9.5 Joints and gears

Name: _____ Class: _____ Date: _____ **Total: 14 marks**

KEY WORDS bolted joint • preload • spur gear • module • Lewis form factor

Objective

Preload a bolted joint and find the bolt's share of an external load, its load factor and the separation load; then check spur-gear teeth in bending with the Lewis equation.

1 Key knowledge and worked examples

■ Bolts and gear teeth

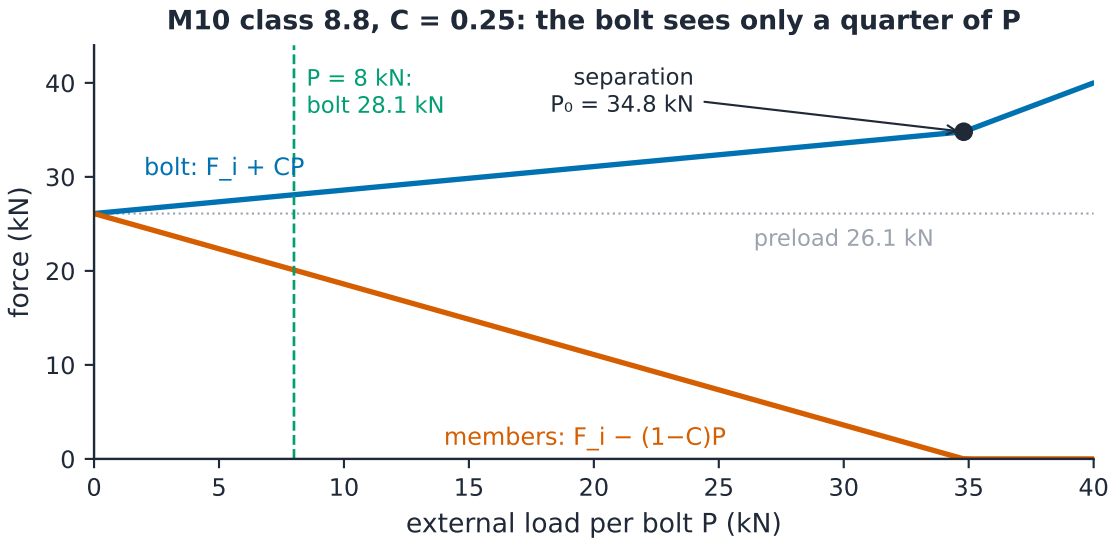
- **Bolted joint** : **preload** $F_i = 0.75 A_t S_p$; the bolt takes a share C of the external load: $F_b = F_i + CP$.
- Load factor $n = (S_p A_t - F_i)/(CP)$; the joint separates at $P_0 = F_i/(1 - C)$.
- **Spur gear** : $d = mN$ with **module** m; pitch-line speed $V = \pi dn/60$; $K_v = (6.1 + V)/6.1$ for cut teeth.
- Lewis bending: $\sigma = K_v W_t/(FmY)$, with the **Lewis form factor** Y.

■ Worked example. The flange bolts

M10 class 8.8: $A_t = 58.0$ mm^2, $S_p = 600$ MPa; $C = 0.25$, $P = 8$ kN per bolt.

- $F_i = 0.75 A_t S_p = 0.75 \times 58.0 \times 600 = \mathbf{26.1}$ kN.
- $F_b = F_i + CP = 26.1 + 0.25 \times 8 = 28.1$ kN, stress 484 MPa.
- $n = (S_p A_t - F_i)/(CP) = \mathbf{4.35}$; separation at $P_0 = 26.1/0.75 = \mathbf{34.8}$ kN.

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2 Practice

2.1 An M12 class 8.8 bolt ($A_t = 84.3$ mm^2, $S_p = 600$ MPa) is preloaded to 75% of proof. Find the preload (one decimal, kN). [2]

2.2 The joint stiffness share is $C = 0.30$ and each bolt carries $P = 10$ kN. Find the bolt force (one decimal, kN), its stress (nearest MPa), the load factor (two decimals) and the separation load (one decimal, kN). [5]

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3 Exam-style questions

3.1 A pinion of module 2.5 mm with 20 teeth ($Y = 0.322$) and face width 25 mm carries $T = 30$ N $\cdot$ m at 1200 rpm. Find its pitch diameter, tangential force, pitch-line speed, K_v and bending stress (one decimal, MPa). With an allowable 150 MPa, find the factor of safety and one way to raise it without changing the gear ratio. [7]

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Solutions

2.1

- $F_i = 0.75 A_t S_p = 0.75 \times 84.3 \times 600 = \mathbf{37.9}$ kN.

2.2

- $F_b = F_i + CP = 37.9 + 0.30 \times 10 = \mathbf{40.9}$ kN; $\sigma_b = F_b / A_t = 40\,935 / 84.3 = \mathbf{486}$ MPa, below S_p.
- $n = (S_p A_t - F_i)/(CP) = (50.58 - 37.94)/3.0 = \mathbf{4.21}$.
- $P_0 = F_i/(1 - C) = 37.9/0.70 = \mathbf{54.2}$ kN.

3.1

- $d = mN = 2.5 \times 20 = 50$ mm; $W_t = 2T/d = 2 \times 30/0.050 = \mathbf{1200}$ N.
- $V = \pi d n/60 = \pi \times 0.050 \times 1200/60 = \mathbf{3.14}$ m/s; $K_v = (6.1 + 3.14)/6.1 = \mathbf{1.515}$.
- $\sigma = K_v W_t/(FmY) = 1.515 \times 1200/(25 \times 2.5 \times 0.322) = \mathbf{90.3}$ MPa.
- $n = 150/90.3 = \mathbf{1.66}$.
- A wider face, a larger module with fewer teeth at the same ratio, or a stronger, hardened steel.

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