LOSS COEFFICIENT OF AN ELBOW

PLEASE BRING A USB STICK TO THE LAB TO SAVE YOUR DATA

Objectives To calculate the loss coefficient of a 90 degree elbow

I. Background

In a fully developed flow the fluid's acceleration becomes zero which means that in a horizontal pipe system the pressure and viscous forces will be balanced. Since the friction between the fluid and the pipe due to wall shear stress opposes the flow, the pressure decreases along the flow direction in order to balance this friction force. This leads to the well-known pressure loss (or head loss) phenomenon in the pipe systems. In a pipe system the drop in pressure is written as:

$$\Delta p = \rho g h_L \qquad (1)$$

where h_L is the amount of head loss given in meters for SI units. The total head loss in a pipe system is due to major losses due to friction in pipes and minor losses due to valves, fittings, bends, elbows, tees,, area changes, etc… Therefore,

$$h_L = h_{L,major} + h_{L,minor} = \sum_i f_i \frac{L_i}{D_i}\frac{V_i^2}{2g} + \sum_j K_{L,j}\frac{V_j^2}{2g} \qquad (2)$$

where f is the Darcy friction factor which is a function of Reynolds number (based on pipe diameter) and the surface roughness of the pipe, L is the length of the pipe segment, D is te pipe diameter, V is the average velocity in the pipe and K_L is the minor loss coefficient. The average flow velocity inside the pipe is found from the volumetric flow rate Q using;

$$V = \frac{Q}{A_c} \qquad (3)$$

where Ac is the cross-sectional area of the pipe.

In this experiment the pipe system analyzed consists of three pipe segments connected using two identical elbows. The diameters of the pipe segments are same. For a specified flow rate you will measure the pressure at the inlet and the exit of this pipe system and then obtain the total head loss. Since the pipes are made of plastic we will assume that their interiors are smooth. Calculating the Reynolds number from the flow rate, you will read the Darcy friction factor from the Moody chart and then you will predict the loss coefficient of the elbow used using equation 2.

II. Equipment

Hardware:

- Centrifugal Pump
- 2 x SICK Pressure Transducer (0 – 0.25 bar)
- YF-S201b Flowmeter
- NI cDAQ-9178 Dock
  - NI 9203 Current Input Module
  - NI 9213 Thermocouple Module
- Thermocouple Wire
- PVC Pipes
  - 2 x T-Junction
  - 7 x 90º Elbow
  - Straight Pipes
  - Butterfly Valve
- Arduino UNO R3 Clone
- Jumper Wires
- 2 x Adjustable DC Power Supply Units

Software:

- LabView
- Arduino IDE

Figure 4. SICK PFT Pressure Sensor

A pressure transducer is a measuring device which converts an applied pressure into an electrical signal. Generally, a pressure transducer consists of two parts, an elastic material which deforms under the application of pressure and an electrical part which detects this deformation.

<u>How low pressure transducers work:</u>

Depending on the range of pressures to be measured the elastic material is given different shapes and sizes, such as bourdon tube, piston, diaphragm, and bellows. Most common among them is the diaphragm.

Three different types of electrical device can be attached to this elastic material to make pressure transducers. These include resistive, capacitive and inductive types.

- Resistive pressure transducers uses strain gauges, which are bonded the deformable material. Any change in the deformation causes the change in the electrical resistance of each strain gauge which can be measured by a Wheatstone bridge.
- In the capacitance type pressure transducers, change in pressure is measured change in capacitance between two capacitance plates. One plate bonded to the deformable side of the elastic material while other one is bonded to the unpressurized surface.
- In inductive pressure transducer the deformation of the elastic material is used to provide linear movement of a ferromagnetic core. This linear movement will vary the induced AC current.

<u>How Flowmeter Works:</u>

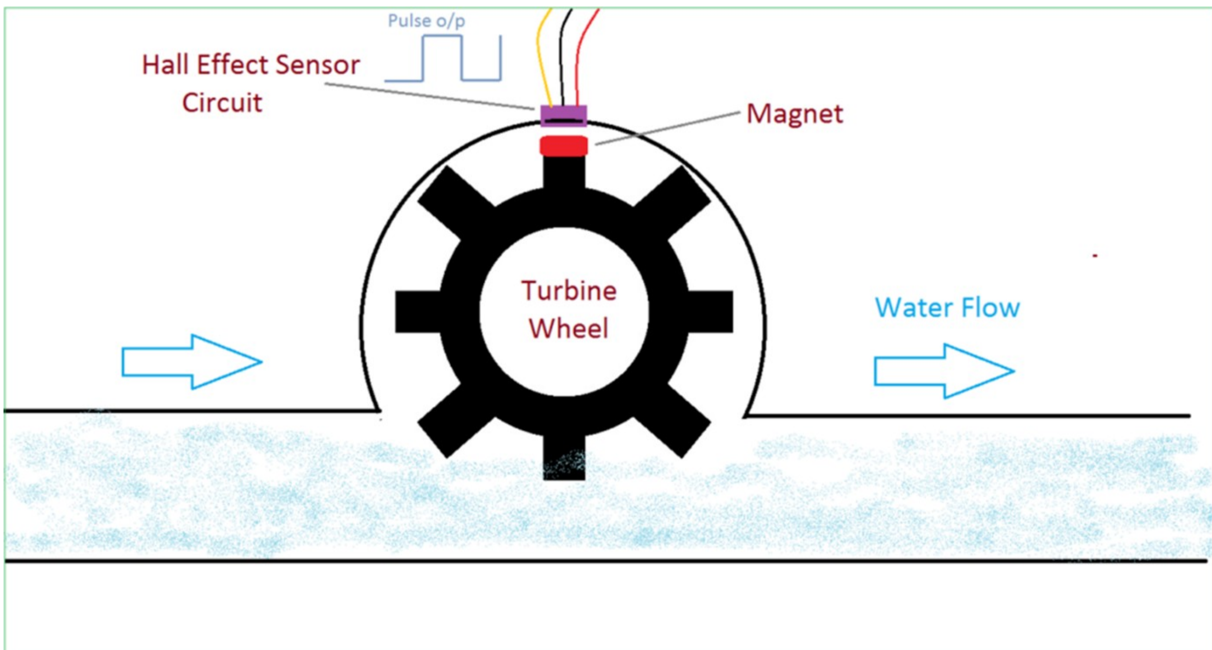

Figure 1. Working Principle of the Flowmeter

This illustration gives detailed working method of hall effect sensor based water flow sensor, a turbine wheel embed with magnet is placed on a closed plastic envelope and a Hall effect sensor placed, When the water flows through the pipeline, it makes the turbine wheel to rotate and hence the magnet flux interferes the hall sensor, the rate of interference is depends on the speed of water flow, so the hall effect sensor produce pulse signal output, this pulse output can be calculated as water volume.

Figure 2. Working Principle of the Flowmeter

This water flow sensor has only three wires and it can be easily interfaced between any microcontroller and Arduino board. It requires only +5V and gives pulse output, the sensor needs to be tightly fitted between water pipeline.

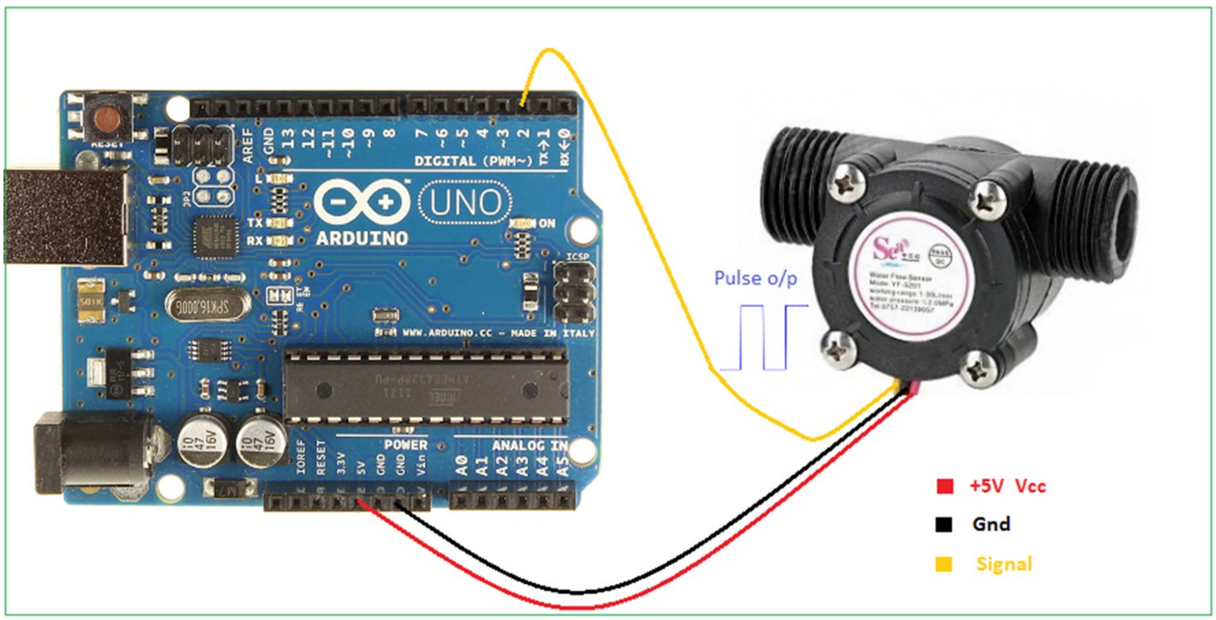

Figure 3. Flowmeter – Arduino Wire Connections

III. Experimental Procedure

Complete the wiring as seen in figure 3 (Arduino-Flowmeter connections):

- *Connect the +5V wire to Arduino power pin 5V*
- *Connect the Ground to Arduino GND pin*
- *Connect Signal pin to Digital pin D2.*

- *Connect the Arduino Uno card to the computer using a printer-cable*

Powering the Pressure Transducers:
- *Turn on the Power Supply connected to the Pressure Sensors*
- *Adjust the voltages to 20 V*

Controlling the flow rate through the voltage supply to Centrifugal Pump Motor:
- *Turn on the Power Supply connected to the Pump Motor*
- *Pick 3 different voltages limited between 5 – 20 V*

Filling the reservoir and Temperature measurement:
- *Pour 5 L of water into the reservoir*
- *Place the thermocouple wire tip inside the water in the reservoir*

Figure 4. Experimental Setup & Individual Components

Part I – Q_1 (Volumetric Flow Rate – 1)

- *Open the LabVIEW file "ME4001_Exp"*
- *Run the program and see the changes in the graphs*
- *Open the Arduino file "Flowmeter"*
    - *Click on the "Tools" tab and open the "Serial Monitor" or use the shortcut keys "CTRL + SHIFT + M"*

- *Adjust the voltage of the power supply connected to the pump motor to the first value you choose between 5 – 20 V*
- *Check the data files saved into the folder*

When you turn on the switch controlling the pump motor, you will observe a transient data flow from all the sensors. After a certain time passes, the system will reach the steady-state condition. The measurement values will be fixed for the flow rate, temperature and the pressure values with slight oscillations.

The first voltage value you picked: [ ]

Read the steady-state value of the flow rate from the monitor and note it in the box below.

Flow Rate you observed for the first voltage value: [ ]

Save your data into USB stick.

Part II – Q_2 (Volumetric Flow Rate – 2)

- *Open the LabVIEW file "ME4001_Exp"*
- *Run the program and see the changes in the graphs*
- *Open the Arduino file "Flowmeter"*
    - *Click on the "Tools" tab and open the "Serial Monitor" or use the shortcut keys "CTRL + SHIFT + M"*
- *Adjust the voltage of the power supply connected to the pump motor to the second value you choose between 5 – 20 V*
- *Check the data files saved into the folder*

When you turn on the switch controlling the pump motor, you will observe a transient data flow from all the sensors. After a certain time passes, the system will reach the steady-state condition. The measurement values will be fixed for the flow rate, temperature and the pressure values with slight oscillations.

The second voltage value you picked: [ ]

Read the steady-state value of the flow rate from the monitor and note it in the box below.

Flow Rate you observed for the second voltage value: [ ]

Part III – Q_3 (Volumetric Flow Rate – 3)

- *Open the LabVIEW file "ME4001_Exp"*
- *Run the program and see the changes in the graphs*
- *Open the Arduino file "Flowmeter"*

- *Click on the "Tools" tab and open the "Serial Monitor" or use the shortcut keys "CTRL + SHIFT + M"*
- *Adjust the voltage of the power supply connected to the pump motor to the third value you choose between 5 – 20 V*
- *Check the data files saved into the folder*

When you turn on the switch controlling the pump motor, you will observe a transient data flow from all the sensors. After a certain time passes, the system will reach the steady-state condition. The measurement values will be fixed for the flow rate, temperature and the pressure values with slight oscillations.

The third voltage value you picked: [ ]

Read the steady-state value of the flow rate from the monitor and note it in the box below.

Flow Rate you observed for the third voltage value: [ ]

Table 1. Experimental Measurements

	Voltage supplied to the Pump [V]	Steady state value of the flow rate [m^3/s]	Pressure Sensor – 1 [Pa]	Pressure Sensor – 2 [Pa]	Temperature [K]
1					
2					
3					

NOTE: For each voltage value you will repeat the readings three times. Save all nine sets of data into your USB stick.

IV. Assignments

Part I:

Using data of part I:

- Plot t versus Pressure in Excel/Matlab
- Fit a linear equation to the data set.
- Calculate the velocity (v) using the measured flow rate and pipe diameter, Reynolds Number (Re), friction factor (f) and head loss (h_L).
- Calculate the minor loss coefficient of the elbow
- Perform an uncertainty analysis for the minor loss coefficient by computing the mean, standard deviation and standard error of the mean.

Part II:

Using data of part II:

- Plot t versus Pressure in Excel/Matlab
- Fit a linear equation to the data set.
- Calculate the velocity (v) using the measured flow rate and pipe diameter, Reynolds Number (Re), friction factor (f) and head loss (h_L).
- Calculate the minor loss coefficient of the elbow
- Perform an uncertainty analysis for the minor loss coefficient by computing the mean, standard deviation and standard error of the mean.

Part III:

Using data of part III:

- Plot t versus Pressure in Excel/Matlab
- Fit a linear equation to the data set.
- Calculate the velocity (v) using the measured flow rate and pipe diameter, Reynolds Number (Re), friction factor (f) and head loss (h_L).
- Calculate the minor loss coefficient of the elbow.
- Perform an uncertainty analysis for the minor loss coefficient by computing the mean, standard deviation and standard error of the mean.