4.5 MAJOR AND MINOR LOSSES OF FLOW IN PIPES

Major Losses

The major losses of energy are due to friction. Which are considerable hence it is called as major losses. It is determined by Darcy- Weisbach formula and Chezy's formula. Head loss due to friction is denoted by h_f.

Darcy- Weisbach formula

$$h_f = \frac{4 f L V^2}{2 g d}$$

Where, hf – loss of head due to friction in meter of fluid

f - Coefficient of friction

Coefficient of friction is function of Reynolds's Number (Re).

If Re is less than 2000 (i.e. laminar flow) $f = \frac{16}{Re}$

If Re is greater than 4000 (i.e. turbulent flow) $f = \frac{0.0719}{Re^{1/4}}$ L- Length of pipe in m.

V- Velocity of flow in m/s.

d- Diameter of pipe in m.

Let, $V = \frac{Q}{A}$, Hence Darcy-Weisbach formula in the term of discharge Q,

$$h_f = \frac{f L Q^2}{12 d^5}$$

Chezy's formula-

$$V = C\sqrt{mi}$$

Where V – velocity of flow in m/s

C – Chezy's constant

i – Loss of head per unit length of pipe = $\frac{hf}{L}$

m – Hydraulic mean depth = (Area of flow/ Perimeter) = A / P

$m = \frac{d}{4}$ for pipe flow

Minor losses

The losses due to disturbances in flow pattern or due to change in velocity are called as minor losses. These losses may occur due to sudden change in the area of flow and the direction of flow. These losses are less as compare to major losses. The minor loss of the head (energy) includes the following cases:

1. Loss of head due to sudden enlargement

2. Loss of head due to sudden contraction

3. Loss of head at the entrance of a pipe

4. Loss of head at the exit of a pipe

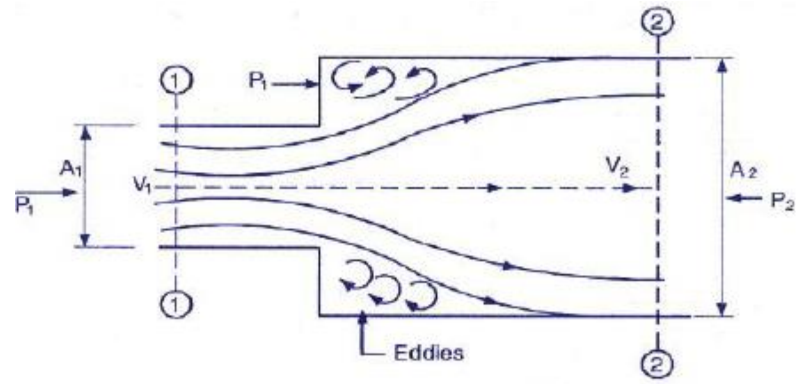
5. Loss of head due to bends

6. Loss of head in various pipe fittings

7. Loss of head due to obstruction

1. Loss of head due to sudden enlargement

Fig. represents a pipe in which fluid experiences sudden enlargement. Here the head lossoccurs due to the separation of the flow at the periphery of the smaller pipe, which leads to eddying motion in the corner region.



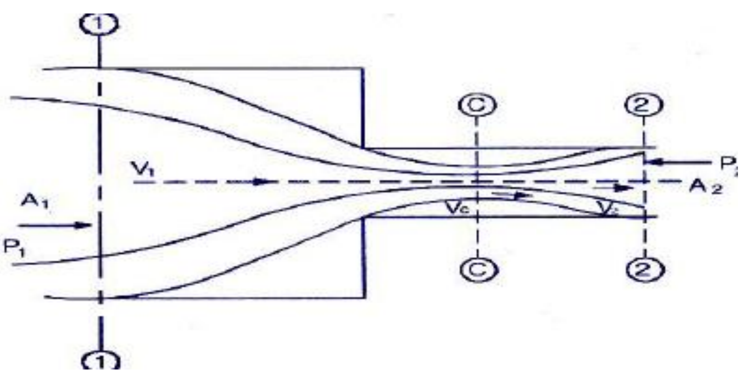
The Equation gives head loss due to sudden expansion.

$$he = \frac{(V_1 - V_2)^2}{2g}$$

Where, V1 = Velocity of fluid at section 1-1
V2 = Velocity of fluid at section 2-2

2. Loss of Head Due to Sudden Contraction

Fig. represents a pipe in which fluid experiences sudden contraction. The stream lines are converging from section 1-1 to section C-C. The head loss occurs only after the vena contracta CC. This is because the flow up to this section is accelerating and the boundary layer separation does not occur.



Using Bernoulli's equation, continuity and momentum equation at section 1-1 and 2-2, it can be proved that head loss due to sudden contraction is,

$$hc = \left(\frac{1}{c_c} - 1\right)^2 \frac{v_2^2}{2\,g}$$

Where, V2 = Velocity of fluid at section 2-2

Cc = Coefficient of contraction = Ac /A2

If Cc not given,

$$hc = 0.5\,\frac{v_2^2}{2\,g}$$

3. Loss of Head at the entrance of a pipe

The loss of head at the entrance of pipe is a similar case to loss of head due to sudden contraction as there is an abrupt reduction in area from an area of reservoir to area of a pipe. The loss of head is caused mainly by the turbulence created by the sudden enlargement of the jet after it has passed through the vena contracta.

$$h = 0.5\,\frac{v^2}{2\,g}$$

4. Loss of head at the exit of a pipe

When the fluid from the pipe enters into a relatively larger reservoir the entire velocity is dissipated. If V is the velocity of fluid in a pipe, the head loss at exit is given by

$$h = \frac{v^2}{2\,g}$$

5. Loss of head due to bends

The loss of head in bends provided in pipes may be expressed as,

$$h = k\,\frac{v^2}{2\,g}$$

V is the mean velocity of flow of liquid and K = coefficient of bend and is depends on the angle of bend, radius of the curvature and diameter of pipe.

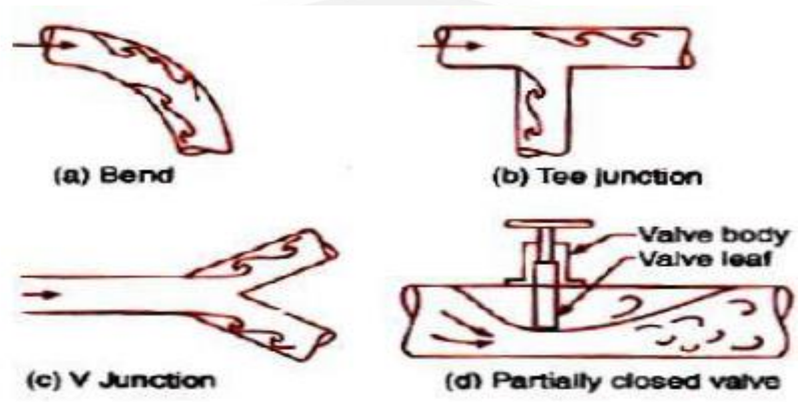
6. Loss of Head in Various Pipe Fittings

Pipe fittings in a piping system cause obstruction to flow and the loss of head occurs. The loss of head may be expressed as,

$$h = k \frac{v^2}{2g}$$

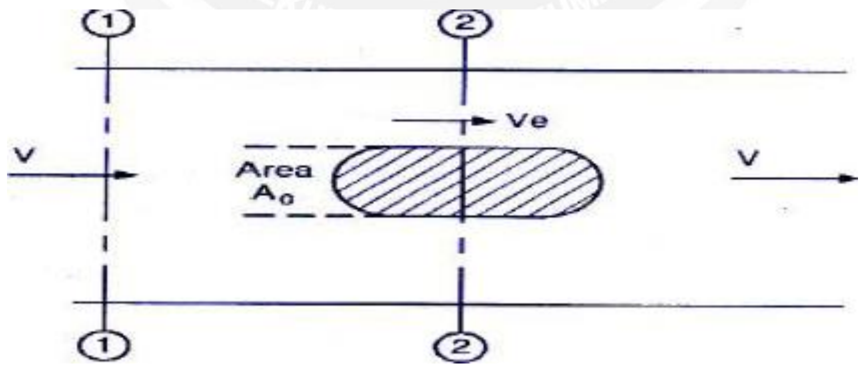
Where, K = Coefficient of pipe fitting

Various pipe fitting shown in following figure,



7. Loss of head due to obstruction

The loss of head due to obstruction in a pipe takes place due to reduction in the cross sectional area of the pipe by the presence of obstruction which is followed by an abrupt enlargement of the stream lines beyond the obstruction. (Shown in figure)



Let, V = Velocity of fluid in pipe

A0 = Maximum area of obstruction

A = Area of pipe

ho = head loss due to obstruction

$$h_o = \left[\frac{1}{Cc\,(A-Ao)} - 1\right]^2 \frac{v^2}{2g}$$

PROBLEM 1. At a sudden enlargement of a water main from 240mm to 480mm diameter, the hydraulic gradient rises by 10mm. Estimate the rate of flow.

Given: Dia. of smaller pipe D1= 240mm =0.24m

$$\text{Area } A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4}(0.24)^2$$

Dia. of larger pipe D2 = 480mm = 0.48m

$$\text{Area } A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4}(0.48)^2$$

Rise of hydraulic gradient i.e. $Z_2 + \frac{P_2}{\rho g} - Z_1 + \frac{P_1}{\rho g} = 10\text{mm} = \frac{10}{1000} m = \frac{1}{100} m$

Let the rate of flow = Q

Applying Bernoulli's equation to both sections i.e smaller and larger sections

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + \text{Head loss due to enlargement} \quad \text{———}(1)$$

But head loss due to enlargement, $h_e = \frac{(V_1 - V_2)^2}{2g}$ ———(2)

From continuity equation, we have $A_1 V_1 = A_2 V_2$ $\quad V_1 = \frac{A_2 V_2}{V_1}$

$$V_1 = \frac{\frac{\pi}{4} D_2^2 V_2}{\frac{\pi}{4} D_1^2} = \left(\frac{D_2}{D_1}\right)^2 \times V_2 = \left(\frac{0.48}{0.24}\right)^2 V_2 = 2^2 V_2 = 4V_2$$

Substituting this value in equation (2), we get

$$h_e = \frac{(4V_2 - V_2)^2}{2g} = \frac{(3V_2)^2}{2g} = \frac{9V_2^2}{2g}$$

Now substituting the value of he and V1 in equation (1)

$$\frac{P_1}{\rho g} + \frac{(4V_2)^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + \frac{9V_2^2}{2g}$$

$$\frac{16V_2^2}{2g} - \frac{V_2^2}{2g} - \frac{9V_2^2}{2g} = \frac{P_2}{\rho g} + Z_2 - \frac{P_1}{\rho g} + Z_1$$

But Hydraulic gradient rise = $\frac{P_2}{\rho g} + Z_2 - \frac{P_1}{\rho g} + Z_1 = \frac{1}{100} m$

$\frac{6V_2^2}{2g} = \frac{1}{100}$ m $\quad V_2 = \frac{2\times9.81}{6\times100} = 0.1808 = 0.181 m/sec$

Discharge $\quad Q = A_2 V_2 = \frac{\pi}{4} D_2^2 V_2$

$$= \frac{\pi}{4}(0.48)^2 \times 0.181 = 0.03275 m^3/sec$$

= 32.75Lts/sec

PROBLEM 2. A 150mm dia. pipe reduces in dia. abruptly to 100mm dia. If the pipe carries water at 30lts/sec, calculate the pressure loss across the contraction. Take co-efficient of contraction as 0.6.

Given: Dia. of larger pipe D1 = 150mm = 0.15m

Area of larger pipe $A_1 = \frac{\pi}{4}(0.15)^2 = 0.01767 m^2$

Dia. of smaller pipe D2 = 100mm = 0.10m

Area of smaller pipe $A_2 = \frac{\pi}{4}(0.10)^2 = 0.007854 m^2$

Discharge Q = 30 lts/sec = 0.03m3/sec Co-efficient of contraction CC = 0.6

From continuity equation, we have Q = A1 V1 = A2 V2

$$V_1 = \frac{Q}{A_1} = \frac{0.03}{0.01767} = 1.697\ m/sec$$

$$V_2 = \frac{Q}{A_2} = \frac{0.03}{0.007854} = 3.82\ m/sec$$

Applying Bernoulli"s equation before and after contraction

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_c \quad \text{\_\_\_\_\_\_\_\_(1)}$$

But Z1 = Z2 and hc the head loss due to contraction is given by the equation

$$hc = \left(\frac{1}{c_c} - 1\right)^2 \frac{v_2^2}{2g} = \frac{3.82^2}{2\times9.81}\left(\frac{1}{0.6} - 1\right)^2 = 0.33$$

Substituting these values in equation (1), we get

$$\frac{P_1}{\rho g} + \frac{1.697^2}{2\times9.81} = \frac{P_2}{\rho g} + \frac{3.82^2}{2\times9.81} + 0.33$$

$$\frac{P_1}{\rho g} + 0.1467 = \frac{P_2}{\rho g} + 0.7438 + 0.33$$

$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = 0.7438 + 0.33 - 0.1467 = 0.9271\ m\ of\ Water$$

$$P_1 - P_2 = \rho g \times 0.9271 = 1000 \times 9.81 \times 0.9271 = 0.909 \times 10^4\ N/m^2$$

$$= \mathbf{0.909\ N/cm^2}$$

Pressure loss across contraction = P1- P2 = 0.909N/cm^2

PROBLEM 3. Water is flowing through a horizontal pipe of diameter 200mm at a velocity of 3m/sec. A circular solid plate of diameter150mm is placed in the pipe to obstruct the flow. Find the loss of head due to obstruction in the pipe, if C_C =0.62.

Given: Diameter of pipe D = 200mm = 0.2m

Velocity V = 3m/sec

$$\text{Area of pipe } A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.2)^2 = 0.03141m^2$$

Diameter of obstruction d = 150mm =0.15m

$$\text{Area of obstruction } a = \frac{\pi}{4}(0.15)^2 = 0.01767m$$

C_C = 0.62

$$\text{The head loss due to obstruction} \quad h_o = \left[\frac{1}{Cc\ (A-Ao)} - 1\right]^2 \frac{V^2}{2g}$$

$$= \frac{9}{19.62} \quad [3.687 - 1]^2$$

$$= \mathbf{3.311m}$$