7.5 Pipe flow and losses

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

KEY WORDS head loss • friction factor • minor loss

Objective

Find friction and fitting losses in laminar and turbulent pipe flow, size the pump head and power, and find where a pump and a pipe system actually run.

1 Key knowledge and worked examples

■ Losses, head and the operating point

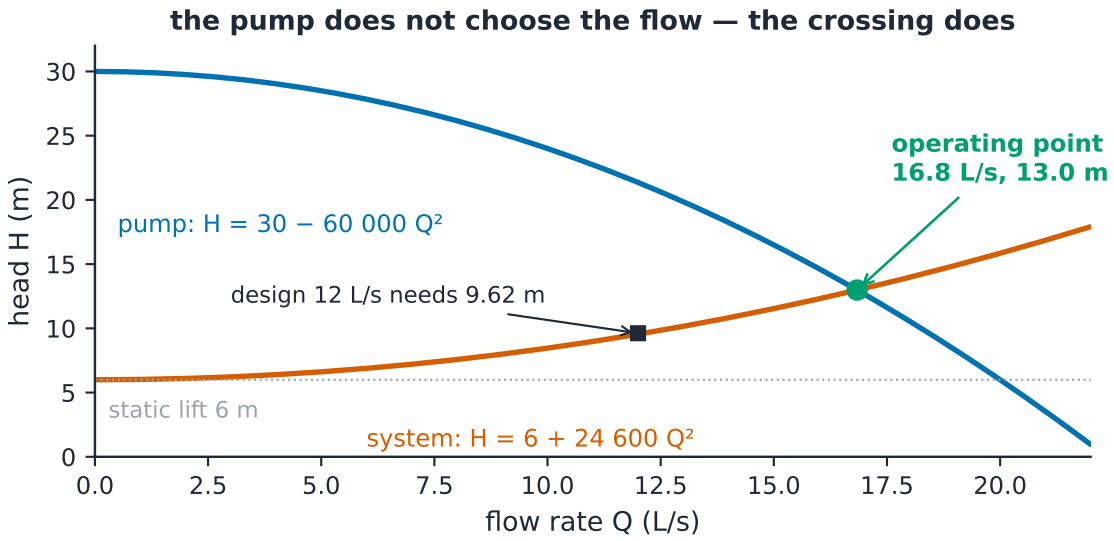
- Friction **head loss** : $h_f = f(L/D)\,V^2/2g$.
- **Friction factor** : $f = 64/Re$ laminar; Colebrook or the Moody chart turbulent.
- Fittings: **minor loss** $h_m = \sum K\,V^2/2g$.
- Pump head $H = \Delta z + h_f + h_m$; power $P = \rho g Q H/\eta$.
- The pump runs where its curve crosses the system curve.

■ Worked example. The loop and its pump

40 m of 80 mm steel, $\sum K = 2.85$, 6 m lift, design 12 L/s: $Re = 1.90\times10^5$, Colebrook $f = 0.0192$, $V^2/2g = 0.290$ m.

- $h_f = f(L/D)V^2/2g = 0.0192 \times 500 \times 0.290 = 2.79$ m.
- $h_m = \sum K\,V^2/2g = 2.85 \times 0.290 = 0.83$ m.
- $H = 6 + 2.79 + 0.83 =$ **9.62** m; the pump curve $H = 30 - 60\,000Q^2$ crosses the system curve at 16.8 L/s and 13.0 m.

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2 Practice

Water $\rho = 998$ kg/m^3; oil $\rho = 880$ kg/m^3, $\nu = 1.2 \times 10^{-4}$ m^2/s; $g = 9.81$ m/s^2.

2.1 Oil flows at 0.6 m/s in a 25 mm line 15 m long. Find Re, f, the head loss (two decimals, m of oil) and the pressure drop (one decimal, kPa). [5]

2.2 Water flows at 2.0 m/s in 60 m of 100 mm pipe with $f = 0.020$ and fittings totalling $\sum K = 3.5$. Find the friction and minor losses (two decimals, m). [4]

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2.3 The pipe of 2.2 also lifts the water 5 m. Find the flow (two decimals, L/s), the pump head (two decimals, m) and the shaft power at 75% efficiency (nearest watt). [4]

3 Exam-style questions

3.1 A pump with curve $H = 25 - 40\,000Q^2$ (H in m, Q in $\mathrm{m^3/s}$) serves a system $H = 5 + 25\,000Q^2$. Find the operating flow (one decimal, L/s) and head (one decimal, m), and the shaft power at 70% efficiency (nearest watt). If the design flow is 15.7 L/s, what must the operator do, and what does it cost? [6]

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Solutions

2.1

- $Re = VD/\nu = 0.6 \times 0.025/(1.2 \times 10^{-4}) = \mathbf{125}$: laminar, so $f = 64/Re = \mathbf{0.512}$.
- $h_f = f(L/D)V^2/2g = 0.512 \times (15/0.025) \times 0.6^2/(2 \times 9.81) = \mathbf{5.64}$ m of oil.
- $\Delta p = \rho g h_f = 880 \times 9.81 \times 5.64 = \mathbf{48.7}$ kPa.

2.2

- $V^2/2g = 2.0^2/(2 \times 9.81) = 0.204$ m.
- $h_f = f(L/D)V^2/2g = 0.020 \times 600 \times 0.204 = \mathbf{2.45}$ m.
- $h_m = \sum K\, V^2/2g = 3.5 \times 0.204 = \mathbf{0.71}$ m.

2.3

- $Q = VA = 2.0 \times \pi(0.05)^2 = \mathbf{15.71}$ L/s.
- $H = \Delta z + h_f + h_m = 5 + 2.45 + 0.71 = \mathbf{8.16}$ m.
- $P = \rho g Q H/\eta = 998 \times 9.81 \times 0.01571 \times 8.16/0.75 = \mathbf{1673}$ W.

3.1

- At the crossing: $25 - 40\,000Q^2 = 5 + 25\,000Q^2$, so $Q = \sqrt{20/65\,000} = \mathbf{17.5}$ L/s.
- $H = 25 - 40\,000 \times 0.01754^2 = \mathbf{12.7}$ m.
- $P = \rho g Q H/\eta = 998 \times 9.81 \times 0.01754 \times 12.69/0.70 = \mathbf{3114}$ W.
- The pump delivers 12% too much: throttle a valve, which burns the extra head as loss, or slow the pump with a drive, which saves the power.

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