AE 204 FLUID MECHANICS

PIPE LOSS EXPERIMENT / EXP9

2024

OBJECTIVE

The purpose of the experiment is to examine the pressure losses in pipes and special pipe elements (valves, elbows, etc.). During the experiment, the students expected to measure the pressure losses in the local connection devices which are used in fluid lines and restrict the flow lines by changing them geometrically and to calculate the local loss coefficient K value according to these measurement values.

THEORY

The Bernoulli equation can be derived by integrating Newton's 2nd law along a streamline with gravitational and pressure forces as the only forces acting on a fluid element. There is no effect of gravity on a horizontal pipe and the pressure difference between points 1 and 2, which provides fluid movement, is $\Delta P = P_1 - P_2$. Due to the force balance, the viscous effects that cause pressure drop must be met by the pressure force. If it is not a horizontal pipe, the fluid weight in this part is a factor that causes the pressure gradient to occur besides the viscous effects.

The flow characteristic within the pipe is directly related to its regime, i.e. the flow being laminar or turbulent. The shear stresses in laminar and turbulent flow are different from each other and are the main reasons for the difference in flow characteristic.

The energy equation for steady incompressible flow is:

$$\frac{p_1}{\gamma} + \alpha_1 \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_L$$

where h_L is the head loss between sections (1) and (2). With the assumption of a constant diameter ($D_1 = D_2$ so that $V_1 = V_2$) so that horizontal ($z_1 = z_2$) pipe with fully developed flow

($\alpha_1 = \alpha_2$) this becomes $\Delta P = P_1 - P_2 = \gamma\, h_L$, which can be combined with the equation above to give:

$$h_{L\,\text{major}} = f\frac{\ell}{D}\frac{V^2}{2g}$$

called the Darcy–Weisbach equation, is valid for any fully developed, steady, incompressible pipe flow—whether the pipe is horizontal or on a hill.

$h_{L\ \text{major}}$: Major head loss (m)

f : Darcy friction factor

D : Pipe inner diameter (m)

V : Fluid velocity (m/s)

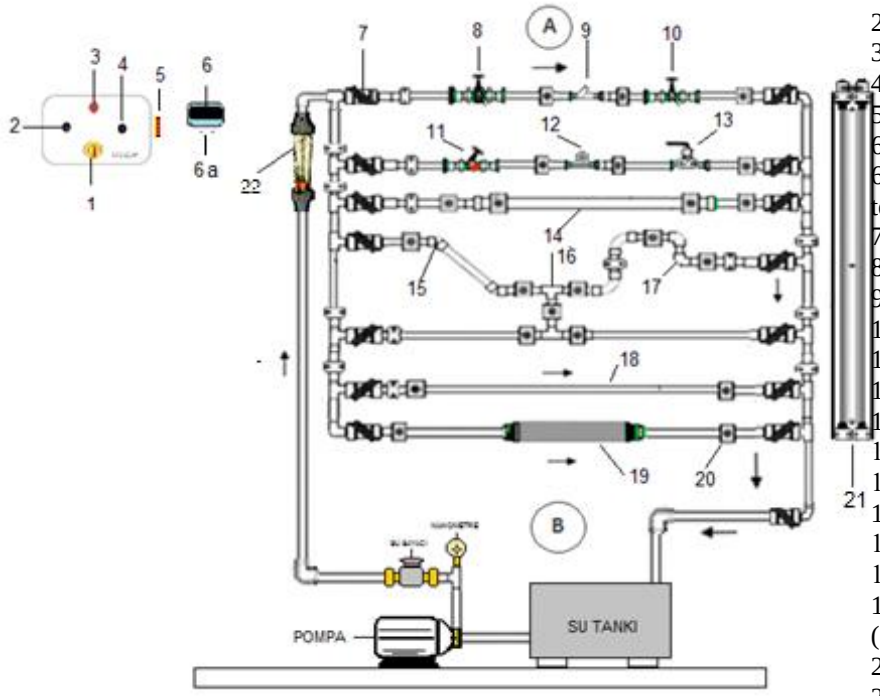
ℓ : Pipe length (m)

g : Gravitational acceleration (m/s^2)

In order to calculate the pressure losses in the valves, elbows etc., which are defined as special pipe elements, loss coefficients obtained as a result of experimental studies are used. The following equations, where K is the loss coefficient, give pressure losses and local head losses in special pipe elements, respectively.

$$P_L = K\rho\frac{V^2}{2} \qquad H_L = K\frac{V^2}{2g}$$

DESCRIPTION OF APPARATUS



1. Emergency stop
2. Pump stop/start switches
3. Power control lamb
4. Flow rate adjusting switch
5. Main switch
6. Differential pressure (Digital) indicator
6a. Differential pressure measuring terminal
7. Control valves
8. Sliding valve
9. Filter
10. Stop valve
11. Discharge valve
12. Check valve
13. Ball valve
14. Test pipe Ø 32mm
15. 45° elbow
16. T-fastener
17. 90° elbow
18. Test pipe Ø 16 mm
19. Sudden contraction and expansion part (16-32-16)
20. Pressure reading tip
21. U-type manometer
22. Rotameter

- A-B test zone

Figure 1. “Pipe Pressure Losses” Experimental Setup

PROCEDURE

1. After plugging in the device, open the valve of the line you will test and close the other line valves.
2. Push the pump start button.
3. Set the flow rate using the pump speed potentiometer.
4. Insert the high pressure measuring hose on the high pressure side of measuring point.
5. Insert the low pressure hose on the low pressure side of the measuring point.
6. If the pressure of the section you are measuring is below 50 mbar, you can get different results because of the sensitivity of the pressure transmitters. In such a case, use only the hose of the high-pressure transmitter.
7. When measuring with a single pressure hose; measure and note the high pressure side first, measure the low pressure side, and then locate the differential pressure by removing it from one.

Temperature, °C	Density, kg/m^3
15	999,0
16	998,8
17	998,7
18	998,5
19	998,4
20	998,2
21	998,0
22	997,8
23	997,5
24	997,3
25	997,0
26	996,8
27	996,5
28	996,2
29	995,9
30	995,6

Table 1: Density of water at different temperatures

U turn (Closed)		2.2
Standard 45° elbow		0.4
Standard 90° elbow		0.9
Long radius (coarse) 90° elbow		0.6
Gear connection (Union)		0.05
T-fastener (flow along the line)		0.4
T-fastener (flow from the side)		1.8
Sudden expansion		$(1-A_1/A_2)^2$
Sudden contraction (A_2/A_1)	0	0.5
	0.1	0.4
	0.3	0.45
	0.5	0.3
	0.7	0.2
	0.9	0.08
Slow contraction		Negligible
Slow expansion, depends on the angle:	50°	1.0
	40°	0.9
	30°	0.7
	20°	0.4
	10°	0.15
Sliding (Gate) valve,	fully open	0.2
	¾ open	0.9
	½ open	5.0
	¼ open	24
Stop (Globe) valve,	fully open	10.0
	¾ open	11.0
	½ open	12.5
	¼ open	50.0
Swing check valve,	with joint	2.0
	Lift type	10.0
Flap check valve,	with joint	2.5
	Ball type	4.0
	Lift type	15.0

Table 2: K values for different pipe elements

REFERENCES

1. http://www.ogen.com.tr/katalog/basinc_kayiplari_int.pdf, Access date: 30.04.2024.
2. Munson, B.R. et al., Fundamentals of Fluid Mechanics, 7th Ed., 2013.

The Moody Chart

Material	Roughness, ε ft	mm
Glass, plastic	0 (smooth)	
Concrete	0.003–0.03	0.9–9
Wood stave	0.0016	0.5
Rubber, smoothed	0.000033	0.01
Copper or brass tubing	0.000005	0.0015
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Wrought iron	0.00015	0.046
Stainless steel	0.000007	0.002
Commercial steel	0.00015	0.045

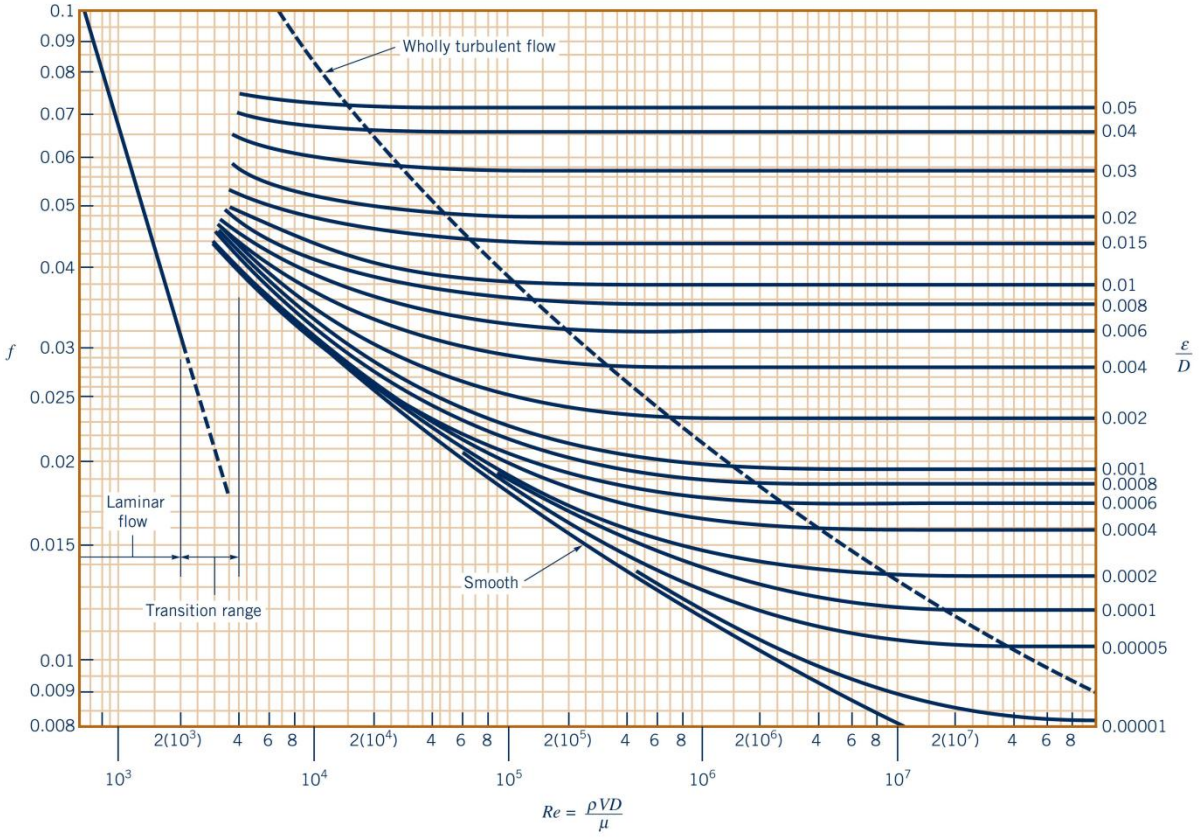
* The uncertainty in these values can be as much as ±60 percent.

*Equivalent roughness values for new commercial pipes**

Relative Roughness, ε/D	Friction Factor, f
0.0*	0.0119
0.00001	0.0119
0.0001	0.0134
0.0005	0.0172
0.001	0.0199
0.005	0.0305
0.01	0.0380
0.05	0.0716

* Smooth surface. All values are for Re = 10^6 and are calculated from the Colebrook equation.

The friction factor is minimum for a smooth pipe and increases with roughness.



THE PIPE LOSS EXPERIMENT / LAB 9 DATA SHEET DATE:

STUDENT NAME, SURNAME: SIGNATURE:

TABLE 1

Data No	Q, Volumetric flow rate (m^3/h)	Element names	Measured pressure losses (P_L) (mbar)	Measured head losses (h_L) (m)	Total head loss ($h_{L,tot}$) (m) MEASURED	V, Velocity (m/s)	Reynolds number	Total head loss ($h_{L,tot}$) (m) CALCULATED	K, Head loss coefficient CALCULATED
1	2.5	Element 1:	Element 1:	Element 1:					
		Element 2:	Element 2:	Element 2:					
		Element 3:	Element 3:	Element 3:					
		Element 4:	Element 4:	Element 4:					
		Element 5:	Element 5:	Element 5:					
2	2.0	Element 1:	Element 1:	Element 1:					
		Element 2:	Element 2:	Element 2:					
		Element 3:	Element 3:	Element 3:					
		Element 4:	Element 4:	Element 4:					
		Element 5:	Element 5:	Element 5:					
3	1.5	Element 1:	Element 1:	Element 1:					
		Element 2:	Element 2:	Element 2:					
		Element 3:	Element 3:	Element 3:					
		Element 4:	Element 4:	Element 4:					
		Element 5:	Element 5:	Element 5:					
4	1.0	Element 1:	Element 1:	Element 1:					
		Element 2:	Element 2:	Element 2:					
		Element 3:	Element 3:	Element 3:					
		Element 4:	Element 4:	Element 4:					
		Element 5:	Element 5:	Element 5:					
5	0.5	Element 1:	Element 1:	Element 1:					
		Element 2:	Element 2:	Element 2:					
		Element 3:	Element 3:	Element 3:					
		Element 4:	Element 4:	Element 4:					
		Element 5:	Element 5:	Element 5:					

Calculation steps:

1. Set the flow rate (2.5 m^3/h) using the pump speed potentiometer.
2. Change the flow rate to 2 m^3/h, 1.5 m^3/h, 1 m^3/h and 0.5 m^3/h and fill in the table above.
3. Using "pressure loss formula", find the head loss for each element (use table 1) for the density.
4. Calculate the velocities in each sections of the corresponding pipe element. Calculate total head loss and find also the K value of the selected pipe line.
5. Draw total head loss ($h_{L,tot}$) vs. flow rate (Q) and K vs. flow rate (Q) graphs for the pipe line selected.
6. Compare total head loss (measured) with total head loss (calculated). Comment on the faults met during the experiment.

LAB RULES:

•Each group should submit one report.

•Each group should write each part by their own and get together with their group members to merge all of them.

•Reports are due to next Monday. They must be submitted to the corresponding assistant **till 17:00** on the next Monday.

•Students must sign the data sheet from the lab assistant at the end of each experiment and the signed sheet must be attached with the report. Reports without the signed data sheet will not be graded.

•Students are advised to read the detail of each experiment sheet before coming to the corresponding lab class.

LAB REPORT FORMAT (HANDWRITTEN EXCEPT COVER PAGE, TABLES AND PLOTS):

The lab report (no longer than 15 pages – all included –) should include the followings (unless otherwise specified):

1. Objective
2. Theory
3. Procedure
4. Results
5. Sample calculation
6. Necessary plots
7. Discussion on results, errors and graphs
8. Conclusion