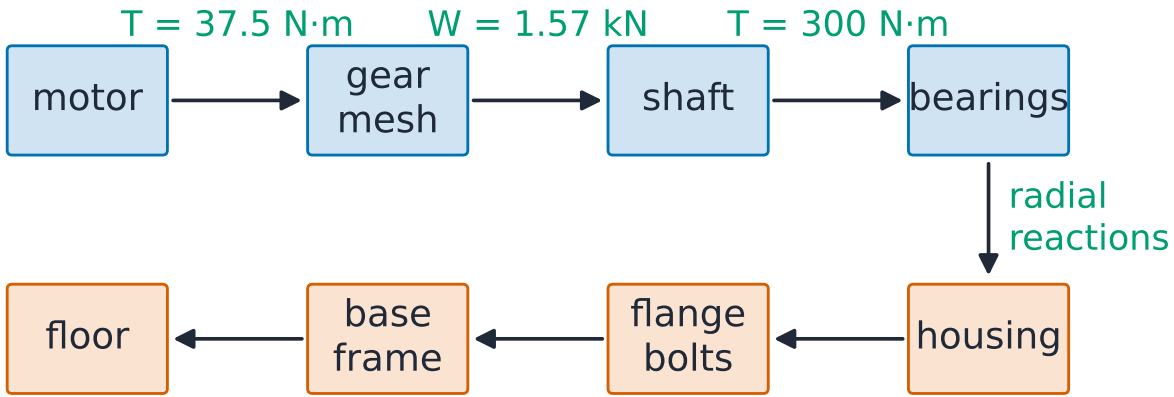
Exercise walk-through

9.2
Load paths and design safety

University Mechanical Engineering

The load path: motor to floor

every force needs a path to ground: trace it, then size each link



$T = \mathbf{37.5}$ N · m at the pinion, $W = \mathbf{1.57}$ kN at the mesh, $T = \mathbf{300}$ N · m on the output shaft - every arrow is a link to check.

Duty cycle and mesh forces

1. **Duty cycle** 60% at 2 kN, 30% at 3 kN, 10% at 5 kN.
2. **Cube mean** $P_{eq} = (0.6 \cdot 2^3 + 0.3 \cdot 3^3 + 0.1 \cdot 5^3)^{1/3} = \mathbf{2.94}$ kN, not the average 2.6 kN.
3. **Mesh** $W_t = 2T/d = 2 \times 37.5/0.051 = \mathbf{1471}$ N; $W_r = W_t \tan 20° = \mathbf{535}$ N.

Decision

Average loads underrate bearings; use the mean that matches the life law.

Exercises 2.1·2.2

2.1 A bearing sees 1.5 kN for 50% of the time, 2.5 kN for 40% and 6 kN for 10%. Find the plain average and the cube-mean equivalent load (two decimals, kN). Why is the second larger? [4]

2.2 A 4 kW motor runs at 960 rpm and drives a pinion of 60 mm pitch diameter with $\phi = 20°$. Find the torque (one decimal, N · m), and the tangential, radial and total tooth forces (nearest N). [5]

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2.1

- Plain average $= 0.5 \times 1.5 + 0.4 \times 2.5 + 0.1 \times 6 =$ **2.35** kN.
- $P_{eq} = (\sum f_i P_i^3)^{1/3} = (0.5 \times 1.5^3 + 0.4 \times 2.5^3 + 0.1 \times 6^3)^{1/3} =$ **3.09** kN.
- Damage grows with the cube of load, so the rare 6 kN peaks count far more than their share of time.

2.2 A 4 kW motor runs at 960 rpm and drives a pinion of 60 mm pitch diameter with $\phi = 20°$. Find the torque (one decimal, N · m), and the tangential, radial and total tooth forces (nearest N). [5]

2.2

- $T = P/\omega = 4000/(960 \times 2\pi/60) =$ **39.8** N · m.
- $W_t = 2T/d = 2 \times 39.79/0.060 =$ **1326** N.
- $W_r = W_t \tan\phi = 1326 \tan 20° =$ **483** N; $W = \sqrt{W_t^2 + W_r^2} = \sqrt{1326^2 + 483^2} =$ **1411** N.

Exercise 3.1

3.1 The total tooth force of 2.2 acts on a gear 60 mm from bearing A on a 180 mm span between bearings A and B. Find both bearing reactions (nearest N). If a bracket on the load path has a yield strength of 250 MPa and works at 95 MPa, find its factor of safety and say whether it is reasonable for a pump drive. [6]

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3.1

- Moments about B: $R_A \times 180 = 1411 \times 120$, so $R_A = \mathbf{941}$ N.
- $R_B = 1411 - 941 = \mathbf{470}$ N (check about A: $470 \times 180 = 1411 \times 60$).
- $n = 250/95 = \mathbf{2.63}$.
- Reasonable for steady loads on a ductile part; shock loads or fatigue would need more margin or a fatigue check.