Kenny Fluid Mechanics

12.4. In the branched system shown in fig P12.4 1350 gal/min of benzene (sg = 0.87 at 140 °F is flowing in the 8 in pipe. Calculate the volume flow rate in the 6 in and the 2 in pipes. All pipes are standard schedule 40 steel pipes

given: $Q = 850 L/min = 14.17 L/s \doteq 0.01417 m^3/s$, DN 100 40 (D = 0.1043 m)

DN 50 schedule 40 (D = 0.0603 m)

Solution: step 1

upper branch 6 inch pipe

Diameter D = 6 in = 0.1524 m

Minor loss

Globe valve K = 10

swing type check valve K = 2

Elbows K = 0.9

total minor loss coefficient

K upper = 10 + 2 + 3 × 0.9 = 14.7

lower Branch (2 inch pipe, 500 ft length)

D = 2 in = 0.0508 m

L = 500 ft = 152.4 m

K = 0.9 × 2

total minor loss

K lower = 2 × 0.9 = 1.8

step 2

upper branch (6 inch pipe

$Q_1 = 0.01 m^3/s$

cross section: $A = \frac{\pi (D/2)^2}{4} = 0.0182 m^2$

velocity $v = \frac{Q_1}{A} = 0.549 m/s$

$h_{minor\ upper} = K_{upper} \frac{v^2}{2g} = 14.7 \frac{0.549^2}{2 \times 9.81} = 0.216 m$

Tower Branch: (2 inch pipe, 500 ft)

$Q_2 = 0.01 m^3/s$

Cross sectional Area $A = \frac{\pi (D/2)^2}{4} = 0.00202 m^2$

velocity $v = \frac{Q2}{A} = 4.95 m/s$

Reynold number: $Re = \frac{VD}{\nu} = \frac{4.95 \times 0.0508}{1.31 \times 10^{-6}} = 1.92 \times 10^5$

Friction factor $f = 0.02$

Head loss due to minor loss

$h$ minor lower $= K_{lower} \frac{V^2}{2g} = 1.8 \frac{4.95^2}{2 \times 9.81} = 2.23 m$

Total head loss

$h$ total lower $= hf + h$ minor lower $= 12.7 + 2.23 = 14.93 m$

Step 3: Adjust flow rate

Head loss difference

$\Delta h = h$ total lower $- h$ minor upper $= 14.93 - 0.216 = 14.7 m$

12.8 In the branched pipe system shown in fig 12.3 850 L/min of water at 10°C in a DN 100 Schedule 40 pipe at A. The flow splits into two DN Schedule 40 pipes as shown and then rejoins at B. Calculate (a) the flow rate in each of the branches and (b) the pressure difference pA - pB. Include the effect of the minor losses in the lower branch of the system. The total length of pipe in the lower branch is 60 m

Given: $Q = 850 \, L/min = 850/60$ $LK = 14.17 \, L/s = 0.01417 \, m^3/s$

$10°C$ density $\rho = 999.7 \, kg/m^3$, $\nu = 1.31 \times 10^{-6} \, m^2/s^2$

Solution = Initial Flow Assumption

$Q_1 + Q_2 = Q$

$Q_1 = 0.007 \, m^3/s$ and $Q_2 = 0.00717 \, m^3/s$

Head loss

$D = 0.0603 \, m$

$A = \pi D^2 = 0.00286 \, m^2$

$V_1 = \frac{Q_1}{A} = \frac{0.007}{0.00286} = 2.45 \, m/s$

Lower Branch:

$D = 0.0603 \, m$

$A = \frac{\pi D^2}{4} = 0.00286 \, m^2$

$V_2 = \frac{Q_2}{A} = \frac{0.00717}{0.00286} = 2.51 \, m/s$

$R_2 = \frac{V_2 D}{\nu} = \frac{2.45 \times 0.0603}{1.31 \times 10^{-6}} = 1.15 \times 10^5$

$f = 0.02$

$h_f = f \frac{L}{D} \frac{V_2^2}{2g} = 0.02 \frac{60}{0.0603} \frac{2.51^2}{2 \times 9.81} = 2.54$

minor loss due to friction

total minor loss $k = 10+4 \times 0.9 = 13.6$

$h_{minor} = k \frac{V_2^2}{2g} = 13.6 \frac{2.51^2}{2 \times 9.81} = 4.29m$

total head loss in lower branch

$h_{total} = h_f + h_{minor} = 2.54 + 4.29 = 6.83m$

Cross method
flow adjustment

Head loss in balance ; $h_{total\,lower} - h_{upper} = 6.83 - 0 = 6.83m$

upper branch $k_{upper} = 0$

lower branch $k_{lower} = 13.6$

Flow adjustment factor $\Delta Q = \frac{\Delta h}{2\Sigma\left(\frac{k}{QA}\right)}$

1. Flow rates assuming initial $Q = 0.007 m^3/s$

$Q_2 = 0.00717 m^3/s$

Head loss

$h_{lower} = 6.83m$

Flow adjustment

$\Delta Q = \frac{6.53}{2\left(\frac{13.6}{0.0003^{2}}\right)} = 1.05 \times 10^{5} = 6.69 \times 10^{-6} m^3/s$

Adjust flow rates:

$Q_1 = Q_1 + \Delta Q = 0.007 + 6.69 \times 10^{-6} = 0.00700669 m^3/s$

$Q_2 = Q_2 - \Delta Q = 0.00717 - 6.69 \times 10^{-6} = 0.00716331 m^3/s$

Flow rates each branch

upper branch $Q_1 = 0.00700669 m^3/s$

lower branch $Q_2 = 0.00716331 m^3/s$

$P_A - P_B = 67.01 kPa$

11.42: A trapezoidal channel with a bottom width of 3.0 ft and side slopes having ratio of 1:0.75 carries 0.60 $ft^3/s$ of water and is made from float finished concrete. use $n = 0.05$ ft in

Given: $b = 3.0$ ft, $z = 0.75$, $Q = 0.60\ ft^3/s$, $y = 0.05$ ft

solution: step 1 calculate cross sectional Area

$A = y(b + zy) = 0.05(3.0 + 0.75 \times 0.05) = 0.05(3.0 + 0.0375) = 0.05 \times 3.0375 = 0.151875\ ft^2$

wetted perimeter P

$P = b + 2y\sqrt{1+z^2} = 3.0 + 2 \times 0.05\sqrt{1 + 0.75^2} = 3.0 + 0.1\sqrt{1.5625}$
$= 3.0 + 0.1 \times 1.25 = 3.0 + 0.125 = 3.125$ ft

Hydraulic Radius

$R = \frac{A}{P} = \frac{0.151875}{3.125} = 0.0486$ ft

calculate slope S:

$Q = 0.60\ ft^3/s$

$n = 0.015$

manning's equation solve for S

$S = \left(\frac{Qn}{1.49AR^{2/3}}\right)^2$

$R^{2/3} = (0.0486)^{2/3} = 0.072$

$S = \left(\frac{0.60 \times 0.015}{1.49 \times 0.151875 \times 0.072}\right)^2 = 0.55$

14.36 I.T.B. design to carry 1.25 ft³/s of water at a velocity of 2.75 ft/s. Design the channel cross section for each of the shapes shown in table 14.3 which lists the most efficient sections for open channels

Given flowrate $Q = 1.25\ ft^3/s$

velocity $V = 2.75\ ft/s$

cross sectional Area

$A = \frac{Q}{V} = \frac{1.25\ ft^3/s}{2.75\ ft/s} = 0.4545\ ft^2$

channel shape

a. rectangular channel

rectangular channel section half a square $b = 2y$

Area $A = b \cdot y = 2y \cdot y = 2y^2$

set area to 0.4545 ft²

$2y^2 = 0.4545$

$y^2 = 0.22725$

$y = \sqrt{0.22725}$

$y = 0.477\ ft$

$b = 2y = 2 \times 0.477 = 0.954\ ft$

rectangular channel

Area $A = \frac{by}{2} = y^2 = 0.4545\ ft^2 = \sqrt{y^2} = \sqrt{0.4545} = 0.674\ ft$

triangular channel

Depth $y = 0.674\ ft$

$T = 2y = 2 \times 0.674 = 1.348\ ft$

trapezoidal channel $= 7b = 1.1554$ and $T = 2.309y$, $z = 0.577$, $A = 1.73y^2$

area to $= 1.73y^2$

$1.73y^2 = 0.4545$

$y^2 = \sqrt{0.2627} = 0.513\ ft$

$b = 1.155y = 1.15 \times 0.513 = 0.593\ ft$

$T = 2.309y = 2.309 \times 0.513 = 1.184\ ft$

15.4: A sharp-edged orifice is placed in a 10 in diameter pipe carrying ammonia. If the volume flow rate is 25 gal/min, calculate the deflection of a water manometer (a) if the orifice diameter is 1.0 in and (b) if the orifice diameter is 7.0 in. The ammonia has a specific gravity of 0.83 and a dynamic viscosity of $2.5\times10^{-6}$

Given $D = 10$ in, $Q = 25$ gal/min, $sg = 0.83$, $\mu = 2.5\times10^{-6}$ lb s/ft

convert flow rate:

1 gallon $= 0.133681\ ft^3$

$Q = 25\ gal/min \times 0.133681\ ft^3/gal = 3.342\ ft^3/min = \frac{3.342}{60} ft^3/s$

$= 0.0557\ ft^3/s$

Flow velocity

$A = \frac{\pi D^2}{4} = \frac{\pi (10/12)^2}{4} ft = \frac{\pi (5/6)^2}{4} ft\ 0.545\ ft^2$

Flow velocity

$V = \frac{Q}{A} = \frac{0.0557}{0.545} ft/s = 0.102\ ft/s$

orifice diameter 1.0 in

$B = d = 1.0\ in = \frac{1}{12} ft$

$B = \frac{d}{D} = \frac{1/12}{10/12} = \frac{1}{10} = 0.1$

pressure drop

$\Delta p = \frac{\rho V^2}{2}\left(\left(\frac{1}{B^2} - 1\right)\right) = \frac{51.792 \times 0.102^2}{2}\left(\left(\frac{1}{0.1^2} - 1\right)\right) = 0.2693 \times 99 = 26.66\ lb/ft^2$

manometer Deflection

$h = \frac{\Delta p}{\rho_{water} g} = \frac{26.66.6}{62.4 \times 3.2} = 0.159\ in$ inch orifice Diameter 7.0in

$d = 7.0in = \frac{7}{12}$ ft

$\beta = \frac{d}{D} = \frac{7/12}{10/12} = \frac{7}{10} = 0.7$

pressure drop $\Delta P$

$\Delta p = \frac{\rho V^2}{2}\left(\left(\frac{1}{\beta^2} - 1\right)\right) = \frac{1.292 \times 0.102^2}{2}\left(\left(\frac{1}{0.7^2} - 1\right)\right) = 0.5795\ lb/ft^2$

manometer deflection

$h = \frac{\Delta p}{\rho_{water}\, g} = \frac{0.275}{62.4 \times 32.2} = 0.00145$ ft $= 0.00168$ inch

15.9 A flow nozzle is to be installed in a 5 in Type K copper tube carrying linseed oil at 77°F. A mercury manometer is to be used to measure the pressure difference across the nozzle when the expected range of the flow rate is from 700 to 1000 gal/min. The manometer scale ranges from 0 to 8.6 of mercury. Determine an appropriate diameter of the nozzle.

Given Data

5 inch, fuel at 77°F, flowrate = 700 to 1000 gal/min

manometer mercury 0 to 8 inches of mercury

Solution:

1 gal = 0.133681 $ft^3$

Flowrate range 700 to 1000 gal/min

$Q_{min} = 700\ gal/min \times \frac{0.133681\ ft^3}{1\ gal} \times \frac{1\ min}{60\ s} = 1.558\ ft^3/s$

$Q_{max} = 1000\ gal/min \times \frac{0.133681\ ft^3}{1\ gal} \times \frac{1\ min}{60\ s} = 2.228\ ft^3/s$

2. Linseed oil

sg at 77°F is 0.93

Density: $\rho = sg \times \rho_{water} = 0.93 \times 62.416/ft^3 = 58.0 3216/ft^3$

manometer details

1 inch Hg

$\Delta p = h_{Hg} \times \rho_{Hg} \times g$

$\rho_{Hg} = 848.71\ lb/ft^3$

$g = 32.2\ ft/s$

$\Delta p_{max} = 8\ in \times \frac{1\ ft}{12\ in} \times 848.71\ lb/ft^3 \times 32.2\ ft/s^2 = 1822\ lb/ft^2 = 12.8\ psi$

pressure difference determine nozzle diameter

$\Delta p = \frac{K \rho v^2}{2} \Rightarrow v = \frac{Q}{A_{pipe}} \Rightarrow A_{pipe} = \frac{\pi D^2}{4},\ D = 5\ in = \frac{5}{12}\ ft = 0.4167\ ft$

max flow rate $Q = 2.228\ ft^3/s$

$\Delta p_{max} = \frac{58.03 \cdot 2.228^2}{2 \cdot 0.62 (\pi \frac{(0.4167)^2}{4})^2} \Rightarrow \frac{1}{\beta^4} = 1.0456 \Rightarrow \beta^4 = 0.9564,\ \beta = 0.987$

$h = 0.987 \times 0.4167 = 0.411\ ft = 4.93\ in$