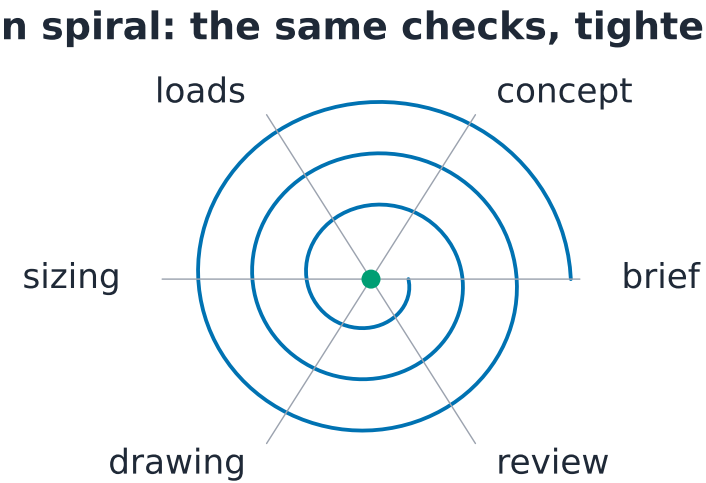
Exercise walk-through

9.6
Constrained design project

University Mechanical Engineering

The design spiral



Brief → concept → loads → sizing → drawing → review, then round again with better numbers.

Choosing the concept

Concept	Cost, size, efficiency, maintenance (1–5)	Weighted score
A spur gears	4, 3, 4, 3	3.60
B belt drive	5, 2, 3, 3	3.45
C gearmotor	3, 4, 4, 5	**3.80**

The design file

1. **Shaft** Ø30 C45, Goodman $n = 2.21$, yield $n = 3.40$.
2. **Bearing** 6206, $L_{10} = 27\,000$ h against 20 000 h.
3. **Bolts** M10 8.8, load factor 4.35, separation 34.8 kN.
4. **Gears** Bending 87.9 MPa; contact 633 MPa $\rightarrow$ through-hardened, about 300 HB.

Decision

Limits stated: no shock loads, no deflection or key check yet, lubrication assumed.

Check yourself

- The safety factor and the duty cycle? ($1.2 \times 1.15 \times 1.1 = 1.52$; cube mean 2.94 kN.)
- The **endurance limit** and the shoulder? (222 MPa; Goodman n = 2.21, yield 3.40.)
- The seat and the bearing? (29.0 $\rightarrow$ 30 mm; C 17.6 kN needed, 6206 gives 27 000 h.)
- The bolt and the pinion? (26.1 kN **preload**, 28.1 kN at 8 kN, separation 34.8 kN; 87.9 and 633 MPa.)

Exercises 2.1·2.2

2.1 Find each concept's weighted score (two decimals) and the winner. [4]

2.2 The client now weights cost 0.45, size 0.20, efficiency 0.20 and maintenance 0.15. Recompute and say whether the choice is robust. [4]

Exercises 2.1·2.2

2.1 Find each concept's weighted score (two decimals) and the winner. [4]

2.1

- A: $0.30 \times 4 + 0.30 \times 3 + 0.25 \times 4 + 0.15 \times 3 = \mathbf{3.55}$.
- B: $0.30{\times}5{+}0.30{\times}4{+}0.25{\times}3{+}0.15{\times}2 = \mathbf{3.75}$; C: $0.30{\times}3{+}0.30{\times}4{+}0.25{\times}5{+}0.15{\times}4 = \mathbf{3.95}$.
- C, the gearmotor, wins.

2.2 The client now weights cost 0.45, size 0.20, efficiency 0.20 and maintenance 0.15. Recompute and say whether the choice is robust. [4]

2.2

- A $= \mathbf{3.65}$; B $= 0.45 \times 5 + 0.20 \times 4 + 0.20 \times 3 + 0.15 \times 2 = \mathbf{3.95}$; C $= \mathbf{3.75}$.
- B now wins: the choice flips with a cost-heavy brief, so it is not robust and the weights must be agreed with the client first.

Exercise 3.1

3.1 A design file lists: shaft Goodman $n = 2.13$, shaft yield $n = 3.95$, bearing $L_{10} = 49\,100$ h against 30 000 h required, bolt load factor 4.21, gear bending $n = 1.66$. Turn the bearing life into a factor on load (life $\propto 1/P^3$), name the governing check, and list two assumptions the next turn of the spiral must test. [6]

Exercise 3.1

3.1 A design file lists: shaft Goodman $n = 2.13$, shaft yield $n = 3.95$, bearing $L_{10} = 49\,100$ h against 30 000 h required, bolt load factor 4.21, gear bending $n = 1.66$. Turn the bearing life into a factor on load (life $\propto 1/P^3$), name the governing check, and list two assumptions the next turn of the spiral must test. [6]

3.1

- Life ratio $49\,100/30\,000 = 1.64$, so the load could rise by $1.64^{1/3} = \mathbf{1.18}$ before the life falls short.
- The gear's 1.66 is the lowest of the stress factors, but on load the bearing's 1.18 is the tightest margin: it **governs**.
- Assumptions to test: no shock loads; shaft deflection and the key not yet checked; adequate lubrication.