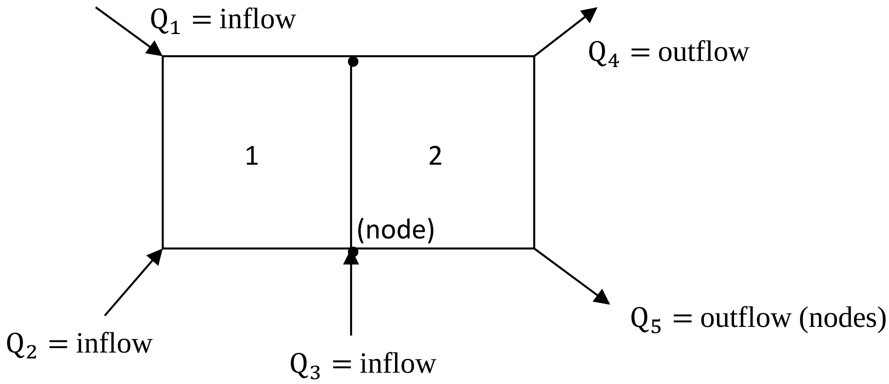
LECTURE 4: PIPELINES and PIPE NETWORKS-III

(HARDY-CROSS METHOD)

Hardy – Cross Mehtod

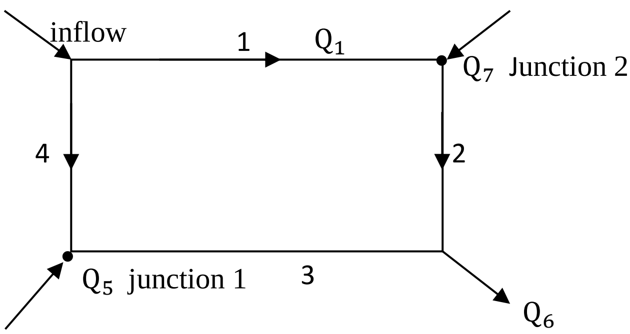
This method is applicable to closed loop systems



The outflows from the system occurs at the nodes (NODE: End of each pipe section)

Hardy – Cross Method is based on principles that

1. **At each junction the total inflow must be equal to the total outflow.**



$$\underbrace{Q_4}_{\text{Total inflow}} = \underbrace{Q_5 + Q_3}_{\text{Total outflow}} \quad \text{for junction point 1}$$

Junction 2

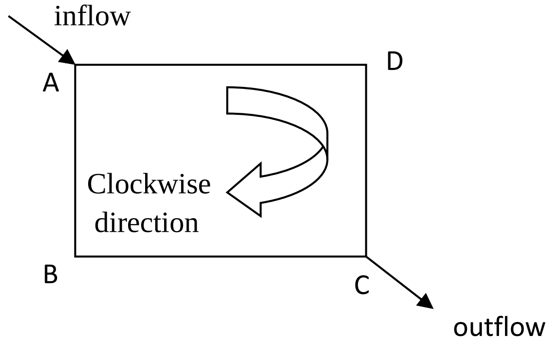
Total inflow $= Q_1 \quad +Q_7$

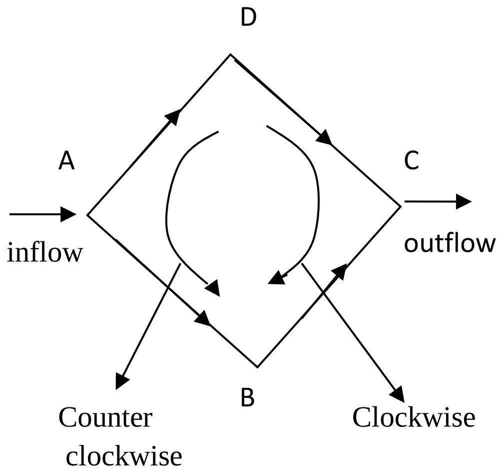
Total outflow $= Q_2$

$$Q_7 + Q_1 = Q_2$$

2. Head Loss Balance Criteria:

Algebric sum of the head losses around any closed loop is zero:





$$\sum H_{LADC} = \sum H_{LABC}$$

(Clockwise direction) (Counter clockwise direction)

For a given pipe system, with known junction outflows, Hardy – Cross Method is an iterative procedure based on initially estimated in pipes.

Estimated pipe flows are connected with iteration until head losses in clockwise direction is equal to the counterclockwise direction in each loop.

$$h_L = R.Q^2 \qquad R = \frac{f.L}{2g.D.A^2}$$

$$h_L = R.Q^{1.85} \qquad R = \left[\frac{L}{C^{1.85}.D^{4.87}} \cdot \frac{7.88}{B^{1.85}}\right]$$

B = 1.318 in BS B = 0.85 in SI

$$h_L = R.Q^2 \qquad R = \left[\frac{10.29}{B^2} \cdot \frac{L.n^2}{D^{5.33}}\right]$$

Apply Darcy Weisbach Equation

$$\sum h_f(c) = \sum h_f(cc)$$

c = clockwise

cc = counterclockwise

$$\sum h_f(c) = \sum R_c . Q_c{}^2$$

$$\sum h_f(cc) = \sum R_{cc} . Q_{cc}{}^2$$

With initially estimated flowrates, it's not expected that These head losses will be equal to each other.

$$\sum R_c . Q_c{}^2 - \sum R_{cc} . Q_{cc}{}^2 = \text{ Closure error of the first trial}$$

Flow correction, ΔQ

Assume

$$\sum h_f(c) > \sum h_f(cc)$$

To equalize head losses => substract ΔQ from Q_c

=> add ΔQ to Q_{cc}

$$\sum R_c . (Q_c - \Delta Q)^2 = \sum R_{cc} . (Q_{cc} + \Delta Q)^2$$

$$\sum R_c . (Q_c{}^2 - 2Q_c . \Delta Q - \Delta Q^2) = \sum R_{cc} . (Q_{cc}{}^2 + 2Q_{cc} . \Delta Q + \Delta Q^2)$$

$$\Delta Q = \frac{\sum R_c . Q_c{}^2 - \sum R_{cc} . Q_{cc}{}^2}{2(\sum R_c . Q_c + \sum R_{cc} . Q_{cc})}$$

$$\Delta Q = \frac{\sum h_f(c) - \sum h_f(cc)}{2\left(\frac{\sum h_f c}{Q_c} + \frac{\sum h_f cc}{Q_{cc}}\right)}$$

$$\Delta Q = \frac{\sum H_L}{2 \sum (H_L / Q)}$$

for Darcy Weisbach

$$\Delta Q = \frac{\sum H_L}{1.85 \sum (H_L/Q)} \quad \text{for Hazen Williams}$$

$$\Delta Q = \frac{\sum H_L}{2 \sum (H_L/Q)} \quad \text{for Manning's Equation}$$