DEPARTMENT OF AGRICULTURAL ENGINEERING

COURSE CODE & NAME: 19MEB201 & FLUID MECHANICS AND MACHINERY

II YEAR / III SEMESTER

UNIT - 2

TOPIC : HEAD LOSS IN PIPE FLOW

HEAD LOSS OF FLOWING FLUID

The change in velocity of the liquid in a flow (either in magnitude or direction) induces large-scale turbulence due to formation of eddies. A portion of energy possessed by the flowing liquid is ultimately dissipated as heat and is considered to be the loss of energy.

TYPES OF ENERGY LOSSES

Major Energy Losses – due to friction

Minor Energy Losses – due to

- Sudden Enlargement of pipe
- Sudden Contraction of pipe
- The Entrance to a pipe from large vessel
- The Exit from a pipe
- An Obstruction in the flow passage
- Gradual Contraction or enlargement
- Bends and in various pipe fittings

Major energy losses

This loss is due to friction

The losses which are due to friction are calculated by

Darcy-weisbachformula (used for flow through pipes)

$$h_f = \frac{4LfV^2}{2gD}$$

Where, h_f = loss of head due to friction

f = coefficient of friction(function of Reynolds number)

$f = \frac{16}{R_e}$ for $R_e < 2000$(laminar/viscous flow)

$f = \frac{0.0791}{(R_e)^{1/4}}$ for R_e varying from 4000 to 10^6

L = length of pipe, V = mean velocity of flow

D = diameter of pipe

Chezy'sformula (used for the flow through open channel)

$$V = C\sqrt{m.i}$$

$$C = \sqrt{\frac{w}{f}}$$

$$i = \frac{h_f}{L}$$

$$m = \frac{A}{p}$$

Where,

V = mean velocity

C = Chezy's constant

m = hydraulic mean depth

i = slope

Problem:5

Ina a pipe of diameter 350 mm and length 75 m water is flowing at a velocity of 2.8 m/s. find the head lost due friction using,

i) Darcy-Weisbach formula
ii) Chezy's formula for which $C = 55$.

Assume kinematic viscosity of water as 0.012 stoke.

Solution:

Diameter of the pipe, $D = 350\ mm = 0.35\ m$

Length of the pipe, $L = 75\ m$

Velocity of flow, $V = 2.8\ m/s$

Chezy's constant $C = 55$

kinematic viscosity of water $\nu = 0.012\ stoke = 0.012 \times 10^{-4}\ m^2/s$

head lost due to friction, h_f

Darcy-Weisbach formula:

$$h_f = \frac{4fLV^2}{D \times 2g}$$

$$f = \frac{0.0791}{(Re)^{1/4}}$$

$$Re = \frac{V \times D}{\nu} = \frac{2.8 \times 0.35}{0.012 \times 10^{-4}} = 8.167 \times 10^5$$

$$f = \frac{0.0791}{(8.167 \times 10^5)^{1/4}} = 0.00263$$

Head lost due to friction,

$$h_f = \frac{4 \times 0.00263 \times 75 \times 2.8^2}{0.35 \times 2 \times 9.81} = 0.9\ m$$

Chezy's formula:

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

$$C = 55, m = \frac{A}{p} = \frac{\frac{\pi}{4} \times D^2}{\pi D} = \frac{D}{4} = \frac{0.35}{4} = 0.0875\, m$$

$$2.8 = 55 \times \sqrt{0.0875 \times i}$$

$$i = 0.0296$$

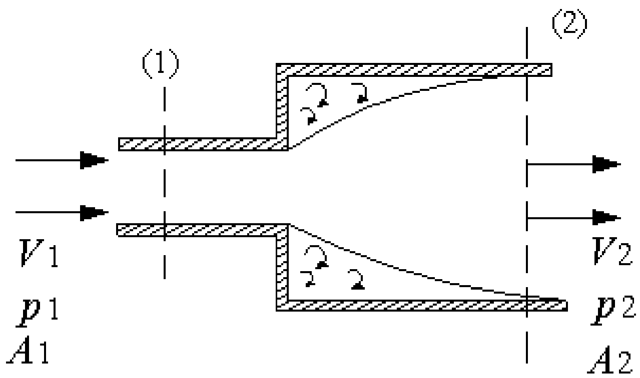
But $i = \frac{h_f}{L} = 0.0296$

$$\frac{h_f}{75} = 0.0296$$

$$h_f = 2.22\, m$$

Loss of Energy due to Sudden Enlargement

Consider a pipe of cross-sectional area A_1 and carrying a liquid of specific weight γ. It is connected to another pipe of larger cross-sectional area A_2(A_2>A_1).



For a horizontal pipe, $z_1=z_2$, so that

$$h_L = \left(\frac{p_1}{\gamma} - \frac{p_2}{\gamma}\right) + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$$

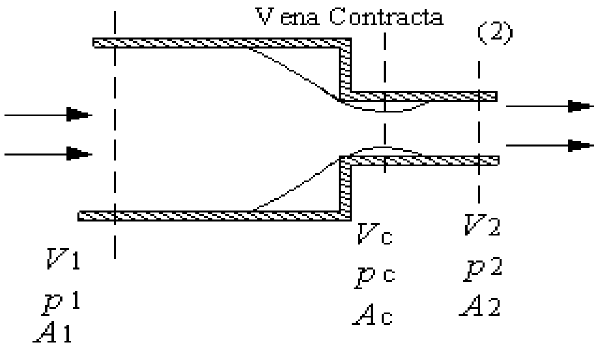
$$h_L = \frac{(V_1 - V_2)^2}{2g}$$

$$h_L = \frac{V_1^2}{2g}\left(1 - \frac{A_1}{A_2}\right)^2$$

$$= \frac{V_2^2}{2g}\left(\frac{A_2}{A_1} - 1\right)^2$$

Loss of Energy due to Sudden Contraction :

A pipe carrying certain liquid of specific weight γ whose cross-sectional area at a certain section reduces abruptly from A_1 to A_2



$$h_L = \frac{V_2^2}{2g}\left(\frac{A_2}{A_c} - 1\right)^2 = \frac{V_2^2}{2g}\left(\frac{1}{C_c} - 1\right)^2 = k.\frac{V_2^2}{2g}$$

Where k is coefficient of contraction, $k = 0.5$

Loss of Energy at the Entrance and Exit to a Pipe :

Energy loss at the entrance to the pipe is also called as 'inlet loss'. It occurs, when the liquid enters to the pipe from a large vessel (or tank). The loss of head at the entrance $h_L = 0.5\frac{V_2^2}{2g}$

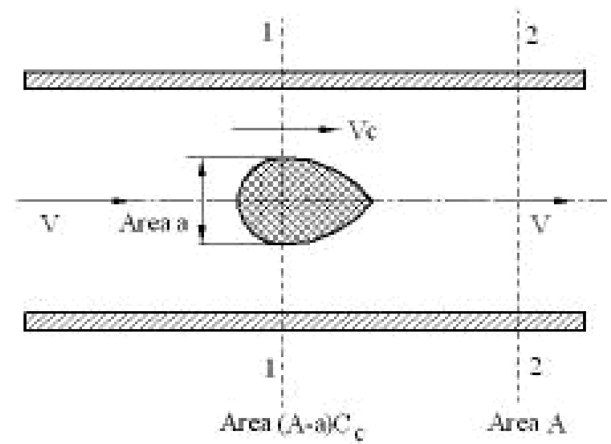
where V is the mean velocity of flow of liquid in the pipe.

The loss of head at the Exit $h_L = 0.5\frac{V_2^2}{2g}$

Loss of Energy due to Obstruction in Flow Passage

The loss of energy due to flow obstruction in a pipe occurs due to the sudden reduction in the cross-sectional area followed by an abrupt enlargement of the stream beyond the obstruction.

$$h_L = \frac{V^2}{2g}\left(\frac{A}{C_c[A-a]} - 1\right)^2$$



Loss of Energy in Bends

Head loss, $h_L = k\frac{V^2}{2g}$

k depends on the total angle of bend, radius of curvature of the pipe axis and pipe diameter.

Loss of Energy in Various Pipe Fittings

$$\text{Head loss, } h_L = k\frac{V^2}{2g}$$

value of k depends on the type of pipe-fittings.

Problem:6

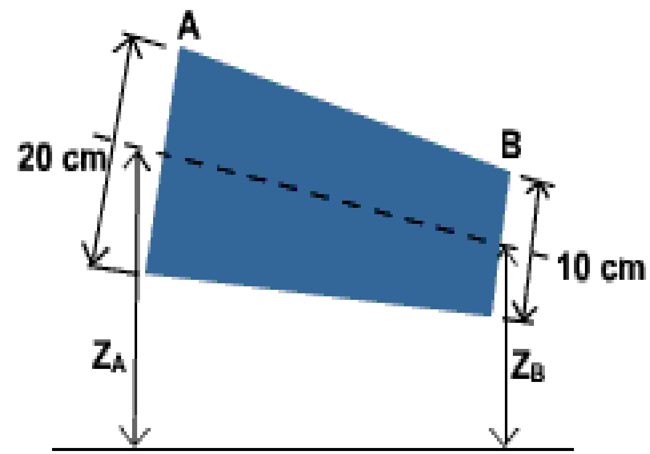
A pipe having diameters 20cm and 10cm at two sections A and B, carries water that flows at a rate 40L/s. Section A is 5m above datum and section 'B' is 2m above datum. If the pressure at section A is 4 bar, find the pressure at section 2.

Solution:

Diameters, $D_A = 20\ cm = 0.2\ m,\ D_B = 10\ cm = 0.1\ m$

$$P_A = 4\ bar = 4 \times 10^5\ N/m^2,\ Z_A = 5m, Z_B = 2m$$

$$Q = 30\ \ lits/s = 0.04\ \ m^3/s$$



By continuity equation,

$$V_A = \frac{Q}{A_A} = \frac{0.04}{\pi/_4\,(0.2)^2} = 1.27\ \ m/s$$

$$V_B = \frac{Q}{A_B} = \frac{0.04}{\pi/_4(0.1)^2} = 5.093\ \ m/s$$

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2} + Z_B$$

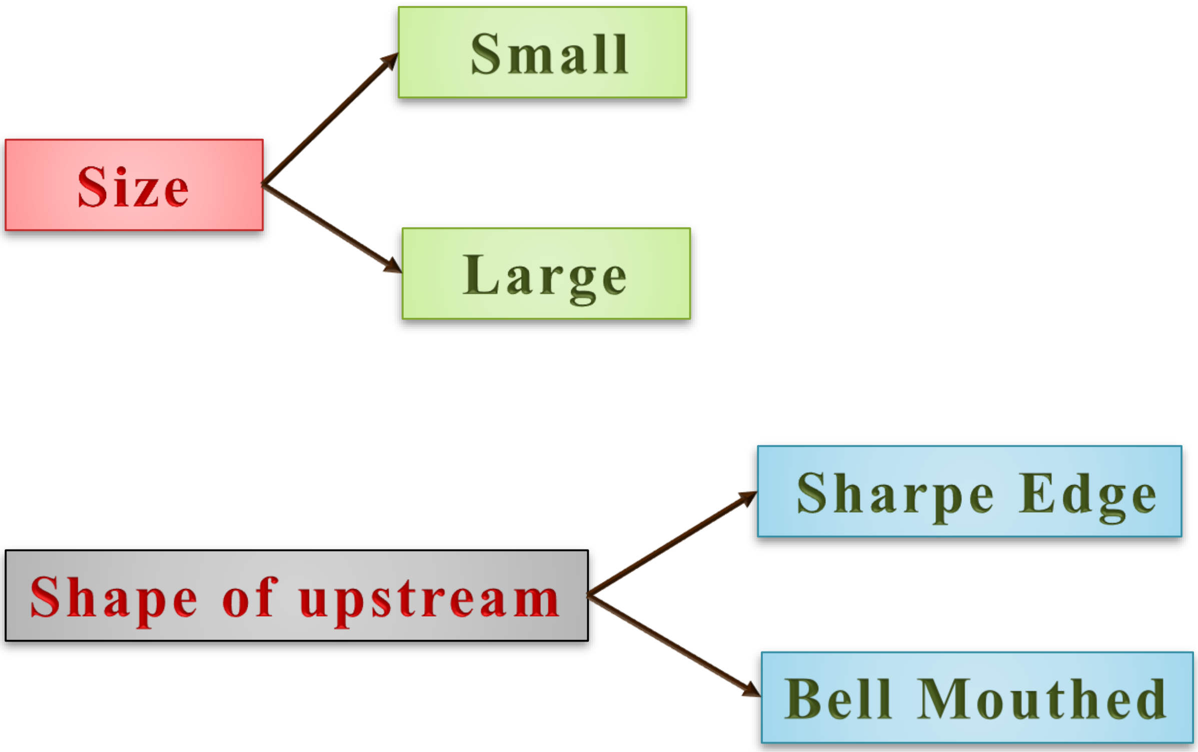
$$\Rightarrow \frac{4 \times 10^5}{1000 \times 9.81} + \frac{1.27^2}{2} + 5 = \frac{P_B}{1000 \times 9{,}81} + \frac{5.093^2}{2} + 2$$

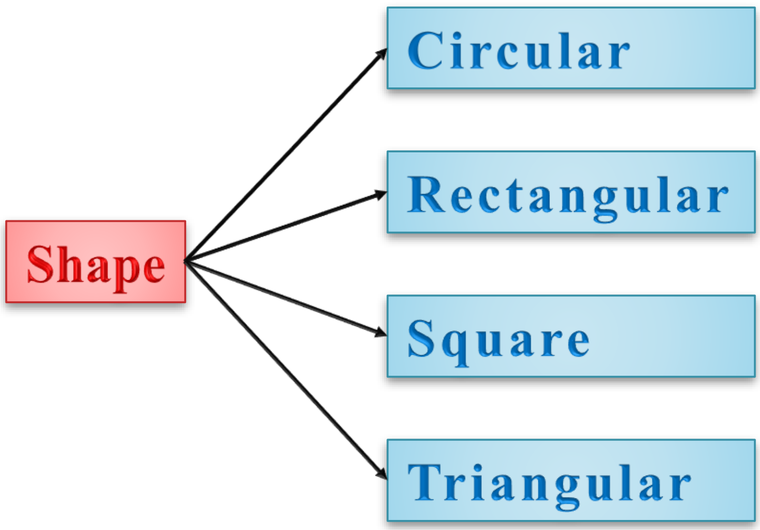
$$\mathbf{P_B = 3.1\ bar}$$

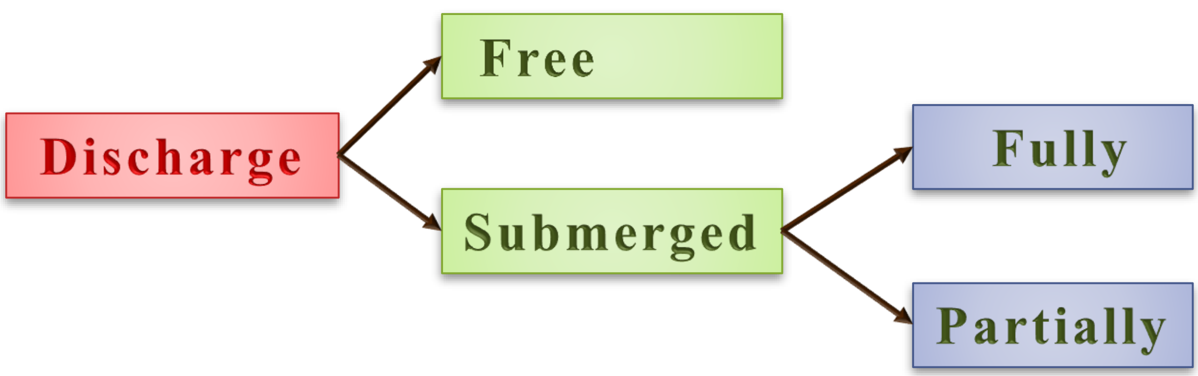
FLOW THROUGH ORIFICE

An orifice is an opening in the wall or base of vessel through which the fluid flows. The top edge of the orifice is always below the free surface. Orifice is used to measure the discharge.

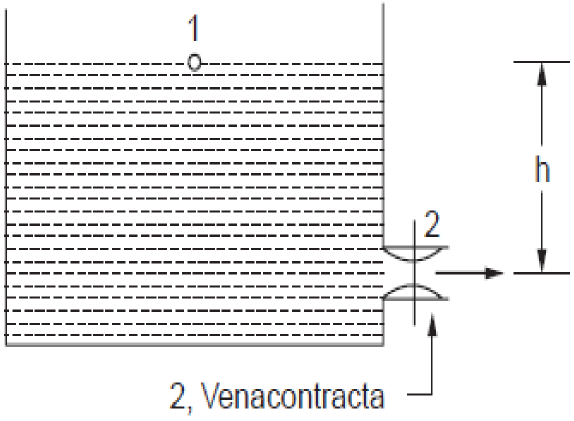
Classification of orifice:




Shape
Circular
Rectangular
Square
Triangular


Discharge
Free
Submerged
Fully
Partially

Flow through an Orifice discharging free:



A small circular orifice with Sharpe edge in the side wall of tank discharge free into atmosphere.

Coefficient of contraction (C_c)

$$C_c = \frac{Area\ \ of\ the\ jet\ at\ venacontracta}{Area\ of\ orifice} = \frac{a_c}{a}$$

$C_c = 0.61\ to\ 0.69$, depending on the shape and size of the orifice.

Co efficient of velocity(C_v)

$$C_v = \frac{Actual\ velocity\ of\ jet\ at\ venacontracta}{Theoritical\ velocity} = \frac{V}{\sqrt{2gh}}$$

$C_v = 0.95\ to\ 0.99$different orifices depending on their shape

Coefficient of discharge (C_d)

$$C_d = \frac{Actual\ discharge}{Theoretical\ discharge}$$

$$= \frac{Actual\ area}{Theoretical\ area} \times \frac{Actual\ velocity}{Theoretical\ \ velocity} = C_c \times C_v$$

Average value of C_d for orifices is 0.62 to 0.65 depends on size and shape of the orifice.

Coefficient of resistance (C_r)

It is define as the ratio loss of head in the orifice to the head of water available at the exit of the orifice

$$C_r = \frac{\text{Loss of head in the orifice}}{\text{The head of water}}$$

Problem:8

The actual velocity of a liquid issuing through a 7 cm diameter orifice fitted in an open tank is 6 m/s under a head of 3 m. If the discharge measured in a collecting tank is 0.020 m^3/s, calculate the coefficient of velocity, coefficient of contraction and the theoretical discharge through the orifice.

Flow velocity in orifice $= V = C_v\sqrt{2gh}, 6 = C_c\sqrt{2 \times 9.81 \times 3}$

Coefficient of velocity, $C_v = 0.9124$

Actual discharge, $Q = C_d\sqrt{2gh}$

$$0.02 = C_d \frac{\pi}{4} \times \left(\frac{7}{100}\right)^2 \times \sqrt{2 \times 9.82 \times 3}$$

Coefficient of discharge, $C_d = 0.6774$

Coefficient of contraction, $= C_c = \frac{C_d}{C_v} = \frac{0.6774}{0.9124} = 0.7424$

Discharge through large rectangular orifice:

The head of liquid is less than five times the height of the orifice.

Discharge through large orifice $Q = \frac{2}{3} C_d b \sqrt{2g} \left(H_2^{3/2} - H_1^{3/2} \right)$

Discharge through small orifice $Q = a \times C_d \sqrt{2gh}$

Discharge through fully submerged orifice:

An orifice has its whole of the outlet side submerged under a liquid it discharges a jet of liquid into the liquid of same.

Discharge through orifice $Q = C_d b (H_2 - H_1) \sqrt{2gh}$

A depth of submerged orifice(d) instead of H_1 and H_2

Discharge through orifice $Q = C_d b d \sqrt{2gh}$

Discharge through partially submerged orifice:

The outlet side of an orifice is only partially submerged under a liquid. The upper portion behaves an orifice discharging free, the lower portion behaves as submerged orifice.

Therefore total discharge can be calculated by

$$Q = \frac{2}{3} C_d b \sqrt{2g} \left(H_2^{3/2} - H_1^{3/2} \right) + C_d b (H_2 - H_1) \sqrt{2gh}$$

Problem:9

A 1 m diameter circular tank contains water upto a height of 4m.at the bottom of tank an orifice of 40 mm is provided. Find the height of water above the orifice after 1.5 minutes. Take Coefficient of discharge of the orifice, $C_d = 0.6$

Solution:

Diameter of the tank, $D = 1\ m$

$$\text{Area, } A = \frac{\pi}{2} D^2 = \frac{\pi}{2} \times 1^2 = 0.785\ m^2$$

Diameter of the orifice, $d = 40\ mm - 0.04\ m$

Area, $a = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 0.04^2 = 0.001257\ m^2$

Initial height of water, $H_1 = 4\ m$

Time, $T = 1.5\ min = 1.5 \times 60 = 90\ s$

Height of water above the orifice after 1.5 minutes;

H_2 Height of water above the orifice after 1.5 minutes,

$$T = \frac{2A\left(\sqrt{H_1} - \sqrt{H_2}\right)}{C_d \cdot a\sqrt{2g}}$$

$$90 = \frac{2 \times 0.785 \times \left(\sqrt{4} - \sqrt{H_2}\right)}{0.6 \times 0.001257 \times \sqrt{2 \times 9.81}}$$

$$H_2 = 3.269\, m$$

THANK YOU