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Shaft-hub connections

Getting torque from a shaft into a hub — interference fits, keys, splines, tapers and clamp hubs — with the torque each carries, the trade-offs, and how to size them.

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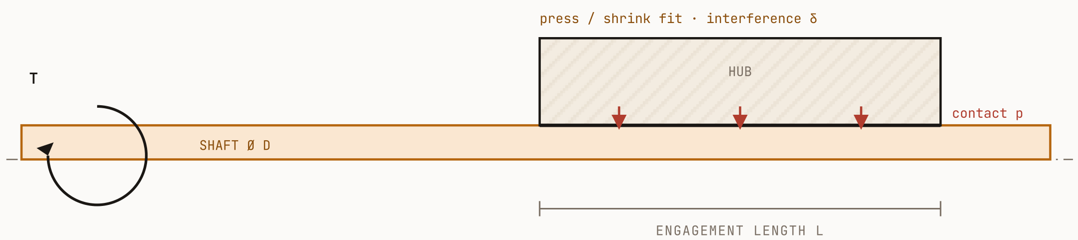
ABSTRACT

A shaft-hub connection transfers torque (and sometimes axial load) between a rotating shaft and a gear, pulley, sprocket or coupling. The choice — interference fit, key, spline, taper, set screw or clamp hub — trades torque capacity against centring accuracy, ease of (dis)assembly, shaft damage and cost.

Section 1 compares the methods. Section 2 covers interference (press/shrink) fits and their torque. Section 3 covers keys and keyways. Section 4 covers splines. Section 5 covers tapers, clamp hubs, keyless bushings and set screws. Section 6 is a selection checklist.

SHAFT-HUB INTERFERENCE FIT — SECTION



AN INTERFERENCE FIT TRANSMITS TORQUE PURELY BY FRICTION AT THE CONTACT PRESSURE — NO KEYWAY, NO STRESS RAISER. OTHER METHODS (KEYS, SPLINES, TAPERS, CLAMPS) TRADE TORQUE, CENTRING, COST AND EASE OF DISASSEMBLY.

CONTENTS

1. Comparing the methods

METHOD	TORQUE	CENTRING	(DIS)ASSEMBLY	SHAFT DAMAGE	NOTES
Interference (press/shrink) fit	high	excellent	hard (press/heat)	none	Clean, no stress raiser; needs force or heat
Parallel key + keyway	moderate–high	good	easy	keyway (stress raiser)	Cheap, standard, the default
Spline	very high	excellent	easy (axial slide)	none extra	Many teeth share load; costly to cut
Taper fit (+ nut)	high	excellent	moderate	none	Self-centring, precise, removable
Clamp / split hub	moderate	good	very easy	none	Repositionable; no machining of shaft
Keyless locking bush / shrink disc	very high	good	moderate	none	High torque without a keyway
Set screw (on flat)	low	poor	very easy	mars shaft	Light duty only; use a flat

1.1 Terms

`Interference (δ)`	How much larger the shaft is than the bore before assembly
`Contact pressure (p)`	Radial pressure at the fit interface (from Lamé equations)
`Engagement length (L)`	Axial overlap of shaft and hub — torque scales with it
`Hub ratio`	Outer/inner diameter of the hub — thin hubs reach hoop-stress limits sooner

2. Interference (press/shrink) fits

The shaft is made slightly larger than the bore; assembly creates a contact pressure **p** (from the interference δ and the Lamé thick-cylinder equations, with hub geometry and both materials' E and ν). Friction at that pressure carries the load:

- **Torque** `T = μ · p · π · D² · L / 2`
- **Axial push-out force** `F = μ · p · π · D · L`

where D is the fit diameter, L the engagement length and μ the friction coefficient (≈0.1–0.15 dry steel; lower if oiled during pressing). Use the *Press-fit interference* tool to get p, T and F from δ.

- **Specify with ISO 286 fits: light `H7/p6`, medium `H7/s6`, heavy `H7/u6`. Bigger interference → more torque, but also more hub hoop stress (check the hub doesn't yield) and more assembly force.**
- **Shrink/expansion fit (heat the hub or chill the shaft) reaches the same interference with little assembly force and full holding capacity**
  best for large or high-interference fits.
- **Surface finish matters: rough surfaces flatten on assembly, so the**
  effective
  interference is less than the measured one
  a fit specced from nominal sizes over-predicts torque on a coarse finish.

3. Keys and keyways

A parallel (square/rectangular) key in matching shaft and hub keyways is the standard, cheap method. Size it so it doesn't shear or crush, and respect the keyway as a fatigue stress raiser in the shaft.

- **Shear: key width × length resists `F = 2T/D` across the key's shear plane.**
- **Bearing/crush: the key side bearing on the keyway wall is usually the limit; check it too.**
- **Standard sizes (DIN 6885, key b × h by shaft Ø):**

SHAFT Ø (MM)	KEY B × H	SHAFT Ø (MM)	KEY B × H
10–12	4 × 4	30–38	10 × 8
12–17	5 × 5	38–44	12 × 8
17–22	6 × 6	44–50	14 × 9
22–30	8 × 7	50–58	16 × 10

The keyway cut in the shaft raises local stress ($K_t \approx 2–3$) — a fatigue concern on reversing/heavily-loaded shafts. Use generous keyway-end radii, or a keyless method, where fatigue governs.

4. Splines

Splines are many keys cut integral to the shaft, so the load shares across all teeth — far higher torque and better centring than a single key, with no separate part to shear.

- **Straight-sided (older, simple) vs involute (stronger, self-centring, easier to manufacture to gauge)**
  involute is the modern default.
- **They allow axial sliding under load (e.g. driveshafts, gear shifts) while transmitting torque.**
- **Costlier to produce (broaching/hobbing), so reserved for high-torque or sliding applications.**

5. Tapers, clamp hubs and keyless bushings

- **Taper fit (+ retaining nut): a tapered shaft/bore self-centres precisely and locks by friction; removable. Common on tool spindles and crankshaft pulleys.**
- **Clamp / split hub: a slit hub squeezed by a screw grips the shaft by friction**
  no shaft machining, infinitely repositionable; moderate torque. Great for prototypes and adjustable setups.
- **Keyless locking bushings / shrink discs: tapered rings draw up to clamp hub-to-shaft at very high torque with no keyway and no fatigue notch**
  used where keys would fatigue.
- **Set screws: light duty only; always seat on a flat (or use a dog-point into a hole) so they don't burr the shaft and slip. Two screws at 90° resist better than one.**

6. Selection checklist

- **Torque**
  steady value, plus reversing or shock peaks (these drive keyless/spline choices).
- **Centring / runout**
  interference, taper and splines centre best; set screws worst.
- **Axial behaviour**
  does the hub need to slide (spline) or stay located (fit/key/nut)?
- **(Dis)assembly**
  service access and frequency: clamp/keyless for easy removal, fits for permanent.
- **Shaft damage**
  avoid keyways/set-screw marks on fatigue-critical or hardened shafts (use keyless).
- **Cost**
  key cheapest; spline and keyless bush most expensive.
- **Then: size the method (interference via the press-fit tool; key by shear + bearing; spline/keyless from supplier torque ratings) and check shaft fatigue at any keyway.**