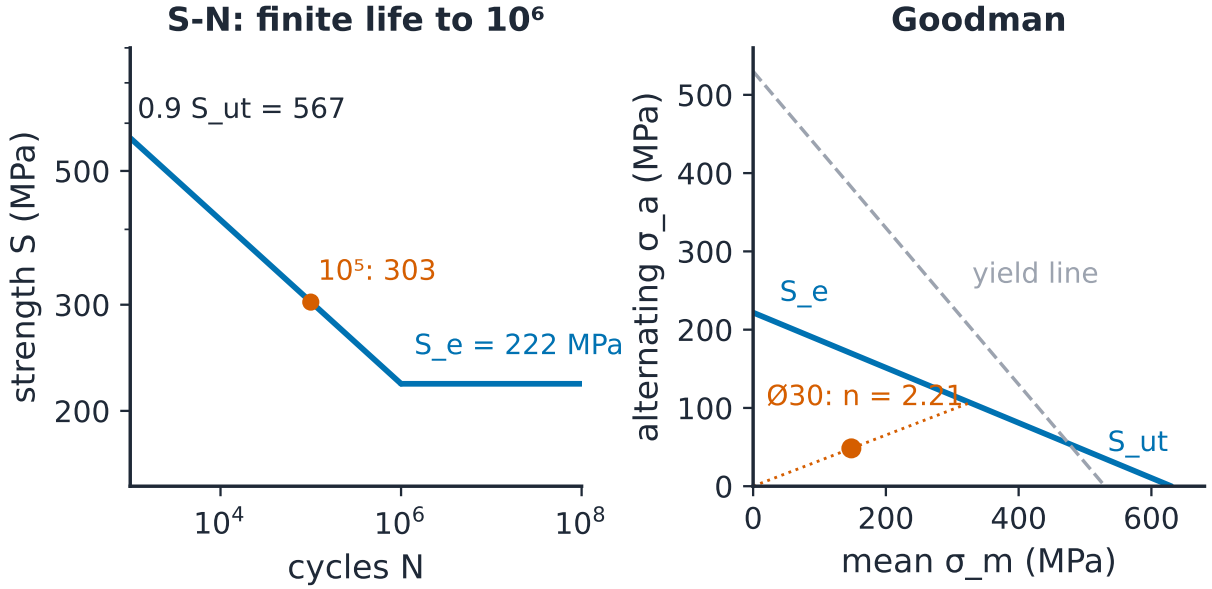
Exercise walk-through

9.3
Static and fatigue criteria

University Mechanical Engineering

S-N curve and Goodman line



C45 machined, $d = 30$: $S_e = 0.817 \times 0.862 \times 315 = \mathbf{222}$ MPa; Goodman at the shoulder gives $n = \mathbf{2.21}$.

Goodman at the shoulder

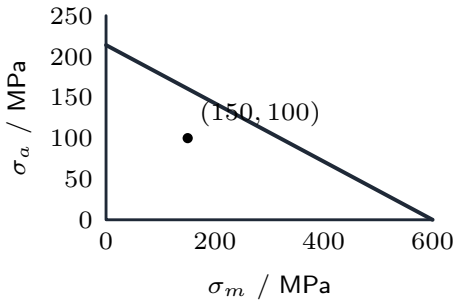
1. **Notch** $K_t = 2.0$, $q = 0.8 \rightarrow K_f = \mathbf{1.8}$; torsion $K_{fs} = \mathbf{1.51}$.
2. **Stresses** $\sigma_a = K_f \cdot 32 M_a / \pi d^3 = \mathbf{48.4}$ MPa; $\sigma_m = \sqrt{3}\, K_{fs} 16\, T_m / \pi d^3 = \mathbf{148.0}$ MPa.
3. **Goodman** $1/n = 48.4/222 + 148.0/630 \rightarrow n = \mathbf{2.21}$.
4. **Yield** $n_y = 530/\sqrt{48.4^2 + 148.0^2} = \mathbf{3.40}$ - **fatigue** governs.

Decision

Check both; the lower factor sets the design.

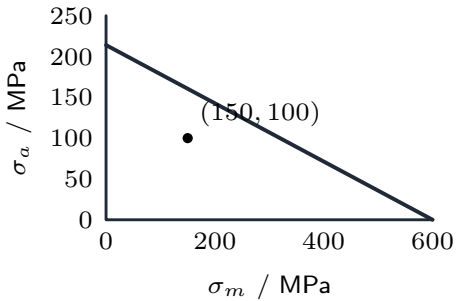
Exercise 2.1

2.1 A part has $\sigma_a = 100$ MPa and $\sigma_m = 150$ MPa, with $S_e = 214$ MPa and $S_{ut} = 600$ MPa. Find the Goodman factor of safety. [3]



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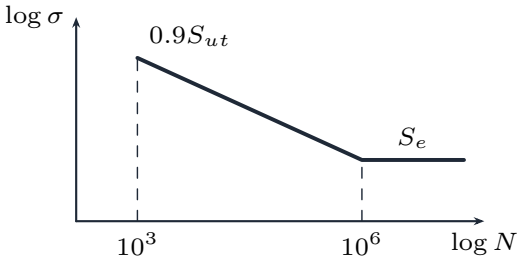


2.1

$$\frac{1}{n} = \frac{100}{214} + \frac{150}{600} = 0.467 + 0.250 = 0.717;\ n = \mathbf{1.39}$$

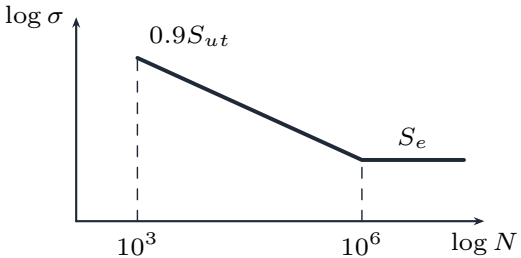
Exercise 2.2

2.2 For the steel of worked example 1, estimate the life at a fully reversed stress of 300 MPa from the S-N line. [3]



Exercise 2.2

2.2 For the steel of worked example 1, estimate the life at a fully reversed stress of 300 MPa from the S-N line. [3]



2.2

line: $\sigma = aN^b$ with $a = \dfrac{(0.9S_{ut})^2}{S_e} = 1362$ MPa, $b = -\frac{1}{3}\log\dfrac{540}{214} = -0.134$; $N = \left(\dfrac{300}{1362}\right)^{1/b} \approx \mathbf{8 \times 10^4}$ **cycles**

Exercises 2.3·2.4

2.3 Explain why K_t is used in a static check of a cast-iron part but not of a mild-steel part. [2]



2.4 Explain why a polished bar has a longer fatigue life than a rough-machined one of the same steel. [2]



Exercises 2.3·2.4

2.3 Explain why K_t is used in a static check of a cast-iron part but not of a mild-steel part. [2]



2.3

mild steel yields locally at the notch and the stress spreads out, so the peak does no harm under a steady load; cast iron cannot yield, so the peak stress starts a crack at once

2.4 Explain why a polished bar has a longer fatigue life than a rough-machined one of the same steel. [2]



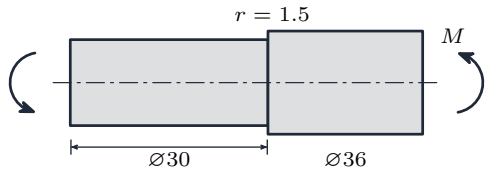
2.4

fatigue cracks start at the surface; machining marks are small notches that raise the local stress, so cracks start sooner

Exercise 3.1

3.1 A rotating steel shaft ($S_{ut} = 600$ MPa, machined) is 30 mm in diameter with a shoulder to 36 mm, fillet $r = 1.5$ mm: $K_t = 1.9$, $q = 0.85$. It carries a steady bending moment of 150 N m, so the stress is fully reversed as it turns. $S_e = 214$ MPa.

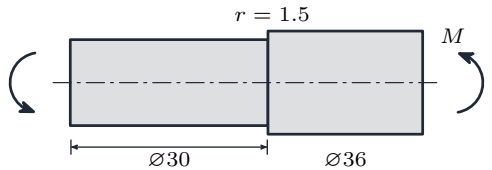
Find K_f, the nominal and the alternating stress at the fillet, the factor of safety and whether the life is infinite. [5]



Exercise 3.1

3.1 A rotating steel shaft ($S_{ut} = 600$ MPa, machined) is 30 mm in diameter with a shoulder to 36 mm, fillet $r = 1.5$ mm: $K_t = 1.9$, $q = 0.85$. It carries a steady bending moment of 150 N m, so the stress is fully reversed as it turns. $S_e = 214$ MPa.

Find K_f, the nominal and the alternating stress at the fillet, the factor of safety and whether the life is infinite. [5]



3.1

$K_f = 1 + 0.85 \times 0.9 = \mathbf{1.77}$

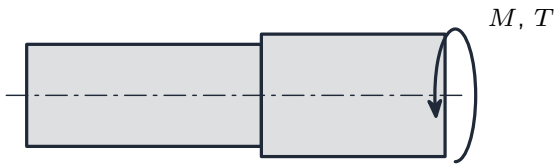
$\sigma = \dfrac{32 \times 150 \times 10^3}{\pi \times 30^3} = \mathbf{56.6\ MPa}$; $\sigma_a = 1.77 \times 56.6 = \mathbf{100\ MPa}$

$n = \dfrac{214}{100} = \mathbf{2.14}$; $\sigma_a < S_e$, so the life is infinite

Exercise 3.2

3.2 The shaft of Q3.1 also carries a steady torque of 200 N m, with $K_{fs} = 1.5$.

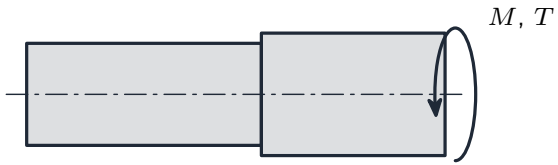
Find the von Mises mean stress and the Goodman factor of safety. [4]



Exercise 3.2

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Find the von Mises mean stress and the Goodman factor of safety. [4]



3.2

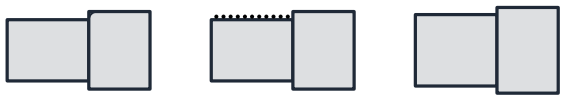
$$\tau_m = \frac{16 \times 200 \times 10^3}{\pi \times 30^3} = 37.7 \text{ MPa}; \; \sigma'_m = \sqrt{3} \times 1.5 \times 37.7 = \mathbf{98 \text{ MPa}}$$

$$\frac{1}{n} = \frac{100}{214} + \frac{98}{600}: \; n = \mathbf{1.59}$$

Exercise 3.3 (a)

3.3 A redesign raises the shaft's bending moment to 220 N m (fully reversed, no torque). The target is $n \geq 2.0$. Options: (i) fillet $r = 3.0$ mm: $K_t = 1.6$, $q = 0.90$; (ii) shot peening , which raises S_e by 20%; (iii) a larger diameter (ignore the small changes in k_b and K_t).

(a) Find the factor of safety of the present design. [3]



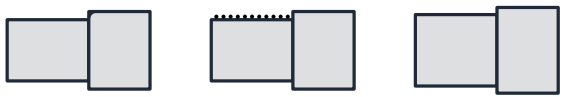
(i) larger r (ii) peened (iii) larger d

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(a) Find the factor of safety of the present design. [3]



(i) larger r (ii) peened (iii) larger d

(a) $\sigma = \dfrac{32 \times 220 \times 10^3}{\pi \times 30^3} = 83.0$ MPa; $\sigma_a = 1.77 \times 83.0 = 147$ MPa; $n = \mathbf{1.46}$

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Exercise 3.3 (b)

3.3 A redesign raises the shaft's bending moment to 220 N m (fully reversed, no torque). The target is $n \geq 2.0$. Options: (i) fillet $r = 3.0$ mm: $K_t = 1.6$, $q = 0.90$; (ii) shot peening , which raises S_e by 20%; (iii) a larger diameter (ignore the small changes in k_b and K_t).

(b) Find n with option (i), and with (i) and (ii) together. [3]

Exercise 3.3 (b)

3.3 A redesign raises the shaft's bending moment to 220 N m (fully reversed, no torque). The target is $n \geq 2.0$. Options: (i) fillet $r = 3.0$ mm: $K_t = 1.6$, $q = 0.90$; (ii) shot peening , which raises S_e by 20%; (iii) a larger diameter (ignore the small changes in k_b and K_t).

(b) Find n with option (i), and with (i) and (ii) together. [3]

(b) $K_f = 1.54$: $n = \dfrac{214}{1.54 \times 83.0} = \mathbf{1.67}$; with peening $1.2 \times 1.67 = \mathbf{2.0}$

Exercise 3.3 (c)

3.3 A redesign raises the shaft's bending moment to 220 N m (fully reversed, no torque). The target is $n \geq 2.0$. Options: (i) fillet $r = 3.0$ mm: $K_t = 1.6$, $q = 0.90$; (ii) shot peening , which raises S_e by 20%; (iii) a larger diameter (ignore the small changes in k_b and K_t).

(c) Find the smallest whole-mm diameter for (iii) alone. Recommend a fix. [2]

Exercise 3.3 (c)

3.3 A redesign raises the shaft's bending moment to 220 N m (fully reversed, no torque). The target is $n \geq 2.0$. Options: (i) fillet $r = 3.0$ mm: $K_t = 1.6$, $q = 0.90$; (ii) shot peening , which raises S_e by 20%; (iii) a larger diameter (ignore the small changes in k_b and K_t).

(c) Find the smallest whole-mm diameter for (iii) alone. Recommend a fix. [2]

(c) $n \propto d^3$: $d = 34$ mm gives $n = 2.13$; fillet plus peening keeps the bearing and hub sizes, so choose it if the bearing allows the larger fillet