

Design Guide: The Rules We Work To

The numbers behind every part we make, from corner radii and threads to fits, finishes and coatings. Free to use on your own drawings.

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These are the numbers we design and machine to every day. Use them to draw parts that are quicker and cheaper to make, and to know exactly what standard your part is built to.

Your drawing always wins. This guide covers what we do when a drawing is silent. If something on your drawing would be expensive or risky to make, we tell you before we quote, not after.

Every figure was cross-checked against at least two published sources (ISO, DIN and manufacturer data), and every formula was checked numerically. Where reputable sources disagree, we give the range.

Drawing defaults

What you get when your drawing doesn't say otherwise.

ISO 2768-mK

GENERAL TOLERANCES

Table below. Tighten only the 3–5 features that matter.

0.2–0.5 mm

SHARP EDGES BROKEN × 45°

One note on the drawing covers it. No need to dimension every chamfer.

Chamfered

BEFORE TAPPING

Threads start clean and don't burr.

Deburred & oiled

BEFORE IT LEAVES

Coastal air rusts bare steel overnight.

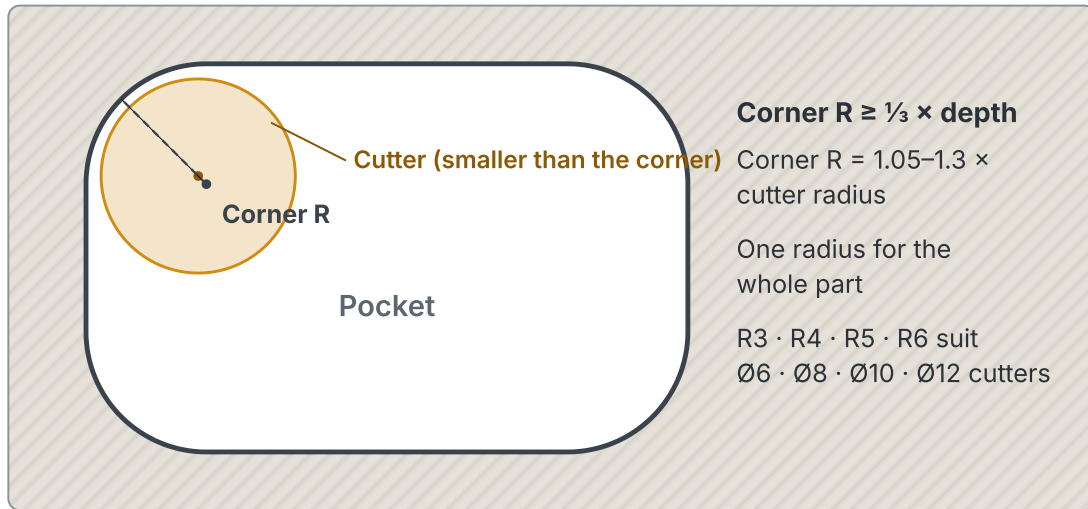
20 °C

MEASURED AT

The standard measuring temperature. A hot part isn't on size yet.

Pockets, corners and walls

The cheapest part is the one a big cutter can reach.



Corner radius: always a little bigger than the cutter, and at least a third of the pocket depth.

$R \geq \frac{1}{3} \text{ depth}$

INTERNAL CORNER RADIUS

Tighter means a long, skinny cutter that bends and chatters.

+1 mm R

CAN HALVE ROUGHING TIME

Bigger corners let a bigger, faster cutter do the work.

1.0 / 1.5 / 1.5 mm

MINIMUM WALL

Steel / aluminium / plastic.
Thinner walls vibrate and move.

Depth $\leq 4 \times$ width

POCKETS AND SLOTS

A slot at least a quarter as wide as it is deep.

Flat, R0.5 or R1

POCKET FLOORS

Odd or full-ball floors need slow 3D finishing.

6 directions

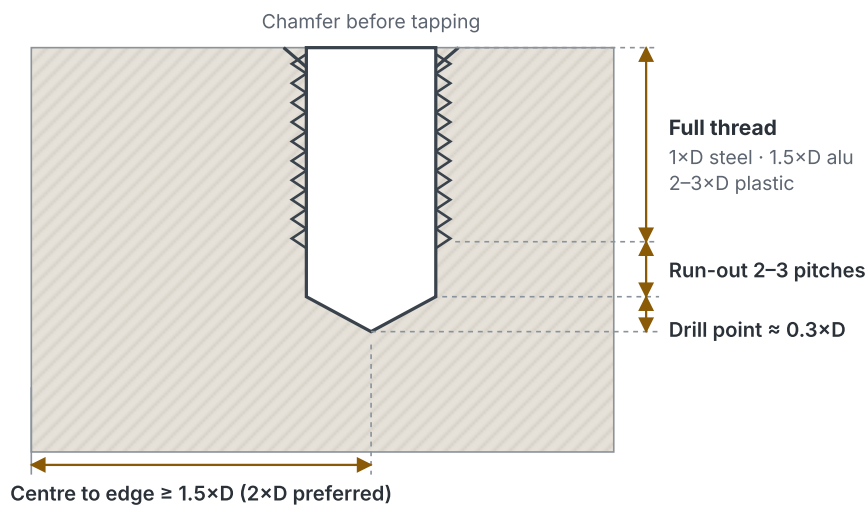
REACHABLE FEATURES

Top, bottom and four sides.
Odd angles cost extra time.

- **One internal radius everywhere on the part.** Every extra radius is another tool and another toolpath.
- **Undercuts:** standard T-slot and 45° or 60° dovetail shapes only.
- **Engraved text:** at least 5 mm high, strokes at least 0.5 mm wide and about 0.3 mm deep (0.84 mm wide in hard metals).

Holes and threads

Standard sizes, sensible depths, room to finish the thread.



A blind tapped hole: full thread, run-out below it, then the drill point.

Size – pitch

METRIC TAP DRILL

M6 → 5.0 · M8 → 6.8 · M10 → 8.5.
About 75 % thread, which is the target.

≤ 4×D

ROUTINE HOLE DEPTH

Up to 10×D is fine.
Deeper is specialist work.

2–3 pitches

THREAD RUN-OUT

Never call up "thread to bottom" in a blind hole.

≥ 1.5×D

TAPPED HOLE TO EDGE

Centre to edge, 2×D preferred. A boss wants an OD of 2.5×D.

METRIC HOLES (MM)

Thread	Tap drill	Clearance close	Normal	Loose	Cap screw c'bore	C'sink Ø 90°
M3	2.5	3.2	3.4	3.6	Ø6.5 × 3	6.0
M4	3.3	4.3	4.5	4.8	Ø8.25 × 4	8.0
M5	4.2	5.3	5.5	5.8	Ø9.75 × 5	10.0
M6	5.0	6.4	6.6	7.0	Ø11.2 × 6	12.0
M8	6.8	8.4	9.0	10.0	Ø14.5 × 8	16.0
M10	8.5	10.5	11.0	12.0	Ø17.5 × 10	20.0
M12	10.2	13.0	13.5	14.5	Ø19.5 × 12	—
M16	14.0	17.0	17.5	18.5	Ø25.5 × 16	—

- **Thread depth by material:** $1 \times D$ steel · $1.25 \times D$ cast iron · $1.5 \times D$ 6061 aluminium · $2 \times D$ soft or cast aluminium · $2.5\text{--}3 \times D$ plastic. Past about $1.5 \times D$ the bolt breaks before the thread strips.
- **Standard drill sizes only.** An odd diameter has to be milled or bored instead.
- **Flat-bottom blind holes are a second operation.** Only call one up if the flat bottom does a job.
- **Hole accuracy:** drilled $\pm 0.05\text{--}0.15$ mm · reamed H7 · bored H6–H7.
- **Countersinks** are cut 0.2–0.3 mm deeper than nominal so the head never sits proud.
- **Helicoil (STI) inserts:** tap drill $\approx$ nominal + $0.1 \times D$ (M6 $\rightarrow$ 6.3, M8 $\rightarrow$ 8.4). Use an insert $1.5 \times D$ long.

Tolerances

Only tolerance what matters. Every tight number costs money.

~2x cost

EACH TIME YOU HALVE IT

Below about ± 0.05 mm, cost roughly doubles every time a tolerance is halved.

± 0.02 mm

SAME SIDE OF THE PART

Features that line up hold best when they're cut without turning the part over.

0.02 / 0.005 mm

FLATNESS OVER 100 MM

Milled / ground.

1/10 rule

MEASURE WHAT YOU CALL UP

± 0.01 mm needs a gauge that reads to 0.002 mm.

ISO 2768 GENERAL TOLERANCES

Size (mm)	f (fine)	m (medium)	c (coarse)
0.5–3	± 0.05	± 0.1	± 0.3
3–6	± 0.1	± 0.2	± 0.5
6–30	± 0.15	± 0.3	± 0.8
30–120	± 0.2	± 0.5	± 1.2
120–400	± 0.3	± 0.8	± 2.0
400–1000	± 0.5	± 1.2	± 3.0

WHAT'S REALISTIC BY PROCESS (MM) — TYPICAL ACROSS THE TRADE

Process	Typical	ISO grade
Turning	± 0.02 – 0.05	IT7–IT9
Milling	± 0.025 – 0.10	IT8–IT10
Boring	± 0.01	IT6–IT7
Reaming	H7	IT7
Cylindrical grinding	± 0.005	IT5–IT6
Surface grinding	± 0.005	—

- **Angles (ISO 2768-m):** $\pm 1^\circ$ on legs to 10 mm · $\pm 30'$ to 50 mm · $\pm 20'$ to 120 mm · $\pm 10'$ to 400 mm.
- **Worst-case stack-up = add every tolerance in the chain.** Use it for one-offs, small batches and anything safety-critical.
- **Statistical (RSS) stacking** needs 4+ independent dimensions on a well-centred process. Five ± 0.1 dimensions give ± 0.22 instead of ± 0.5 . Tempting, but wrong if the process drifts.

- **Datum A is the face the part sits on in service**, not whichever face is easiest to draw from.
- **Use position with datums for anything that assembles.** A round position zone gives about 57 % more room than the same $\pm$ box.
- **Add MMC ($\textcircled{M}$) to clearance-hole patterns.** Bigger holes earn extra position tolerance for free.

Fits, bearings and dowels

Hole-basis: the bore is H7 and the shaft is sized to get the fit.



ISO fits at Ø25 mm. The shaft's position against the H7 band decides how it goes together.

H7/g6

SLIDING

Always clearance.

H7/h6

LOCATION

Assembles by hand.

H7/k6

LIGHT TRANSITION

Tap together with a mallet.

H7/n6

FIRM TRANSITION

Arbor press.

H7/p6

LIGHT PRESS

Needs a press.

H7/s6

HEAVY SHRINK

Carries torque without a key.

ISO 286 LIMITS

Fit (µm)	Ø10	Ø25	Ø50	Ø100
H7 hole	+15/0	+21/0	+25/0	+35/0
g6 shaft	-5/-14	-7/-20	-9/-25	-12/-34
h6 shaft	0/-9	0/-13	0/-16	0/-22
k6 shaft	+10/+1	+15/+2	+18/+2	+25/+3
n6 shaft	+19/+10	+28/+15	+33/+17	+45/+23
p6 shaft	+24/+15	+35/+22	+42/+26	+59/+37
s6 shaft	+32/+23	+48/+35	+59/+43	+93/+71

Press fits and bearings

0.001 × Ø

PRESS FIT INTERFERENCE

0.025 mm on Ø25,
steel on steel.
Double it for shock
loads or thin hubs.

k5/k6

ROTATING SHAFT

m5/m6 for heavy
or shock loads.
Housing H7.

M7 / N7 / P7

ROTATING HOUSING

Split housings are
always H7.

One ring only

GETS THE INTERFERENCE

The other must
float, or heat
growth preloads
the bearing.

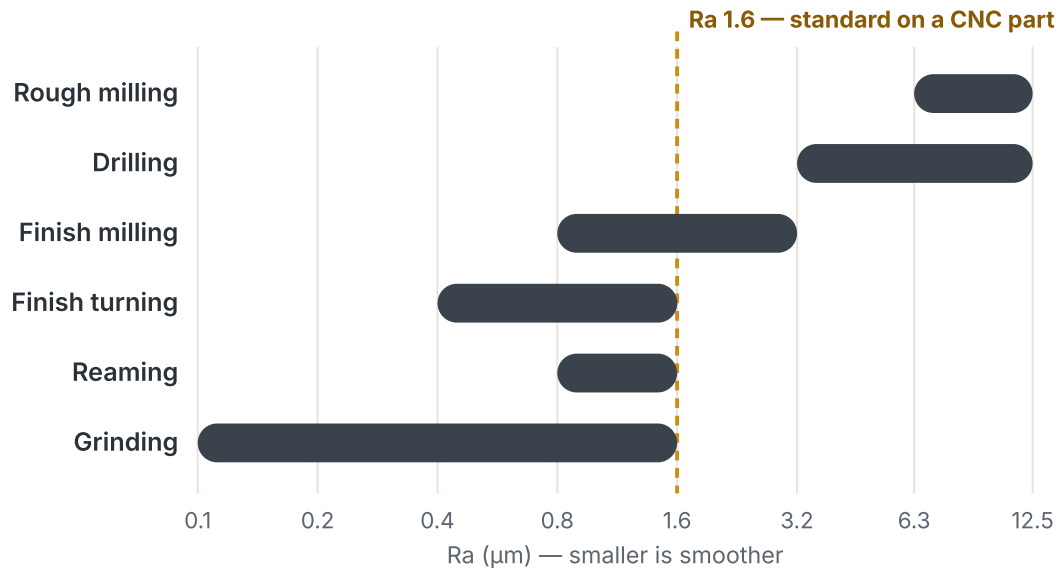
Dowels, keys and circlips

- **Locate with two dowels, clamp with bolts.** Bolts in clearance holes leave 0.2–0.5 mm of play; dowels hold about 0.01 mm.
- **One round pin and one diamond pin,** as far apart as the part allows. Engage each 1.5–2×D per side. Vent blind dowel holes.
- **Shaft shoulder fillet smaller than the bearing chamfer,** or the bearing never seats square.
- **Keys (DIN 6885):** Ø30 → 8×7 · Ø50 → 14×9 · Ø75 → 20×12. Key length about 1.5× shaft Ø.
- **Circlip grooves** at least 1.5× their depth from any shoulder or shaft end.

DIN 471 circlip	Ø12	Ø20	Ø25	Ø30	Ø40	Ø50
Groove Ø	11.5	19.0	23.9	28.6	37.5	47.0
Groove width	1.10	1.30	1.30	1.60	1.85	2.15

Surface finish

Ra 1.6 comes standard. Smoother costs more.



Typical Ra by process. The further left, the smoother — and the more it costs to get there.

Ra 1.6

STANDARD ON CNC

No extra cost.

Ra 0.8

COSTS A LITTLE

A finishing pass.

Ra 0.4

REAL EFFORT

Dedicated strategy.

< Ra 0.4

GROUND

Grinding, honing or lapping.

- **N-grades:** N6 = Ra 0.8 · N7 = Ra 1.6 · N8 = Ra 3.2 · N9 = Ra 6.3.
- **Linished finishes:** 80–100 grit ≈ Ra 1.6 · 180–200 grit ≈ Ra 0.8 (commercial No. 4 satin) · 240–320 grit ≈ Ra 0.4.
- **Don't convert Ra to Rz on a drawing.** The relationship is rough, not exact. Call up the one you need.

Bolts and torque

Lightly oiled, as-received bolts tightened to about 70 % of proof load.

TIGHTENING TORQUE — USE THE FASTENER MAKER'S FIGURE WHERE ONE IS GIVEN

Torque (Nm)	M3	M4	M5	M6	M8	M10	M12	M16
Grade 8.8	1.3	3.0	6.0	10.3	24.9	49.4	86.1	214
Grade 12.9	2.2	5.1	10.4	17.6	42.8	84.9	148	368

0.86 × 12.9

GRADE 10.9

Use the 12.9 row
and take off 14 %.

±25–35 %

TORQUE SCATTER

Don't design a joint
that only works if
the torque is exact.

1× / 2× / 2.5–3×

THREAD ENGAGEMENT

Into steel /
aluminium / cast
iron or plastic.

Tension, not shear

LOAD BOLTS IN

If it takes shear,
dowel it or use
fitted bolts.

Strength and stiffness

Shape beats material, almost every time.

Same beam, same load — cross-sections



Base section
1×



Double the width
2× stiffer



Double the depth
8× stiffer

Stiffness goes with depth cubed. Add depth, not metal.

$r \geq 0.1 \times d$

SHOULDER FILLET

Gets most of the benefit. In fatigue, a bigger radius beats a better steel.

~3×

ALUMINIUM BENDS MORE

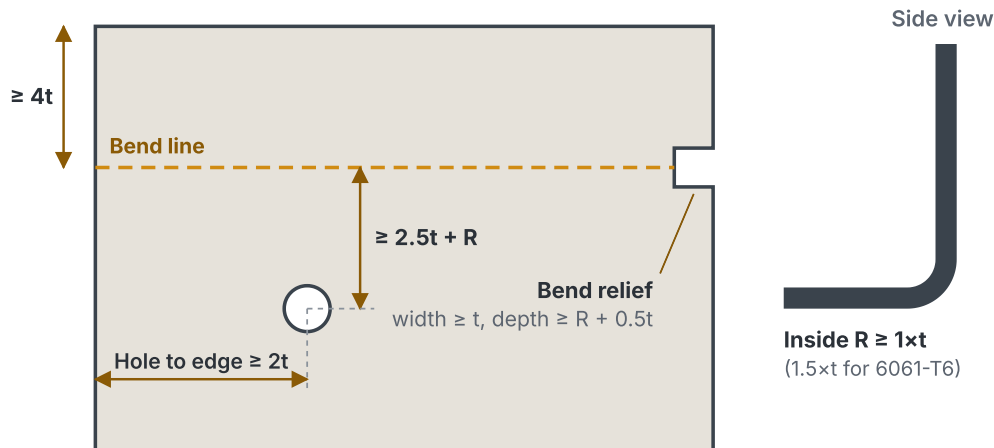
Than steel in the same section. Match it with about 1.4× the depth.

1.25 → 4+

SAFETY FACTOR

1.25–1.5 known load · 2–3 average · 3–4 uncertain · 4+ shock or anything that can hurt someone.

Flat patterns that fold up square the first time.



The four distances that stop holes pulling oval and corners tearing (t = sheet thickness).

$R \geq 1xt$

INSIDE BEND RADIUS

1.5xt for 6061-T6 and high-tensile grades, which crack at 1xt.

$\geq 4xt$

MINIMUM FLANGE

Shorter flanges can't sit on the brake die.

$\geq 1xt$

MINIMUM HOLE $\varnothing$

And at least 2xt from an edge and from each other.

$\pm 1^\circ \cdot \pm 0.25$ mm

TYPICAL RESULTS

Air-bent angle · flat pattern.

- **Slots at least 4xt from a bend**, holes at least $2.5xt + R$.
- **Keep every bend the same direction and radius** where you can. Each change is another brake setup.
- More on our [sheet metal fabrication](#) page.

Common Australian grades and when to use them.

4140

STEEL

Our default strong steel (AS 1444, EN19, 42CrMo4). Supplied hardened and tempered, about 250–300 HB.

4340

STEEL

Over 4140 for sections over 100 mm or anything shock-loaded (EN24).

1045 · 1020

STEEL

1045 for shafts and general parts. 1020 for jigs, spacers and weld-ups.

304 · 316

STAINLESS

304 general purpose. 316 for anything near salt water.

303 · 416 · 431

STAINLESS

303 machines easily but never for marine. 416 hardens and is magnetic. 431 for strong shafts.

6061-T6

ALUMINIUM

General purpose, welds well.

7075-T6 · 5083

ALUMINIUM

7075 for stiff, strong parts (don't weld). 5083 for welded marine plate.

660 · C36000

BRONZE & BRASS

660 bronze for bushes. Free-cutting brass for fittings.

Bisalloy 400 · 500

WEAR PLATE

About 370–430 HB and 470–530 HB.

— **Old British grades:** EN8 ≈ 1040 · EN19 ≈ 4140 · EN24 ≈ 4340.

HARDNESS CONVERSION (APPROXIMATE)

HRC	HV	HB	Tensile (MPa)
20	244	226	835
30	305	286	1050
40	392	371	1350
45	446	420	1550
50	513	481	1770
55	595	—	2050
60	697	—	2400

Hardened parts

Steel moves when it hardens. Design for it.

0.10–0.15 %

SIZE CHANGE ON HARDENING

About 0.025–0.04 mm on 25 mm, 0.1–0.15 mm on 100 mm. Tight features are ground after, so mark which ones matter.

Symmetry

BEATS EVERYTHING

A symmetrical part moves evenly and grinds back true.

$R \geq 1 \text{ mm}$

EVERY INTERNAL CORNER

Sharp corners are where quench cracks start.

$\leq 3:1$

SECTION CHANGE

Thick next to thin cools unevenly and bows.

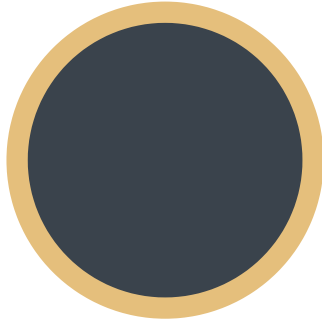
- **Drill, tap and thread before hardening.**

- **Long, thin parts** (over 8:1 length to diameter) will bow and need straightening or grinding.

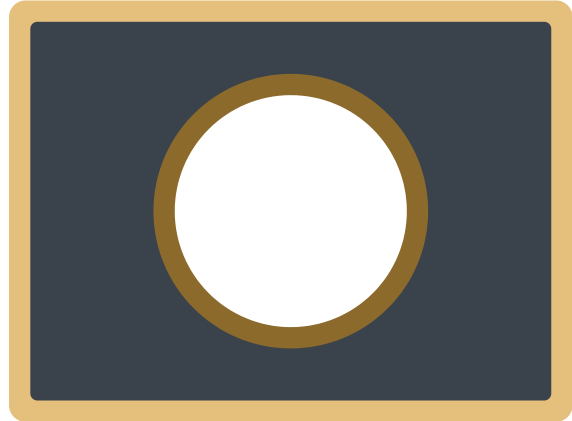
Plating and coatings

Coatings build up on every surface they touch.

t = coating thickness (shown exaggerated)



Shaft grows $+2t$ on $\varnothing$



Hole shrinks $-2t$ on $\varnothing$

A shaft grows by twice the coating thickness. A hole shrinks by twice. Always.

Finish	Thickness	Effect on size
Electroless nickel	5–50 μm (25 typical)	Bores $-2t$, shafts $+2t$
Hard chrome	12–250 μm	Plated oversize, then ground back
Anodise (Type II)	5–25 μm	Usually under 0.01 mm
Hard anodise (Type III)	25–50 μm	Half grows out, half goes in
Black oxide	0.5–2.5 μm	Negligible
Zinc plate	5–25 μm	Bores about -0.02 mm
Passivation (stainless)	0	None

$4 \times t$

OFF A THREAD'S FIT

On a 60° thread. 12 μm of zinc takes about 0.05 mm off the pitch diameter.

Mask it

THE CHEAPEST FIX

Threads and slip-fit bores.
Say so on the drawing.

> 40 HRC

BAKE AFTER PLATING

High-strength steel must be baked to drive out hydrogen, or it can crack.

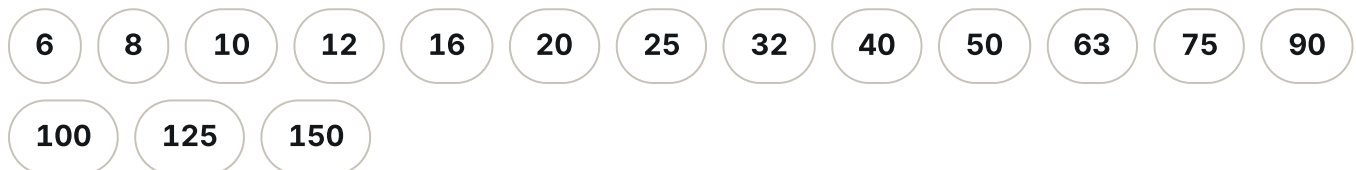
— **Deep and blind holes anodise unevenly.** Mask them or leave them oversize.

Standard stock sizes

Design to the bar and plate that's on the shelf.

A 47 mm boss on Ø50 bar is one light cut. The same boss on Ø63 bar is twenty minutes of turning.

COMMON ROUND BAR (Ø MM)



COMMON PLATE (MM)



**±0.3–1.5
mm**

**BLACK (HOT
ROLLED) BAR**

Always machined
all over.

h10 / h11

**BRIGHT (COLD
DRAWN) BAR**

h10 to Ø25, h11
above.

h9

GROUND (TGP) BAR

Can be used as-is
on non-critical
diameters.

h7

CHROME SHAFTING

Stocked in 1045
(Ø6–200) and 4140
(Ø20–120). Usually
cheaper to buy
than make.

- **Standard fasteners beat clever geometry.** A Ø6 dowel and an M6 cap screw cost less than any feature machined to replace them.

Not sure which way to go?

Send the drawing, a sketch or a photo. We'll tell you what will make it cheaper before we quote.

3D modelling and CAD drawings →