Topic - Problems on Flow through pipes

A crude oil of kinematic viscosity 0.4 stoke is flowing through a pipe of diameter 300 mm at the rate of 300 litres per second. Find the head lost due to friction for a length of 50 m of the pipe.

Solution:

Kinematic viscosity $\nu = 0.4$ stoke

$= 0.4 \ \frac{cm^2}{sec.}$

$= 0.4 \times 10^{-4} \ m^2/s.$

Dia of pipe $d = 300 mm$

$= 0.30 m$

Discharge $Q = 300$ lit/sec.

$= 0.3 \ m^3/sec.$

Length of pipe $L = 50 m$

Velocity of flow $V = \frac{Q}{Area} = \frac{3}{\frac{\pi}{4}(0.3)^2} = 4.24 m/s$

$\therefore$ Reynolds number $Re = \frac{V \times d}{\nu} = \frac{4.24 \times 0.30}{0.4 \times 10^{-4}}$

$Re = 3.18 \times 10^4$

As. Re lies between 4000 & 10000 the value of f is given by

$$f = \frac{0.079}{(R_e)^{1/4}}$$

$$f = \frac{0.079}{(3.18 \times 10^4)^{1/4}}$$

$$\boxed{f = 0.00591}$$

head loss due to friction $h_f = \frac{4 \cdot f \cdot L \cdot V^2}{2 \cdot g \cdot d}$.

$$= \frac{4 \times 0.00591 \times 50 \times (4.24)^2}{2 \times 9.81 \times 0.3}$$

$$\boxed{h_f = 3.61\,m.}$$

water is flowing through a horizontal pipe of diameter 200mm at a velocity of 3m/s. A circular solid plate of diameter 150mm is placed in the pipe to obstruct the flow. Find the loss of head due to obstruction in the pipe if $C_c = 0.62$.

Sol:

Given: $D = 200\ mm = 0.20\ m$

velocity $= 3.0\ m/s$

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

$= 0.03141\ m^2$.

Dia. of obstruction $d = 150mm$

$d = 0.15\ m$

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

$a = 0.01767\ m^2$

$C_c = 0.62$

The head lost due to obstruction is given by equation $= \frac{V^2}{2g}\left[\frac{A}{C_c(A-a)} - 1.0\right]^2$

$= \frac{3\times3}{2\times9.81}\left[\frac{0.03141}{0.62[0.03141 - 0.0176]} - \right]$

$= \frac{9}{2\times9.81}[3.687 - 1.0]^2$

Head loss $= 3.311\ m$.

Two pipes have length L each. One of them has a diameter D, and the other diameter d. If the pipes are arranged in series and the same quantity Q flows through them, the loss of head is H. If $d = \frac{D}{2}$, find the ratio of H to h, neglecting secondary losses and assuming the pipe co-efficient f has a constant value.

Solution:

Length of pipe 1 $L_1 = L$ and its dia $d_1 = D$.

Length of pipe 2 $L_2 = L$ and its dia $d_2 = d$

Total discharge $= Q$

Head loss when pipes are arranged in parallel $= h$

Head loss when pipes are arranged in series $= H$

$d = \frac{D}{2}$ and f is constant

I[st] case: When pipes are connected to parallel

$$Q = Q_1 + Q_2$$

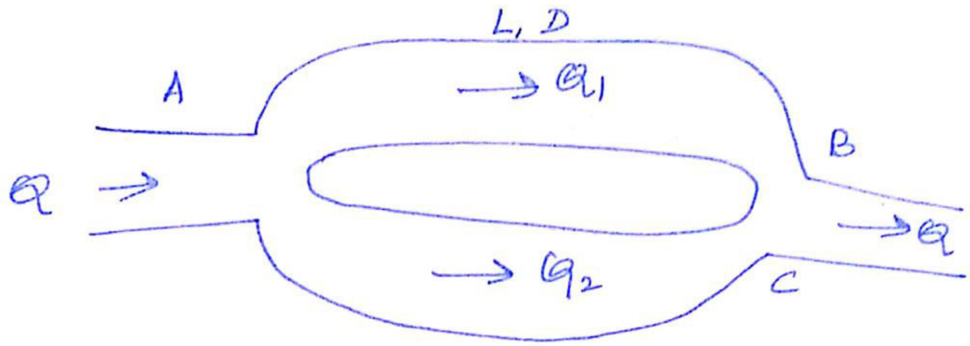
Loss of head in each pipe $= h$

For pipe AB, $\frac{4 f L_1 V_1^2}{2 g d_1}$ where $V_1 = \frac{Q_1}{A_1}$

$d_1 = D$

$$= \frac{Q_1}{\frac{\pi}{4} D^2}$$

$$= \frac{4 Q_1}{\pi D^2}$$



$$\therefore \quad \frac{4fL\left(\frac{4Q_1}{\pi D^2}\right)^2}{2g \cdot D} = h$$

(or)

$$\frac{32\, f L Q_1^2}{\pi^2 D^5 g} = h$$

For pipe $\underline{AC}$ $\frac{32\, f L Q_2^2}{\pi^2 d^5 g} = h$

$$\frac{32\, f L Q_1^2}{\pi^2 D^5 g} = \frac{32\, f L Q_2^2}{\pi^2 d^5 g}$$

$$\frac{Q_1^5}{D^5} = \frac{Q_2^2}{d^5}$$

$$\left(\frac{Q_1}{Q_2}\right)^2 = \frac{D^5}{d^5} \qquad [\because D = 2d]$$

$$= \frac{(2 \times d)^5}{d^5}$$

$$= 2^5 = 32$$

$$\frac{Q_1}{Q_2} = \sqrt{32} = 5.657 \quad \boxed{Q_1 = 5.657\, Q_2}$$

Substitute the values of Q_1 in equation (above)

$$Q = Q_1 + Q_2$$

$$Q = 5.657\,Q_2 + Q_2$$

$$Q = 6.657\,Q_2$$

$$Q_2 = \frac{Q}{6.657}$$

$$Q_2 = 0.15\,Q$$

$$Q_1 = Q - Q_2$$

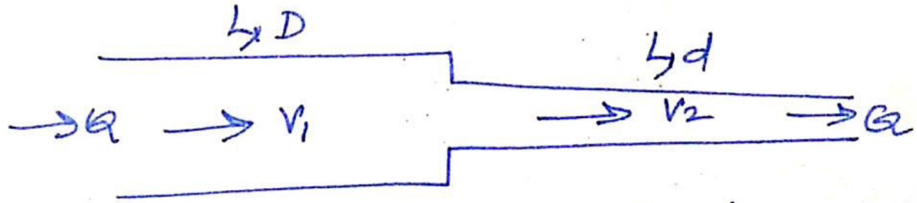
$$= Q - 0.15Q$$

$$Q_1 = 0.85\,Q$$

Case (ii) when pipes are connected in series

Total loss = Sum of head losses in the two pipes

$$H = \frac{4fLV_1^2}{2gd_1} + \frac{4fLV_2^2}{2gd_2}$$



where $V_1 = \frac{Q}{\frac{\pi}{4}D^2} = \frac{4Q}{\pi D^2}$

$$Q = AV_1 = \frac{\pi}{4}D^2 \times V_1$$

$$V_1 = \frac{4Q}{\pi D^2}$$

Ily $V_2 = \frac{4Q}{\pi d^2}$

$$H = \frac{4fL\left(\frac{4Q}{\pi D^2}\right)^2}{2gD} + \frac{4fL\left(\frac{4Q}{\pi d^2}\right)^2}{2gd}$$

$$H = \underbrace{\left[\frac{32fLQ^2}{D^5\pi^2 g}\right]}_{\text{Term-I}} + \underbrace{\left[\frac{32fLQ^2}{d^5\pi^2 g}\right]}_{\text{Term-II}} \quad \text{—— (A)}$$

From equation

$$\frac{32fL}{\pi^5 D^5 g} = \frac{h}{Q_1^2} \quad \text{—— (B)}$$

and

$$\frac{32fL}{\pi^5 d^5 g} = \frac{h}{Q_2^2} \quad \text{—— (C)}$$

Sub the above Eqn in (A) we have

$$H = Q^2 \frac{h}{Q_1^2} + Q^2 \times \frac{h}{Q_2^2}$$

$$= \frac{Q^2}{Q_1^2} h + \frac{Q^2}{Q_2^2} h$$

$$= h\left[\frac{Q^2}{Q_1^2} + \frac{Q^2}{Q_2^2}\right]$$

$$\frac{H}{h} = \frac{Q^2}{Q_1^2} + \frac{Q^2}{Q_2^2}$$

but from the Previous Eqn i.e

$Q_1 = 0.85Q$ and $Q_2 = 0.15Q$

$$\frac{H}{h} = \frac{Q^2}{0.85^2 Q^2} + \frac{Q^2}{0.15^2 Q^2}$$

$$= \frac{1}{0.85^2} + \frac{1}{0.15^2}$$

$$= 1.384 + 44.444$$

$$\boxed{\frac{H}{h} = 45.828}$$