CE 3105 - Mechanics of Fluids Laboratory

Experiment 4: Friction Loss in a Pipe

1 Objectives

- Observe the behavior of flow with change in velocity and Reynolds number
- Observe the variation of frictional loss with change in velocity

2 Theory

Laminar flow occurs at low velocities when the particles of waters move in parallel straight lines. The flow is smooth and well-ordered. As the velocity increases, the movement becomes undulating and at one point it breaks into vortices. The flow is turbulent in this case. Reynolds number can determine whether the flow is laminar or turbulent. For a circular pipe, it can be expressed as

$$Re = \frac{\rho v D}{\mu} \tag{1}$$

or

$$Re = \frac{vD}{\nu} \qquad (\text{where } \nu = \frac{\mu}{\rho}) \tag{2}$$

It is nearly impossible for turbulent flow to occur at Reynolds number less than 2000 as the turbulence will be restrained by the viscous resistance. However, there is a stage when laminar flow is becoming turbulent or turbulent becoming laminar. During this time, the flow is transitional flow. For smooth pipes, the common rule is

- Laminar Flow: Re $<$ 2000
- Transitional Flow: Re $=$ 2000 to 4000
- Turbulent Flow: Re $>$ 4000

For laminar flow, the head loss due to friction is directly proportional to the velocity:

$$i \propto v$$

For turbulent flow, the head loss due to friction is proportional to the velocity to a given power, n:

$$i \propto v^n$$

The index, n varies between 1.75 and 2. Here i is the hydraulic gradient. It can be found as follows:

For the manometer-

$$i = \frac{(h_1 - h_2)}{l} \tag{3}$$

For the pressure manometer-

$$i = \frac{\Delta h}{l} \tag{4}$$

The flow velocity, u can be found from the continuity equation when the cross-sectional area of the pipe is known:

$$u = \frac{Q}{A} \tag{5}$$

The friction factor, f can be found using Darcy-Weisbach equation:

$$f = \frac{iD}{4v^2/2g} \tag{6}$$

The necessary physical water properties corresponding to water temperature should be used. They can be found in tables from the text book. Figure 1 shows the experimental setup

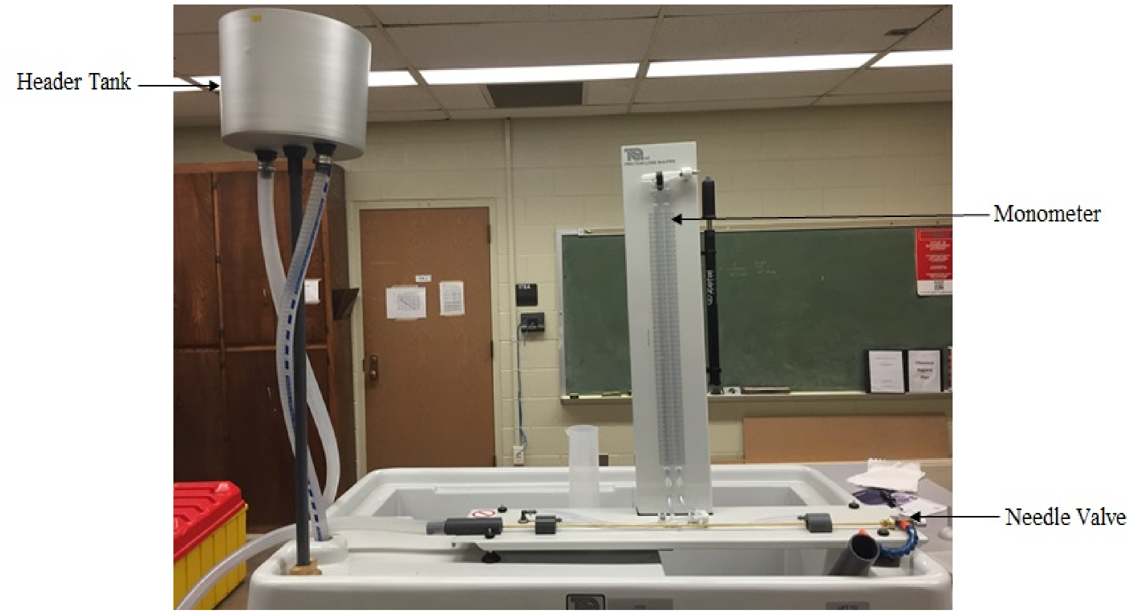

Figure 1: Experimental Setup of Friction Loss in a Pipe

3 Variables/Units

Variables	Description (Units)	Variables	Description (Units)
Re	Reynolds number	ν	Kinematic Viscosity (ft^2)
ρ	Water Density $(slugs/ft^3)$	i	Hydraulic Gradient
v	Flow Velocity (ft/s)	h_1, h_2	Manometer 1 and 2 readings (ft)
D	Pipe Diameter (0.00985 ft)	Δh	Head Difference (ft)
μ	Dynamic Viscosity $(lb.s/ft^2)$	Q	Flow Rate (ft^3/s)
f	Friction Factor	A	Cross Section $(7.60e-5\ ft^2)$
l	Distance Between Tappings (1.72 ft)		

4 Procedure (Lower Flow Rates)

1. Connect the output of the hydraulic bench to the header tank, and the output of the header tank to the inlet of the test pipe
2. Turn on the hydraulic bench pipe and adjust its supply valve carefully to ensure a steady flow without overflowing the header tank
3. Partly open the needle valve of the test pipe at the downstream to pass the water through it
4. Bleed the trapped air as necessary using the bleed pipe and connect the hand-held pressure meter
5. Record the manometer readings.
6. Measure the discharge by collecting a known amount of water in a given time using a beaker and a stopwatch
7. Change the flow rate by operating the needle valve and repeat steps 5 and 6 to have 6-7 records

5 Procedure (Higher Flow Rates)

1. Connect the output of the hydraulic bench to the inlet of the test pipe directly
2. Turn on the hydraulic bench pipe and adjust half open the supply valve
3. Fully open the needle valve of the test pipe at the downstream to pass the water through it
4. Bleed the trapped air as necessary using the bleed pipe and connect the hand-held pressure meter
5. Record the pressure meter readings.
6. Measure the discharge by collecting a known amount of water in a given time using a beaker and a stopwatch
7. Change the flow rate by operating the needle valve and repeat steps 5 and 6 to have 6-7 records

6 Calculations

1. Find the head differences from the manometer readings $(h_1 - h_2)$ for lower flow rates. For higher flow rates, the pressure meter does that automatically
2. Find the velocity for each reading using continuity
3. Calculate the hydraulic gradient
4. Find the Reynolds number
5. Calculate the friction factor
6. Plot hydraulic gradient VS flow velocity for both low and high flow
7. For higher flow, plot a chart of log i VS log u
8. Tabulate all results

7 Interpretation Question (for Report)

1. Identify laminar and turbulent flow from lower flow results and identify the transition point (look at the Hydraulic gradient VS Flow velocity plot)
2. Get the slope of the i VS u plot (i/u) from the laminar flow results. Use the following equation to calculate the water viscosity:

$$\mu = \frac{i}{v}.\frac{\rho g d^2}{32} \tag{7}$$

   Check this theoretical value with the value used in this experiment. In the equation above, make sure you are putting slugs/ft^3 for ρ
3. How do lower and higher flow results compare?
4. For the higher flow log/log plot, get the slope, n from the most linear part, and check it with the relation $i \propto v^n$
5. What are some of the sources of errors?
6. Talk on the practical applications of this experiment

CE3105 Mechanics of Fluids Laboratory,Texas Tech University
Experiment: Friction Loss in a Pipe - Data Sheet
Date of Experiment: .... ,Name:....................

Experimental Data:

Temperature of water, $T=$ celsius , Water density, $\rho =$ $(slugs/ft^3)$, Gravity, g= 32.2 (ft/s^2)

Lower Flow Rates:

Volume	**Time**	**Flow Rate, Q**	**Flow Velocity, u**	h_1	h_2	Δh	**i**	**log i**	**log u**	**Re**	**f**

Higher Flow Rates:

Volume	**Time**	**Flow Rate, Q**	**Flow Velocity, u**	Δh	**i**	**log i**	**log u**	**Re**	**f**

Instructor's Signature