LOSSES DUE TO PIPE FITTINGS

Aim: To determine the losses across the fittings in a pipe network

Theory:

The resistance to flow in a pipe network causes loss in the pressure head along the flow. The overall head loss across a pipe network consists of the following:

- Major losses (h_{major}), and
- Minor losses (h_{minor})

(i) Major losses

Major losses refer to the losses in pressure head of the flow due to friction effects. Such losses can be evaluated by using the *Darcy-Weisbach* equation:

$$h_{major} = f\frac{Lv^2}{2gD} \tag{1}$$

where f is the Darcy friction factor, L is the length of the pipe segment, v is the flow velocity, D is the diameter of the pipe segment, and g is acceleration due to gravity. Equation (1) is valid for any fully-developed, steady and incompressible flow.

The friction factor f can be calculated by the following empirical formula, known as the *Blasius formula*, valid for turbulent flow in smooth pipes with $Re_D < 10^5$:

$$f = 0.316(Re_D)^{-0.25} \tag{2}$$

(ii) Minor losses

In a pipe network, the presence of pipe fittings such as bends, elbows, valves, sudden expansion or contraction causes localized loss in pressure head. Such losses are termed as minor losses. Minor losses are expressed using the following equation:

$$h_{minor} = K\frac{v^2}{2g} \tag{3}$$

where K is called the *Loss Coefficient* of the pipe fitting under consideration.

Minor losses are also expressed in terms of the equivalent length of a straight pipe (L_{eq}) that would cause the same head loss as the fitting under consideration:

$$h_{minor} = K\frac{v^2}{2g} = f\frac{L_{eq}v^2}{2gD}$$

or

$$L_{eq} = K\frac{D}{f} \tag{4}$$

In the present study, we shall determine the head losses across sudden enlargement, sudden contraction, sharp bend (90 ° elbow), smooth bend, and a straight section.

Loss of head due to sudden enlargement: This is the energy loss due to sudden enlargement. Sudden enlargement in the diameter of pipe results in the formation of eddies in the flow at the corners of the enlarged pipe (Fig.1). This results in the loss of head across the fitting.

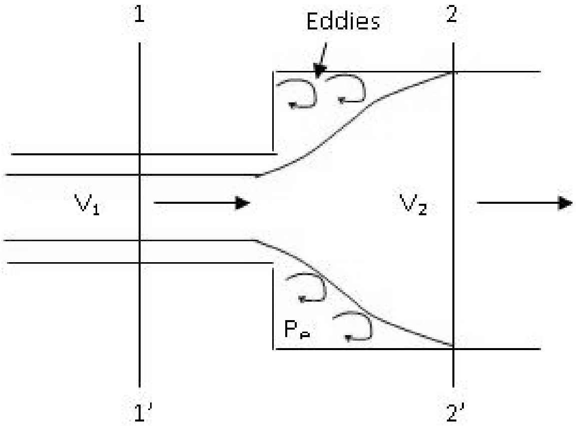

Fig. 1 Sudden Expansion

Loss of head due to sudden contraction: This is the energy loss due to sudden contraction. In reality, the head loss does not take place due to the sudden contraction but due to the sudden enlargement, which takes place just after vena-contracta (Fig. 2).

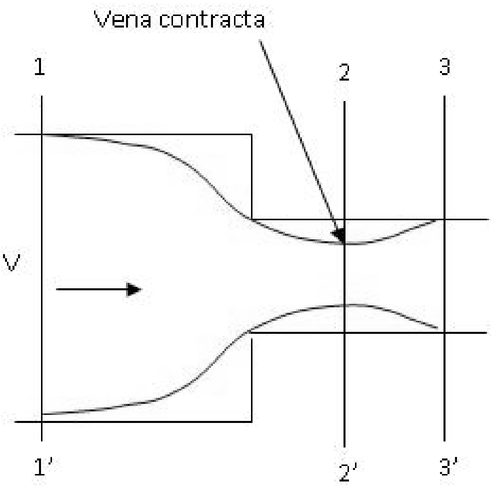

Fig. 2 Sudden Contraction

Loss of head due to bend in pipe: This is the energy loss due to bend. When a bend is provided in the pipeline, there is a change in direction of the velocity of flow (figures 3 and 4). Due to this, the flow separates from the walls of the bend and formation of eddies takes place.

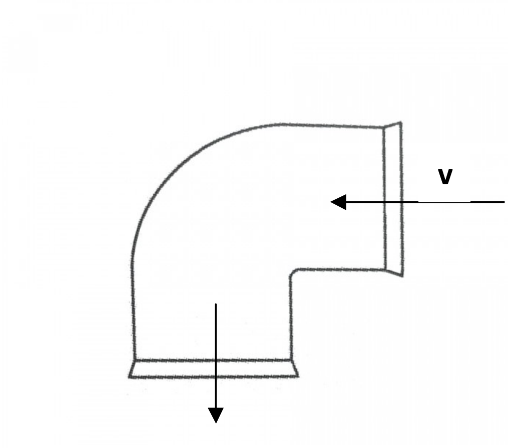

Fig. 3 Sharp Bend (90° elbow)

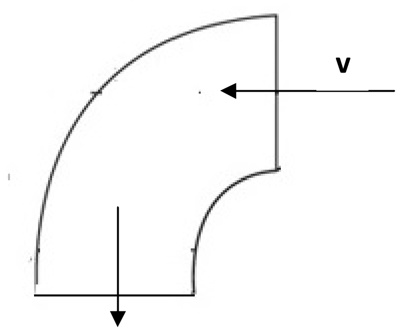

Fig. 4 Smooth Bend

Figure 5 shows the schematic layout of the pipe network to be used in the present study.

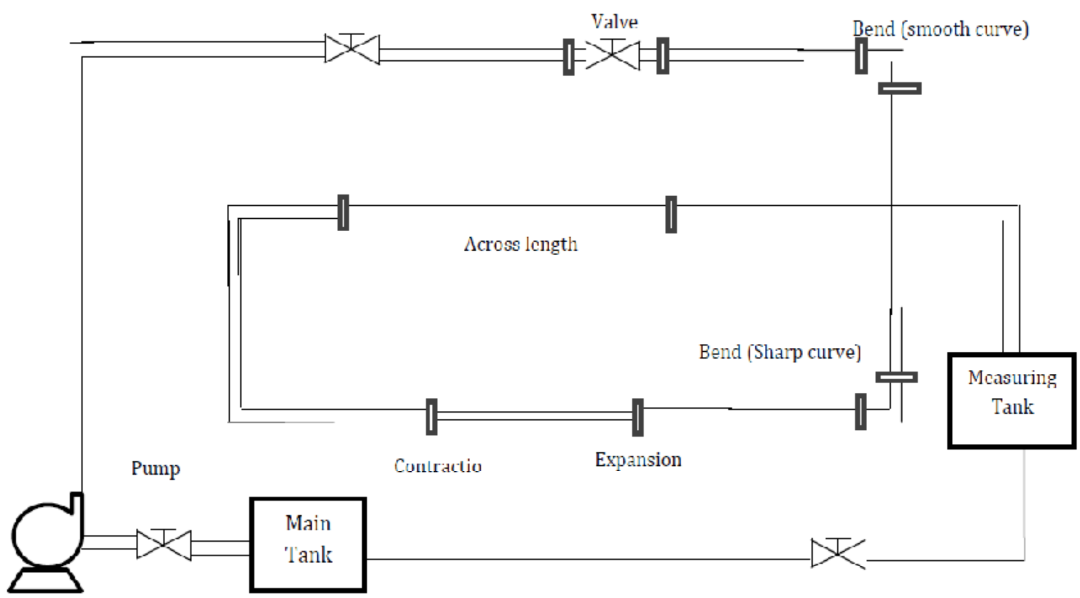

Fig. 5 Schematic layout of pipe network with fittings

Procedure:

1. Start the pump and wait until water flows through all the sections of the piping network and attains a steady state.
2. When steady state is achieved, measure the readings in the manometers across the fittings of interest.
3. With the help of a stop-watch, measure the time required to fill water in the measuring tank to a certain height and then calculate the flow rate.
4. In case of straight section, calculate the Darcy's friction factor f for a given flow rate by using equations (1) and (2) and compare the values thus obtained.

5. For each pipe fitting, find the loss coefficient K from eq. (3). Also, calculate the Darcy's friction factor f from eq. (2) and substitute in eq. (4) to obtain equivalent length for the fitting. Compare the values of K obtained from the experiment with the standard values for a given fitting.

Observations:

Diameter of the collecting tank, D_c = 0.28 m

Diameter of the larger cross-section pipe, D_1 = 14.3 mm

Diameter of the smaller cross-section pipe, D_2 = 9.22 mm

1. <u>Straight section</u>

Length of the pipe between the pressure tapping, L =

Collector tank readings				Manometer Readings			
Initial water level (cm)	Final water level (cm)	Time taken (sec)	Flow rate, Q (m^3/sec)	h_1 (cm)	h_2 (cm)	h_1-h_2 (cm)	Head loss, Δh = $12.6 \times (h_1-h_2) \times 10^{-2}$ (m)

2. <u>Sudden expansion</u>

Length of the pipe between the pressure tapping, L =

Collector tank readings				Manometer Readings			
Initial water level (cm)	Final water level (cm)	Time taken (sec)	Flow rate, Q (m^3/sec)	h_1 (cm)	h_2 (cm)	h_1-h_2 (cm)	Head loss, Δh = $12.6 \times (h_1-h_2) \times 10^{-2}$ (m)

3. Sudden contraction

Length of the pipe between the pressure tapping, L =

Collector tank readings				Manometer Readings			
Initial water level (cm)	Final water level (cm)	Time taken (sec)	Flow rate, Q (m^3/sec)	h_1 (cm)	h_2 (cm)	h_1-h_2 (cm)	Head loss, $\Delta h = 12.6 \times (h_1-h_2) \times 10^{-2}$ (m)

4. Sharp bend

Length of the pipe between the pressure tapping, L =

Collector tank readings				Manometer Readings			
Initial water level (cm)	Final water level (cm)	Time taken (sec)	Flow rate, Q (m^3/sec)	h_1 (cm)	h_2 (cm)	h_1-h_2 (cm)	Head loss, $\Delta h = 12.6 \times (h_1-h_2) \times 10^{-2}$ (m)

5. Smooth bend

Length of the pipe between the pressure tapping, L =

Collector tank readings				Manometer Readings			
Initial water level (cm)	Final water level (cm)	Time taken (sec)	Flow rate, Q (m^3/sec)	h_1 (cm)	h_2 (cm)	h_1-h_2 (cm)	Head loss, Δh $= 12.6 \times (h_1-h_2) \times 10^{-2}$ (m)

Results:

1. Straight section

Flow rate, Q (m^3/sec)	Head loss, Δh (m)	Flow velocity, v (m/s)	Reynolds number, Re_D	Darcy's Friction factor, *f* (Darcy-Weisbach eq.)	Darcy's Friction factor, *f* (Blasius formula)	% difference

2. <u>Sudden expansion</u>

Flow rate, Q (m^3/sec)	Head loss, Δh (m)	Flow velocity, v^* (m/s)	Loss coefficient, *K*	Reynolds number, Re_D	Darcy's Friction factor, *f* (Blasius formula)	Equivalent length, L_{eq} (m)

Average value of *K* (from the above table) = Standard value of *K* =

% Difference =

3. <u>Sudden contraction</u>

Flow rate, Q (m^3/sec)	Head loss, Δh (m)	Flow velocity, v^* (m/s)	Loss coefficient, *K*	Reynolds number, Re_D	Darcy's Friction factor, *f* (Blasius formula)	Equivalent length, L_{eq} (m)

Average value of *K* (from the above table) = Standard value of *K* =

% Difference =

* Flow velocity based on smaller pipe diameter

4. Sharp bend

Flow rate, Q (m^3/sec)	Head loss, Δh (m)	Flow velocity, v (m/s)	Loss coefficient, *K*	Reynolds number, Re_D	Darcy's Friction factor, *f* (Blasius formula)	Equivalent length, L_{eq} (m)

Average value of *K* (from the above table) = Standard value of *K* =

% Difference =

2. Smooth bend

Flow rate, Q (m^3/sec)	Head loss, Δh (m)	Flow velocity, v (m/s)	Loss coefficient, *K*	Reynolds number, Re_D	Darcy's Friction factor, *f* (Blasius formula)	Equivalent length, L_{eq} (m)

Average value of *K* (from the above table) = Standard value of *K* =

% Difference =

Further reading:

Books

- McCabe, W.L., Smith, J.C., and Harriott, P., 1993, *Unit Operations of Chemical Engineering*, McGraw-Hill Inc., Singapore, Chap. 5.
- White, F.M., 2016, *Fluid Mechanics*, McGraw-Hill Education, New York, Chap. 6.

Websites

- www.metropumps.com/ResourcesFrictionLossData.pdf
- http://nptel.ac.in/courses/101103004/module5/lec6/2.html