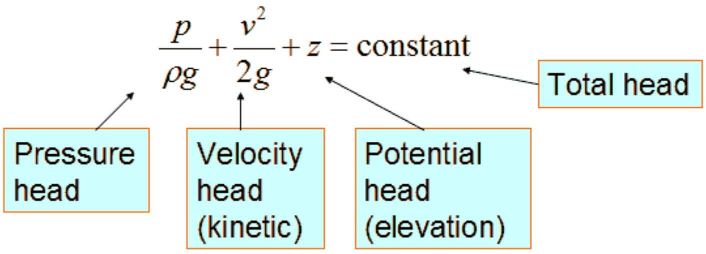
Exercise 01 – Fluid Network Analysis

(* Outline of the solution only)

1. Briefly describe the terms in the generalised Bernoulli equation and their physical meanings in fluid dynamics.

Answer:

Bernoulli equation is a useful basic tool for fluid flow analysis. It can be written in a few different forms and the most common one is shown below, with the physical meaning of each item indicated.



$$\frac{p}{\rho g}+\frac{v^2}{2g}+z=\text{constant}$$

Assume α = kinetic energy factor and heat absorbed is neglected, the generalised Bernoulli equation can be developed to determine the change in energy between two stations.

$$\left(\frac{p}{\rho g}+\alpha\frac{V^2}{2g}+z\right)_1+H_M=\left(\frac{p}{\rho g}+\alpha\frac{V^2}{2g}+z\right)_2+H_L$$

2. A fan-duct system with circular air ducts is delivering 200 litre/second of air from position 1 to position 4 as shown on the following diagram. Calculate the fan pressure required for the system by using two different methods (they shall produce the same results).

   i) Apply the Bernoulli equation to positions 1 and 4 only.

   ii) Apply the Bernoulli equation to positions 1 and 2, 3 and 4, and then 2 and 3.

Answer:

i) Apply the Bernoulli equation to positions 1 and 4 only.

- The pressure terms are the same; velocity is zero

$(p/\rho g) + 0 + 1 + H_M = (p/\rho g) + 0 + 4 + (10+80)$

Therefore, $H_M = 93$ m of air; fan pressure required = 1.2 x 9.81 x 93 = **1095 Pa**

ii) Apply the Bernoulli equation to positions 1 and 2, 3 and 4, then 2 and 3.

- Calculate the kinetic terms at fan inlet (position 2):

$A_2 = \pi (D/2)^2 = \pi (0.25/2)^2 = 0.0491 \text{ m}^2$
$V_2 = Q / A_2 = 0.2 / 0.0491 = 4.07$ m/s
For fan inlet, $V_2^2/2g = (4.07)^2 / 2 (9.8) = 0.846$ m

- Calculate the kinetic terms at fan outlet (position 3):
$A_2 = \pi (D/2)^2 = \pi (0.2/2)^2 = 0.0314 \text{ m}^2$
$V_2 = Q / A_2 = 0.2 / 0.0314 = 6.37$ m/s
For fan outlet, $V_2^2/2g = (6.37)^2 / 2 (9.8) = 2.07$ m

- Apply Bernoulli to stations 1 & 2 and 3 & 4
$(p_1/\rho g) + 0 + 1 + 0 = (p_2/\rho g) + (1.06\text{x}0.846) + 0 + 10$
$(p_3/\rho g) + (1.03\text{x}2.07) + 0 + 0 = (p_4/\rho g) + 0 + 4 + 80$

Therefore,
$(p_2/\rho g) - (p_1/\rho g) = -9.9$ m of air
$(p_3/\rho g) - (p_4/\rho g) = 81.9$ m of air

- Apply Bernoulli to stations 2 & 3 and knowing $p_1 = p_4$ = zero gauge, therefore,
$H_M = 81.9 + (1.03\text{x}2.07) - [-9.9 + (1.06\text{x}0.846)] = 84 - (-9) = 93$ m of air
- Fan pressure required = 1.2 x 9.81 x 93 = **1095 Pa**

3. To perform pipe network analysis, three basic principles of fluid mechanics are being used. Briefly describe each of them.

   What are the three sets of equations commonly used for steady flow analysis of pipe network? Suggest one numerical/mathematical method that can be used for solving the network equations for the flow analysis.

Answer:

Three basic principles of fluid mechanics being used to perform pipe network analysis:

1. Conservation of mass (continuity principle)
   - e.g. for Junction Continuity Equations

2. Work-energy principle (Darcy-Weisbach or Hazen-Williams)
   - e.g. for Energy Loop Equations

3. Fluid friction & energy dissipation

Three sets of equations commonly used for steady flow analysis of pipe network:

- *Q-equations* (pipe charges are the unknowns)
- *H-equations* (heads are the unknowns)
- *ΔQ-equations* (corrective discharges are the unknowns)

Newton method can be used to solve the network equations