ENGR10004

ENGINEERING SYSTEMS DESIGN 1

WORKSHOP 2

PART A

Further development of MATLAB skills involving exporting data, more advanced 2D plotting and introduction to 3D plotting.

Fluid mechanics – pipe flow

The questions from the ESD 1 problem booklet covered in this workshop are, 1, 2, 8, 12 and 13.

PART B

1. Project team management plan
2. Loss measurement of a ball valve, and determination of K-values.

The instructions for part B follow.

Introduction

A common method to determine the pressure drop over a fluid system is the velocity head (or K-value) method. The K-value, or resistance coefficient, is often tabulated for a range of fittings and is used in equation 1 to determine the head loss due to flow over a fitting. The pressure drop can then be determined using equation 2.

$$h = K \cdot \frac{v^2}{2g} = K \cdot \frac{(Q/A)^2}{2g} \qquad \textbf{Equation 1}$$

$$\Delta P = \rho g h = \rho \cdot K \cdot \frac{v^2}{2} \qquad \textbf{Equation 2}$$

where

h - head loss (m)

K - K-value or resistance coefficient

v - average velocity (m/s)

g - standard gravitational acceleration constant (9.81 m/s^2)

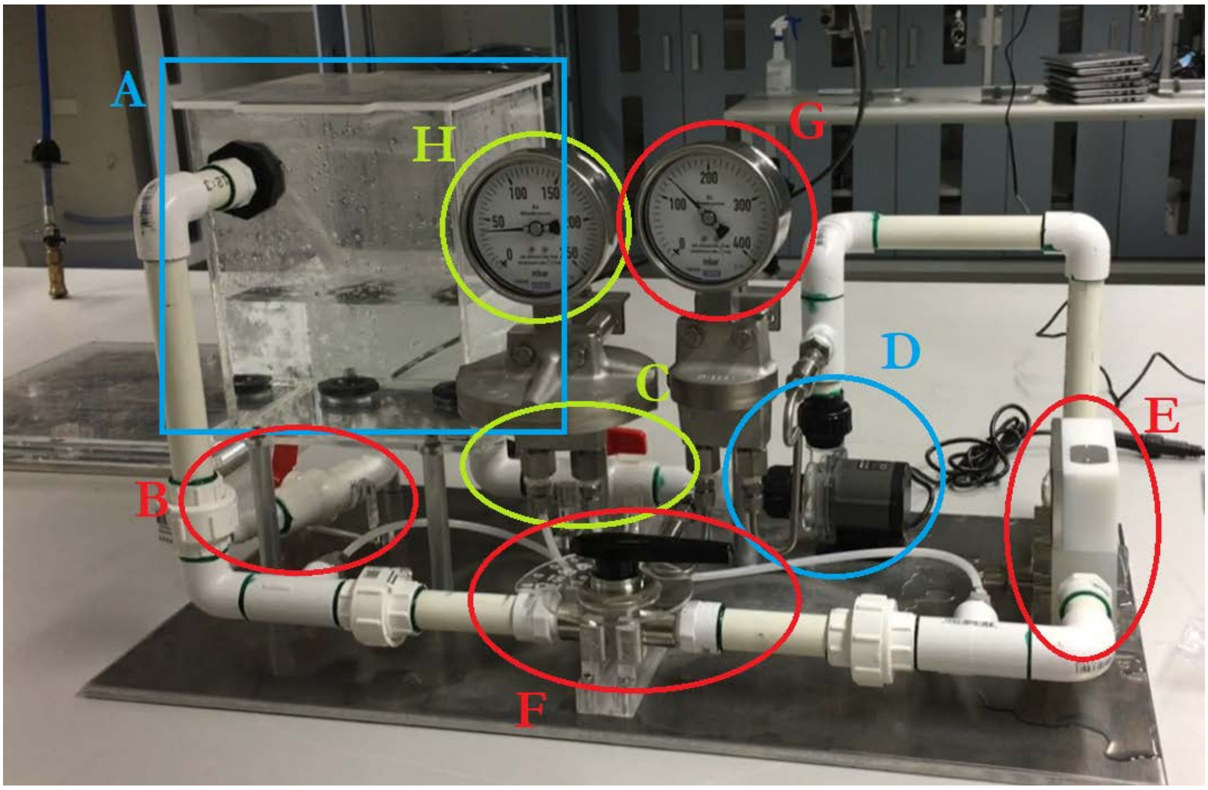
ΔP - the pressure drop (Pa)

ρ - density of the fluid (kg/m^3)

K-values for fittings are determined empirically; in this session, the hydraulic losses over a ball valve will be measured over a range of valve openings. From these measurements, the corresponding K-values for the valve can be calculated. These K-values can then be applied during the design process of your water delivery system where necessary.

Method

The experimental set up contains the following major components:



A – Water tank
B – Drainage valve
C – Isolation valve
D – Pump
E – Flow meter
F – Device under test (DUT) (This workshop: Ball valve)
G – 0 – 400 mbar differential pressure gauge (across pump)
H – 0 – 250 mbar differential pressure gauge (across valve)

In the event of a spillage, leak, or emergency, close the isolation valve (C) and then disconnect any power sources.

Differential pressure gauges have two connections, normally referred to as the high side (high, or, +) and low side (low, or, –). The amount the pointer moves is the difference between the high and low sides; therefore, the pressure drop, or pressure increase, is read off directly.

<u>Part 1 – Experiment initialisation</u>

1. Ensure the drainage and isolation valves are closed (B and C).
2. Once the tank is filled with water, open the isolation valve (C).
3. Check for any leaks between the tank outlet and the pump inlet.
4. Ensure the ball valve under test (F) is in the fully open position.
5. Turn on the power supply for the pump.
6. Check for any leaks in the rest of the circuit.
7. Turn on the power supply for the flow meter.
8. Wait 2 minutes for any air in the system to be flushed out.
9. Check to make sure there are no air bubbles in the system.
    a. Look in the clear section of pump casing (are there a lot of bubbles?) and the front of the flow meter where the paddlewheel is (is there an air pocket?).
    b. If air is trapped in the system, turn off the pump power to allow any trapped air to escape; then, repower the pump.
    c. After repowering the pump, wait for another 2 minutes – or until the air bubbles have been displaced.

Part 2 – Loss measurement over ball valve

10. Using the pump speed controller, set the pump power to the maximum (8). Do not alter the power setting during the measurements.
11. Begin with the ball valve (F) in the fully open position.
12. Wait 1 minute for the flow and readings to stabilise.
13. Record the pressure drop over the valve by reading the 250 mbar differential pressure gauge (H).
14. Record the flow rate.
15. Repeat steps 12 to 15, closing the valve by 5 ° each time, to an angle of 50 °.

Part 3 – Experiment shutdown

16. Return the ball valve (F) to the fully open position.
17. Turn off power supplies.
18. Close isolation valve (C).

Results and discussion

Calculate the K-value for each set of data points and tabulate the values. The inside diameter of the piping is 21 mm, and you can take the density of water as 998 kg/m^3; a sample table is provided below.

If 0 ° is considered fully open (fraction opening of 1), and 90 ° is fully closed (fraction opening of 0), produce a plot of K-value against fraction open for the ball valve under test. You may wish to use a logarithmic y-axis for clarity. Describe the trend and suggest some reasons for the trend.

Valve position (°)	**Measured values**		**Calculated values**		
	Q (L/min)	**ΔP (mbar)**	**Fraction opening (-)**	**v (m/s)**	**K-value (-)**
0					
…					

Another parameter that is commonly specified for valves is the C_V, or flow coefficient, and is based on the fully open condition (0 °). Using equation 3 below, calculate the C_V for the valve using your measured data.

$$Q = n \cdot C_V \cdot \sqrt{\Delta P} \qquad \textbf{Equation 3}$$

Where n is a conversion factor depending on the units used; n = 1 if Q is in U.S.gal/min and ΔP is in psi, or n = 14.42 if Q is in L/min and ΔP is in bar.

How does your calculated value compare to the manufacturer's specified value of $C_V = 6.3$? If there are any discrepancies, what are some possible reasons for this?

What are the sources of error in the experiment, and how could they be rectified or accounted for?