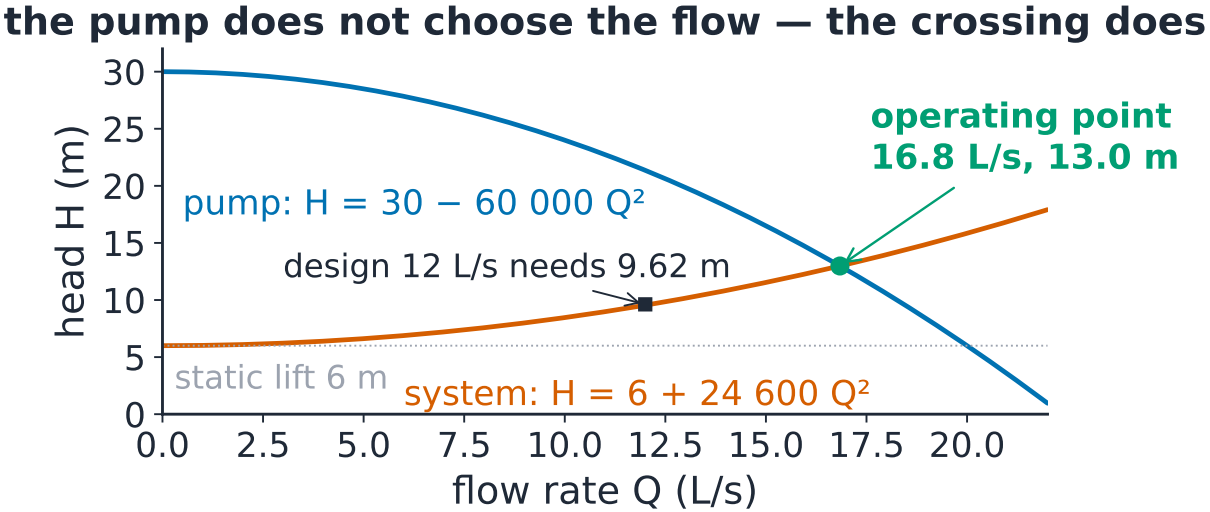
Exercise walk-through

7.5
Pipe flow and losses

University Mechanical Engineering

Pipe flow: the pump meets the system



Pump $H = 30 - 60\,000\,Q^2$ against system $H = 6 + 24\,600\,Q^2$: they cross at $\mathbf{16.8}$ L/s and $\mathbf{13.0}$ m - 40% above the 12 L/s design.

Pricing the loop's losses

1. **Laminar oil** 20 mm line, $Re = 100$: $f = 64/Re = \mathbf{0.64}$, $h_f = \mathbf{4.08}$ m over 10 m ($\Delta p = \mathbf{34.8}$ kPa).
2. **Friction** Loop at 12 L/s: $\varepsilon/D = 5.63 \times 10^{-4}$, Colebrook $f = \mathbf{0.0192}$, $h_f = \mathbf{2.79}$ m.
3. **Fittings** $\sum K = 2.85$: $h_m = \mathbf{0.83}$ m; with 6 m lift the system needs $\mathbf{9.62}$ m.
4. **Power** At the operating point $\rho g Q H = \mathbf{2.14}$ kW; at 70% the shaft needs $\mathbf{3.06}$ kW, inside Course 6's 5.65 kW.

Exercises 2.1·2.2

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]

Exercises 2.1·2.2

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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 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]

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.

Exercises 2.3·3.1

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]

3.1 A pump with curve $H = 25 - 40\,000Q^2$ (H in m, Q in 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]

Exercises 2.3·3.1

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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 A pump with curve $H = 25 - 40\,000Q^2$ (H in m, Q in 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]

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.