Head Loss in Pipes Lab Report

TU23FL Fluids Lab

Sec.3 Gr.4

Will Gehman, Brandon Gomez-Gurrero, Jakob Werle

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# Introduction

In fluid dynamics, head loss describes the loss of energy as a fluid moves across a physical feature. Building an understanding of head loss in pipes is fundamental in designing sophisticated fluid systems. The objective of this lab is to learn how fluid properties and various geometric pipe features affect a fluid’s head loss. Head loss will be experimentally determined by reading flow rate and pressure between several pipe sizes and shapes. The experimental results will be compared to theoretically derived values for each component. Furthermore, the impact the major and minor head losses will be analyzed.

# Theory

The continuity equation for steady, incompressible flow becomes:

Equation

Where Q is volumetric flow rate, V is velocity of the fluid flow, and A is the cross-sectional area. Subscripts 1 and 2 denote any two cross sections in the system. The equation for energy per unit weight is.

Equation

In Equation 2, V is velocity, g is gravity, z is the elevation, P is the static pressure, γ is the specific weight of the given fluid, and is the head loss. In fluid dynamics, head loss is broken into major and minor head loss depending on the feature that the fluid flows through. Major head loss occurs from viscous forces within a straight pipe and is defined by:

Equation

On the other hand, minor losses are energy losses from specific components or pipe features. The loss coefficient will be chosen to match the specific component. Minor head loss is defined by:

Equation

The flow regime is important in figuring out the system’s losses. Reynolds number is used to determine whether the flow is turbulent, laminar, or mixed:

* Re < 2000 ---> laminar flow
* 2000 < Re < 4000 ---> mixed flow
* 4000 < Re ---> turbulent flow

This value can be used to find the friction factor. Equation 5 and Equation 6 are used for laminar and turbulent flow, respectively.

Equation

Equation

# Sample Calculations

For a flow rate of 14.6 gallons per second, sample calculations are shown below to achieve theoretical head loss. The initial flow rate is denoted as

Then to obtain the fluid velocity, equation 1 is used, shown here as

From here, the Reynolds number is calculated. This stays relatively constant throughout the data with this specific flowrate but does drop slightly.

The next step is finding the friction coefficient. This is calculated through equation 6.

We can now calculate the major and minor head losses in this section of pipe. Since there are no obstructions, there is no minor head loss, but major head loss can be determined through equation 3:

Then, to get the total theoretical head loss, both the major and minor losses are added and divided by the specific weight of water.

This value can be compared to the actual head loss observed, which uses the average of the data collected at this location. The pressure here is 1.2666 kPa, so the equation becomes

Finally, to find the velocity at the end of this section of pipe, we will modify the Bernoulli equation.

# Apparatus

The experimental apparatus is made of four main components, consisting of flow and data equipment. As seen in Figure 1,the fluid flow will enter the top of a pipe that snakes back and forth down the testing bench wall. The water exits into a trough to be recycled into the system. The head loss will be analyzed at the following features, which are spread out along the length of the pipe:

1. Smooth straight pipe
2. Rough straight pipe
3. 90° bend
4. 180° bend
5. Ball valve
6. Globe valve
7. Backflow prevention valve

A glass panel with wires and wires

Description automatically generated with medium confidence

Figure : Pipe Apparatus

The pressure and flow rate will be read at each location by a differential pressure transducer and flowmeter, respectively. Pressure data will run through LabVIEW data acquisition software. Flowrate can be read directly from the flowmeter.

# Procedure

To start the procedure, the pump to the system must be started, and initially set to a flow rate of about 15 gallons per minute. To ensure that there is no error in the data collection system when recording pressures, all air bubbles in the differential pressure transducer system must be removed prior to collection.

With the lab view program ready, select the first component and record the pressure drop received, along with the standard deviation. Take three data points and average them for data analysis. Repeat this step for each of the seven components. Once this is done, adjust the flowrate and repeat.

Data should be collected for flow rates of 15, 12.5, 10, 7.5, and 5 gallons per minute. When approaching low flowrates, make sure that there is no leakage at the end of the system, as the pressures may be too high for the glue.

# Data Analysis

Figure : Smooth Straight Pipe Results

Figure : Rough Straight Pipe Results

Figure : 90 Degree Bend Results

Figure : Ball Valve Results

Figure : Globe Valve Results

Figure : 180 Degree Bend Results

Figure : Backflow Valve Results

# Discussion

1. Compare the measured head loss with the theoretical predictions.

As the water goes through multiple components, there is a general pattern that follows in which the theoretical head loss is usually higher than the measured head loss. The valves calculated for the theoretical head loss are close to the measured head loss so there aren’t any large discrepancies between each other throughout each component. The results for some of the components are more accurate than others as the ball valve in Figure 5 has its highest error percentage being 281%. This might be the case if the coefficient KL is an accurate estimation of the minor head loss in addition to the major head loss.

1. Plot the theoretical and actual head loss as a function of the flow rate for each component.

\*See figures above. \*

1. How does head loss change with flow rate?

As seen in all plots, head loss grows exponentially with flowrate.

1. Compare the head loss between the smooth and rough pipes.

During the experiment, the head loss increased between the smooth and rough pipes. Although theoretical data doesn’t suggest much difference, at higher flowrates, there is a significant difference between smooth and rough values. This is likely due to an increase in viscous forces provided by turbulence and friction in the flow.

1. Compare the head loss between the ball and globe valves.

As seen by the plots in Figure 5 and Figure 6, there was no significant difference in head loss at low flow rates. Shown in both the theoretical and experimental results, the globe valve creates a larger head loss when flow rate approached values of 0.2 gal/s.

This is likely due to the physical geometry of each component. A ball valve has a sphere with a hole cut out, which opens up to allows fluid through. Globe valves work by lifting a circular gate normally to a hole face. Practically speaking, fluid can pass through a ball valve with a more direct path than a globe valve which suggests more energy could be lost.

1. Discuss any measurement errors and the discrepancy between measurement and theory.

Since there were only two lines of data recorded, the number of mistakes made while testing was low. However, there remains some error in the testing equipment and methods. Firstly, there are chances for air to be in any of the several pressure lines. In addition, there could be cavitation in the flow around the pump. Secondly, the mass flow rate data points are only as precise as the flowmeter reads. This introduced some human error, as this relies on group members to watch live numbers and manually record the values.

The largest error in our data set potentially comes from the method of solving for theoretical values. It is known that as flow rate increases, turbulent forces take larger effect across the components. As seen in most plots above, the faster flow rates are where the theoretical and experimental data sets begin to diverge. If not calculation mistakes, a hypothetical error could come down to the method for modeling turbulence. Due to the complexity of turbulent flow, it is feasible to say the simple formula breaks down at a certain point.

# Conclusion

In conclusion, this fluids experiment explored the effects of mass flow rate and various pipe components on head loss. The head loss for each part was theoretically calculated and compared to experimentally derived values. Results demonstrated that head loss gets larger as mass flow rate increases. By plotting similar features results together, useful information could be drawn in the case of selecting certain components over another. This lab played a significant role in preparation for designing systems with sophisticated fluid systems.