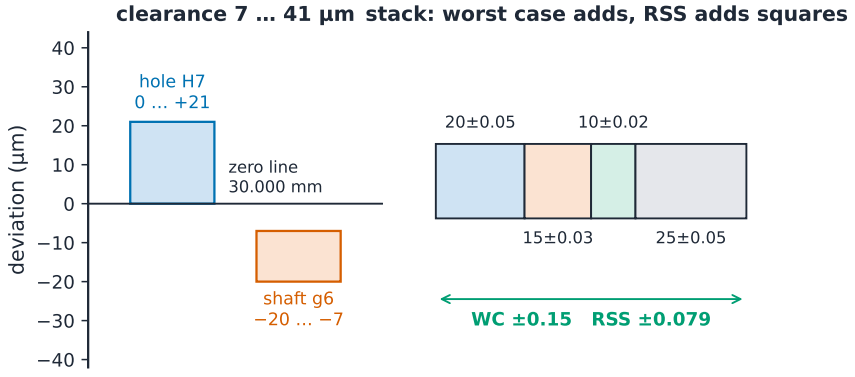
Manufacturing Processes

Curated undergraduate study track (not accredited, no external exam). Original explanations and practice only, following the reviewed course handout.

From drawing to part

- The eighth course: how the pump housing, shaft and bracket from Courses 6 and 7 are specified, made, joined and proved good.
- No workshop; flow stresses, tool-life constants and mould constants are typical teaching values, stated where used.
- Unit 8.1 writes the part down; 8.2-8.4 make it; 8.5 adds printing; 8.6 plans the route and proves the result.

Fits: the shaft must turn, not rattle



30 H7/g6 gives a clearance of $\mathbf{7}$ to $\mathbf{41}$ µm; four spacers stack to $\pm\mathbf{0.15}$ worst case, $\pm\mathbf{0.079}$ RSS.

exercises.lol exercises.com.cn

Worst case or RSS?

1. **Chain** Spacers 20 ± 0.05, 15 ± 0.03, 10 ± 0.02, 25 ± 0.05 plus a bore depth ± 0.04.
2. **Worst case** $\pm(0.05 + 0.03 + 0.02 + 0.05 + 0.04) = \pm\mathbf{0.19}$ mm.
3. **RSS** $\pm\sqrt{0.05^2 + 0.03^2 + 0.02^2 + 0.05^2 + 0.04^2} = \pm\mathbf{0.089}$ mm.

Decision

Worst case when one failure is unacceptable; RSS for high volume with capable processes.

Casting: the riser freezes last

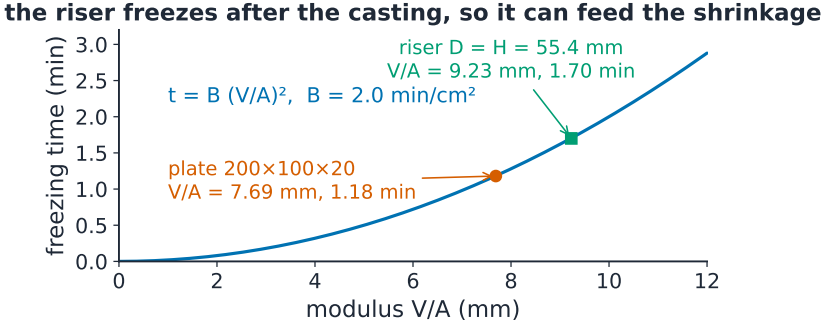
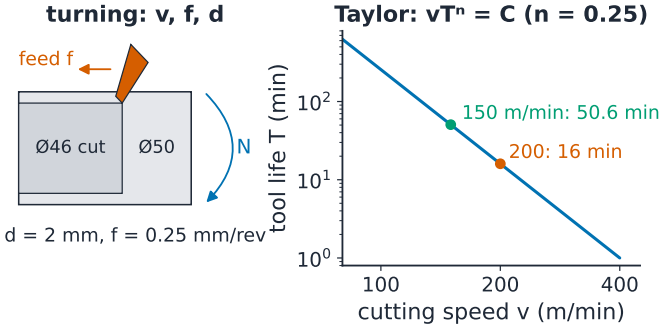


Plate 200×100×20: $V/A = \mathbf{7.69}$ mm, $t = B(V/A)^2 = \mathbf{1.18}$ min. A $D = H$ **riser** needs $D/6 = 1.2 \times 7.69$: $D = \mathbf{55.4}$ mm, freezing in $\mathbf{1.70}$ min.

Forming: drawing the shaft wire

1. **Strain** 6 $\rightarrow$ 5 mm: $\varepsilon = \ln(36/25) = \mathbf{0.365}$.
2. **Flow stress** $K = 500$ MPa, $n = 0.2$: $\overline{Y} = K\varepsilon^n/(1+n) = \mathbf{341}$ MPa.
3. **Stress, force** $\sigma_d = \overline{Y}\varepsilon = \mathbf{124}$ MPa; $F = \mathbf{2.44}$ kN on the 5 mm exit.
4. **Check** Exit **flow stress** 409 MPa, so σ_d is 30% of it; the ideal limit is $\varepsilon = 1 + n$, about 70% reduction.

Machining: speed, feed, depth



50 mm bar, $v = 150$ m/min, $f = 0.25$ mm/rev, $d = 2$ mm: $N = \mathbf{955}$ rpm, MRR $= \mathbf{1250}$ mm^3/s, $P = \mathbf{3.5}$ kW, $\mathbf{0.84}$ min for 200 mm.

Faster is not always cheaper

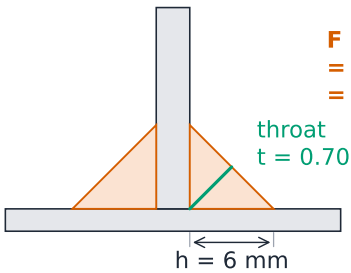
1. **150 m/min** $T = (400/150)^4 = \mathbf{50.6}$ min per edge, about 60 shafts at 0.84 min each.
2. **200 m/min** $T = \mathbf{16.0}$ min, about 25 shafts; each pass 25% faster at 0.63 min.
3. **Finish** $R_a \approx f^2/32r = 0.25^2/(32 \times 0.8)$ mm $= \mathbf{2.44}$ µm.

Decision

The faster speed pays only if machine time costs more than the extra tool changes.

Joining: the throat carries the load

fillet weld: size h, throat 0.707h carries the load



Two 100 mm fillets, $h = 6$ mm, $\tau_{allow} = 0.3 \times 482 = 145$ MPa: $F = 0.707 h L \tau = \mathbf{123}$ kN. **Heat input** $\eta V I / v = \mathbf{800}$ J/mm.

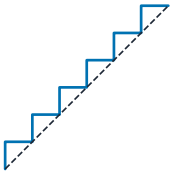
The bonded cover

1. **Lap joint** 25×12.5 mm overlap, epoxy at 20 MPa average shear: $\mathbf{6.25}$ kN.
2. **Ends** The shear peaks at the overlap ends, so doubling the overlap does not double the strength.
3. **Design** Load the bond in shear, never in peel; prepare and clean the surfaces.

Additive: layers make a staircase

0.2 mm layers

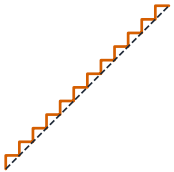
design surface 45°



cusp 0.141 mm, 300 layers

0.1 mm layers

design surface 45°



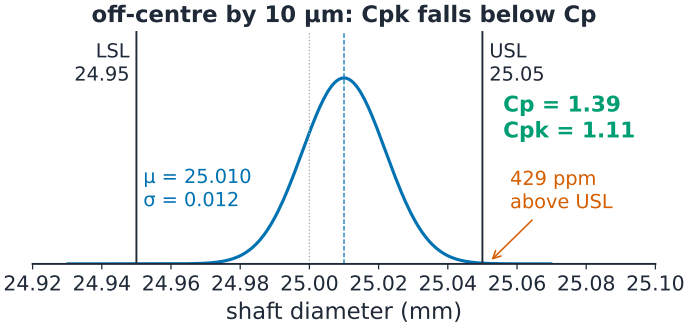
cusp 0.071 mm, 600 layers

60 mm tall: 0.2 mm layers give $\mathbf{300}$ layers and a 45° cusp $c = t\cos\theta = \mathbf{0.141}$ mm; 0.1 mm gives $\mathbf{600}$ layers and $\mathbf{0.071}$ mm.

Print or machine?

1. **Print** About €40 per part, no set-up, internal channels possible.
2. **Machine** €400 set-up plus €12 per part for a simpler two-part version.
3. **Break-even** $400/(40-12) = \mathbf{14.3}$: print up to 14 parts, machine from 15.

Quality: does the process fit the tolerance?



25.00 ± 0.05, $\mu = 25.010$, $\sigma = 0.012$: $C_p = \mathbf{1.39}$ but $C_{pk} = \mathbf{1.11}$, with $\mathbf{429}$ ppm above USL. Re-centred: $C_{pk} = 1.39$ and $\mathbf{31}$ ppm.

Keeping it centred

1. **Plan** Stock $\rightarrow$ rough turn $\rightarrow$ heat treat $\rightarrow$ finish grind $\rightarrow$ inspect, each from its **datum**.
2. **Chart** $n = 5$ per hour: $\bar{x}$ limits $\mu \pm 3\sigma/\sqrt{n} = \mathbf{24.994}$ to $\mathbf{25.026}$ mm.
3. **Act** A point outside, or seven in a row on one side, means the process changed - find the cause.

Check yourself

- The **fit** and the stack? (7-41 µm clearance; ±0.15 worst case, ±0.079 RSS.)
- The **riser** and the wire? (55.4 mm, 1.70 min; 124 MPa, 2.44 kN.)
- The pass, the tool, the weld? (955 rpm, 3.5 kW, 0.84 min; 50.6 vs 16 min; 123 kN.)
- The print and the grinder? (300 layers, 0.141 mm, break-even 14; Cp 1.39, Cpk 1.11, 429 ppm.)