p_2

So, it is not directly possible to find out the pressure drop. So, that is why it may require some trial and error that we have said ok. Now, let us do some problem and as we said that problem solution is one of the best way to understand the topic or subject. So, the problem is like this methane is being pumped through a 1 meter ID pipeline for a distance of 1.0 to the power 5 meter at a rate of 2.0 kg per kg mole per second.





The equivalent roughness of the pipe is 4.6 into 10 to the power of minus 5 meters. It is assumed that the line is isothermal at 290 Kelvin. The viscosity of methane is 1.05 into 10 to the power of minus 5, Pascal seconds. The pressure at the discharge end of the line is 200 into 10 to the power of 3 Pascal absolute. Calculate pressure P_1 at the inlet.

In this regard, I hope you know. But since it has come, the term pressure, you have seen at home that our body pressures. With a dial, right? Nowadays, of course, that is not required; some electronic devices have come up. So, they take and measure the systolic and diastolic pressures.

Have you ever observed that dial anywhere? That indicator or arrow is always at zero. Does zero mean there is no pressure? That is what we understand: zero means nil, nothing. So that means there is no pressure.

You ask yourself. And find out. If you are not able to, then I will tell you at the end of this class, okay? I am giving you some time to find it out. Again, the question is that the dial, that dial you see, as I said, when we are

asked to take the pressure of the body, a small dial is there. Yes, there is a mercury column also; there are electronic devices also, but that is for our body. But commercially, if you go to any industry, you will see at different places there are some dials. And that dial is having some reading. Now, when it is not in working condition or simply the one which has the dial by which the doctor came, if he or she is using the dial gauge, then if you see that it is at 0, where we were that we said that you have, oh, this was in terms of a pressure gauge, right?

So, my question to you was, when the dial is at 0, does it mean that the pressure is zero? Right, that was the question, and I said that if you are able to answer yourself, very good; otherwise, at the end of this class, I will tell you, okay? Now, let us solve this problem. The problem is that methane is a gas which is not like the previous one where the density does not change with pressure, that is incompressible, but it is a compressible fluid; density changes with pressure. So, methane is being pumped through a 1-meter ID pipeline.

for a distance of 1 into 10 to the power 5 meter at a rate of 2.0 kg mole per second. The equivalent roughness of the pipe is 4.6 into the power minus 5 meter. It is assumed that the line is isothermal at 290 Kelvin. The viscosity of methane is 1.05 into 10 to the power minus 5 Pascal second. The pressure at the distance or the at the discharge end of the line is 200 into 10 to the power 3 Pascal absolute.

Calculate the pressure, P_1 at the inlet. So, this is the problem, which we have to find out the solution, find out the pressure. Here it is asked calculate the pressure P_1, so that means, the other pressure P_2 is given, right. the pressure at the discharge that is P_2 is given and that is 200 into 10 to the power 3 Pascal absolute, right. From the given data, what we can see that, it was given that, it is pumping 2.0 kg mole per second, at a rate

2.0 kg mole per second, right. So, this we can convert into kg per meter square second, that is the mass flux. That can be done, that 2 kg mole per second. Methane has a molecular weight of 16, because CH4, 12 plus 4, 16, right? Carbon 12, hydrogen 1, 4 hydrogen, CH4.

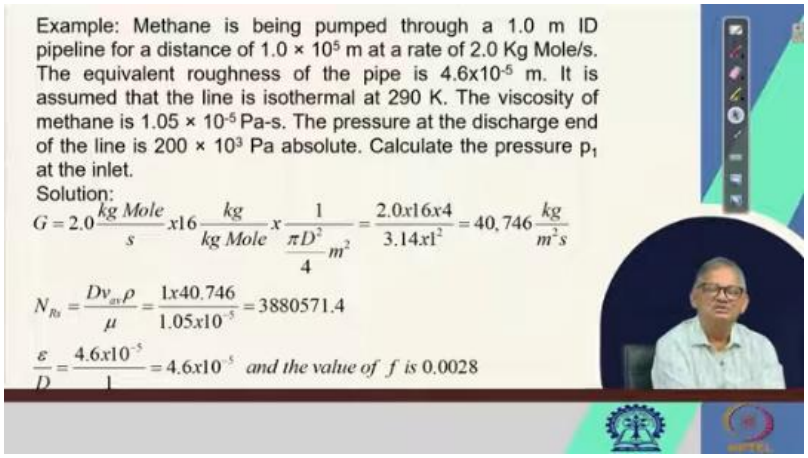
So, it is 16. So, 16 kg per kg mole is the unit. kg per kg mole, right, is divided by rather area that is pi D squared by 4 meter squared, ok. Then kg mole, kg mole goes out, kg per meter square second remains. And the numerical values, if we multiply 2 into 16 into 4 by 3.14, that is pi into diameter is said 1 meter ID pipeline, so 1.

So, it comes to 40.76 kg per meter square per second, right. So, once we know G, we can find out N_{Re} in terms of G, that N_{Re} is D $v_{average}$ rho by mu, right. Here D is given 1 and rho into vaverage is the G that is 40.746 divided by mu, mu is also given 1.05 into 10 to the power minus 5 Pascal second.

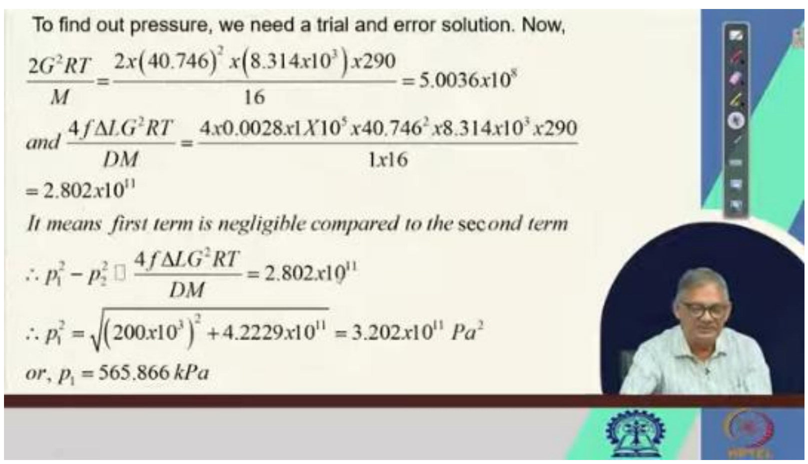
So, we get Reynolds number to be equal to 3880571.4. So, definitely it is highly turbulent 3880571, right, much much more than 4000. We are also given the data for epsilon, relative roughness, we have been given as epsilon by D, that is, epsilon is 4.6 into 10 to the power minus 5, that is what it is given, equivalent roughness of the pipe is 4.6 into 10 to the power minus 5, and

Then, relative roughness, we find out epsilon by D as 4.6 into 10 to the power of minus 5 by 1. So, this is equal to 4.6 into 10 to the power of minus 5, and the value is, and the value of f, yeah. So, we found out epsilon by D, and we found out N_{Re}. So, from Moody's chart for a given N_{Re} and for a given epsilon by D, Moody's chart can be obtained, and from there, the value of f can be found out. And we assume that we have found it out to be 0.0028.

I hope you have seen that Moody's chart; in the previous class, I had shown it to you, right? There, the Reynolds number is plotted against the friction factor; both are in log-log scale, and this value of epsilon by D was also there. Obviously, if you do a number of problems of different types, then you can find out that why it is so, right. So, we found out that f equals 0.0024, okay.



Then, to find out the pressure, we need a trial-and-error solution because, as we have seen earlier, we have a length of pipe at pressures P_1 and P_2 and we have a quadratic equation. So, to solve it, we need to know the pressure drop, right. So, if we need to know the pressure drop, then a trial-and-error is required because a straightforward solution is not possible. First, we find out the constant values like 2 G squared RT by M; the values are known, 2 is known, G squared is 40.746 squared, R is 8.314 into 10 to the power of 3 joules, in terms of joules, and 2 into 290 is the temperature,

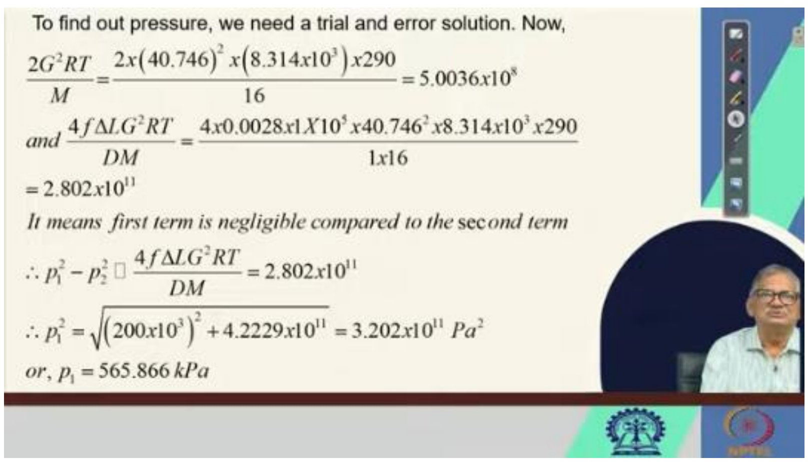


By 16, molecular weight, right. This comes to be equal to 5.0036 into 10 to the power of 8, right. Then the other constant, that is, 4 f delta L G square RT. The other constant, that is, 4 f delta L G square RT by D M. We put individual values: 4 into f, we have obtained as 0.0028; delta L, which is given in the problem, is 1 into 10 to the power of 5 meters.

Into G, which we have found out, 40.746 square into 8.314 R into 10 to the power of 3 joules per kg into 290, that is the temperature, 290. Whole divided by 1 into 16, where was that D, diameter. So, this comes to be equal to 2.802 into 10 to the power of 11, right. So, it means the first term is negligible compared to the second term, you would see That where ln is there, that is 2 G square RT by M, that number being 5.0036 into 10 to the power of 8, and the last term, that is 4 f delta L G square RT by D M.

This is equal to 2.802 into 10 to the power of 11, right. So, compared to the second term, the first term could be neglected. If it is so, then we can easily find out P_1 square minus P_2 square is equal to 4 f delta L G square R T by D M. So, this is equal to 2.802 into 10 to the power of 11. So, therefore, P_1 square can be written as 200 into 10 to the power of 3 whole square, that is P_2 square.

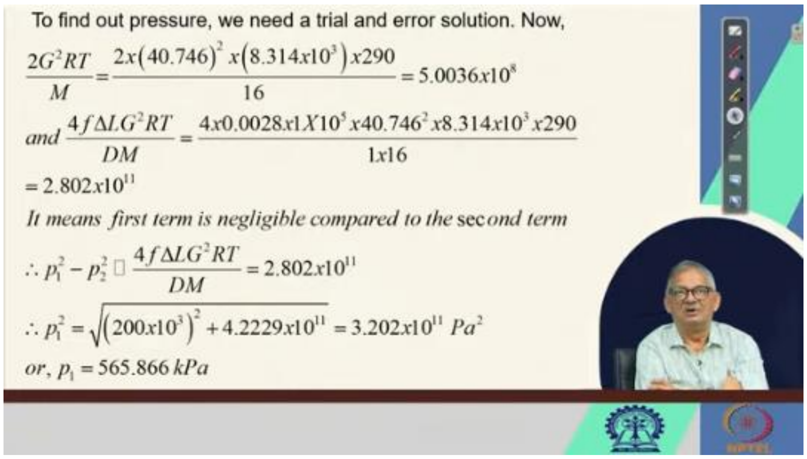
plus 4.229 into 10 to the power 11 under root. So, this is equal to 3.202 10 to the power 11 Pascal square. or from P_1 square, this was 3.022 into 10 to the power 11 Pascal square. So, we get P_1 equals to under root, it is 565.866 kilo Pascal. Now, the question is whether it is correct or not, because P_1 we have found out.



but whether it is correct or not. To know that, let us do another round of this calculation, then you will find that if earlier, we, if you assume, if you see that, for getting ln P_1 by P_2, right not here. Earlier we have shown that the coefficient with ln P_1 by P_2 is very very small, this is in the order of 10 to the power 8 whereas, the last one, c, the order is 4 f delta L G square RT by D M.

So, we can say that if we consider now P_1 as 565.866 kilo Pascal, then put it again to that again find out P_1, because, there, your P_1 by P2 is known, right. Then we find out in this process the value of P_1. square or inverse of, I mean, I mean, under square root of P_1 and that must be closer to 565 may or may not be, I am not sure, because, I have not seen the second order.

So, you can try and finally fix up, because here, our calculation assumption was that we are not taking more than one or two trials, not only more than one or two trials, what we have seen. The value of P_1, which we have obtained for the given value of P_2, and all other given values. This value of P_1, if in the second trial becomes very high or very low, then obviously, our assumption of the first term being very low again, and the second term or last term becoming a little different, right. So, with this, I come to the point where, if you remember, I had said



that if you look at any pressure gauge, the gauge pressure is shown to be zero. Does it mean that the pressure has become zero? Is there no pressure, or is there something else that we should know? You see here, it was written that P_2 was in the absolute pressure, right. So, there are two types of pressures: one is absolute pressure, like this atmosphere is one atmosphere,

This is one atmosphere absolute, that is the pressure, but when we are putting a gauge, that gauge 0 is there, corresponding to the absolute pressure. Whenever any pressure is coming up, then it is called gauge pressure. This is the difference between the gauge pressure being 0 and absolute pressure in any pipeline anywhere, right. So, look into it, see it very carefully. Solve the problem till the second decimal, that means, after the decimal point, you can take two minimum trials and errors.

And you will see your values are converging instead of diverging. Your values are converging, okay. So, our time is up for this class. We will come to other problems and their solutions in the course, with the support of the NPTEL team.

Thank you.