9.2 Load paths and design safety

Name: _____ Class: _____ Date: _____ **Total: 15 marks**

KEY WORDS load path • factor of safety

Objective

Follow a load from the motor to the floor, turn a varying duty into one equivalent load, and find the tooth forces and bearing reactions on a gear shaft.

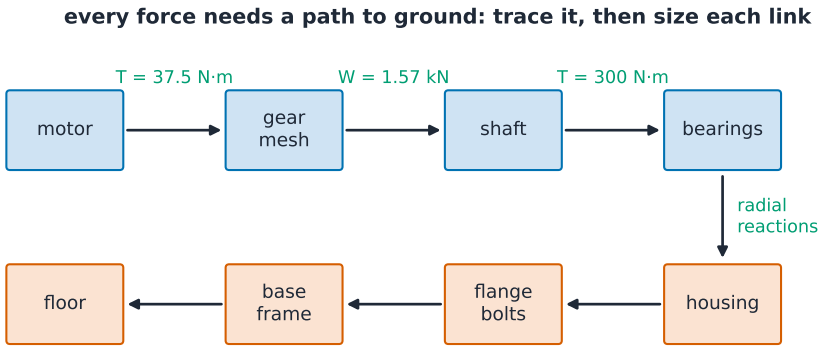
1 Key knowledge and worked examples

Trace the force, then check each part

- **Load path** : motor torque → pinion → gear → shaft → bearings → housing → floor; every link must be checked.
- **Factor of safety** n = strength / stress.
- A varying load on a ball bearing becomes the cube mean $P_{eq} = (\sum f_i P_i^3)^{1/3}$, since life $\propto 1/P^3$.
- Gear forces: $W_t = 2T/d$, $W_r = W_t \tan\phi$, $W = \sqrt{W_t^2 + W_r^2}$.

Worked example. The duty cycle and the pinion force

- Duty 2 kN for 60%, 3 kN for 30%, 5 kN for 10%: $P_{eq} = (0.6\times 2^3 + 0.3\times 3^3 + 0.1\times 5^3)^{1/3} = \mathbf{2.94}$ kN, above the 2.6 kN plain average.
- Pinion torque $T = 37.5$ N · m on $d = 51$ mm: $W_t = 2T/d = 2\times 37.5/0.051 = \mathbf{1471}$ N; $W_r = W_t \tan 20° = \mathbf{535}$ N.



2 Practice

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]

3 Exam-style questions

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]

Solutions

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

- $T = P/\omega = 4000/(960 \times 2\pi/60) =$ **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.

3.1

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