JOINING · WELDS · BRAZING · ADHESIVES · REFERENCE DOCUMENT · PUBLIC

# Welded & adhesive joints

Permanent joining methods — fusion welds and their symbols and sizing, brazing/soldering, and adhesive bonding — with how to size each and the failure modes to design out.

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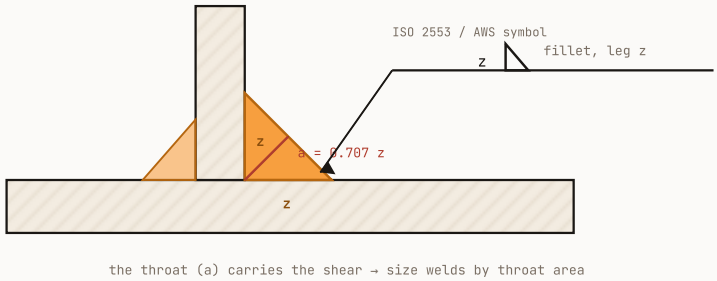
ABSTRACT

When a joint must be permanent, you weld, braze/solder, or bond it. Each suits different materials, loads and tolerances: welding fuses like metals at full strength, brazing and soldering join (including dissimilar metals) with a filler, and adhesives bond almost anything — including plastics — if the joint is designed for shear, not peel.

Section 1 compares the methods. Section 2 is weld joints and symbols. Section 3 is weld strength sizing. Section 4 is brazing and soldering. Section 5 is adhesive bonding. Section 6 is selection and failure modes.

FILLET WELD — THROAT & WELD SYMBOL




A FILLET WELD CARRIES LOAD ACROSS ITS THROAT (A = 0.707 × LEG), NOT ITS LEG — SO WELDS ARE SIZED BY THROAT AREA. THE ISO 2553 SYMBOL PUTS THE WELD TYPE AND SIZE ON THE DRAWING.

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## 1. Joining methods

| METHOD | HEAT | DISSIMILAR METALS | STRENGTH | GAP FILL | NOTES |
|---|---|---|---|---|---|
| **Fusion welding (MIG/TIG/spot/laser)** | very high | same / similar only | full base-metal | none | distortion + heat-affected zone (HAZ) |
| **Brazing** | 450–900 °C | yes | high (joint) | small (capillary) | dissimilar metals, less distortion |
| **Soldering** | < 450 °C | yes | low–moderate | fills | electrical, sealing, electronics |
| **Adhesive bonding** | low / RT cure | yes (incl. plastics) | moderate (area-set) | fills gaps | design for shear; cure time |
| **Riveting / bolting** | none | yes | mechanical | — | serviceable (see *Bolted joint* ref) |

Choose welding for full-strength metal structures, brazing/soldering for dissimilar or delicate joints, adhesives for mixed materials / large thin areas / sealing, and fasteners when it must come apart.

## 2. Weld joints and symbols

- **Joint types: butt, fillet (T / lap / corner), edge. The fillet weld is the workhorse**
  a triangular bead in a corner.
- **Weld symbol (ISO 2553 / AWS A2.4): an arrow points to the joint; a reference line carries the weld symbol. The fillet triangle sits on the line with the leg size before it; symbol**
  **below**
  **the line = arrow side,**
  **above**
  **= other side. Extra flags: length and pitch (intermittent welds), a circle at the elbow = weld all-around, a flag = field weld.**

A complete callout tells the welder the type, size, side, length and location — put it on every structural weld.

## 3. Weld strength sizing

A fillet weld fails across its **throat**, not its leg:

- **Throat `a = 0.707 × z` (z = leg size) for an equal-leg fillet.**
- **Capacity ≈ throat area × allowable shear: `F = a · L · τ_allow` (L = effective weld length).**
- **Size by throat; a bigger leg adds heat and distortion faster than strength**
  often two passes or a longer weld beats one huge fillet.
- **Balance the weld about the load's neutral axis (and the part's centroid) so it doesn't twist.**
- **Fatigue lives at the weld toe**
  it's a severe stress raiser. For cyclic loads use fatigue-classified joint details (lower allowable stress ranges), and grind or peen the toe. See the
  Fatigue primer
  .

## 4. Brazing and soldering

The **filler melts, the base metal doesn't** — so there's no HAZ and dissimilar metals can be joined.

- **Joint design: rely on capillary action into a small, controlled gap (typically 0.05–0.20 mm) and use lap (overlap) joints, not butt** strength comes from bonded area, not filler thickness.
- **Brazing (>450 °C) gives strong, sealed joints (tube fittings, carbide tips, assemblies). Soldering (<450 °C) is lower strength** electronics, sealing, light mechanical.
- **Clean, flux and control the gap; too-wide gaps starve the capillary and weaken the joint.**

## 5. Adhesive bonding

Adhesives bond almost anything — metals, plastics, composites, glass — and spread load over area, but the **joint geometry decides success**:

- **Load it in shear or compression, never peel or cleavage. Use generous overlap (lap joints), and avoid thin edges that pry the bond apart.**
- **Surface prep is everything: clean, degrease, abrade/etch, sometimes prime. A bond is only as good as the surface it grips.**
- **Cure & temperature: respect open time and full cure before loading; check the service-temperature limit.**

| ADHESIVE | STRENGTH | GAP | SERVICE TEMP | USE |
|---|---|---|---|---|
| **Epoxy (2-part)** | high, structural | gap-filling | ~120–180 °C | metal/composite structure |
| **Acrylic / MMA (2-part)** | high | tolerant of oily/rough | ~120 °C | structural, fast, less prep |
| **Polyurethane** | tough, flexible | gap-filling | ~80–100 °C | dissimilar, large panels, sealing |
| **Cyanoacrylate (CA)** | rigid, brittle | thin only | ~80 °C | fast fixturing, small parts |
| **Silicone (RTV)** | low, flexible | gap-filling | ~200–300 °C | sealing, thermal, vibration |
| **Anaerobic** | medium–high | close metal fit | ~150 °C | threadlock, retaining (see *Bolted joint*) |

## 6. Selection and failure modes

| MODE | CAUSE | FIX |
|---|---|---|
| **Weld distortion / HAZ cracking** | heat input, restraint, fast cooling | smaller/balanced welds, preheat, sequence, correct filler |
| **Weld toe fatigue** | stress raiser under cyclic load | fatigue detail, grind/peen toe, lower stress range |
| **Adhesive peel / cleavage failure** | joint loaded the wrong way | redesign for shear, add overlap/fillet, mechanical backup |
| **Adhesive bond-line failure** | poor surface prep / wrong adhesive | clean+abrade+prime, match adhesive to substrate |
| **Braze starved joint** | gap too wide / dirty | control capillary gap, flux, clean |
| **Galvanic corrosion (dissimilar)** | electrolyte at the joint | seal, isolate, matched metals (see *Galvanic chart*) |

**Checklist:** permanent? → weld (same metals, full strength) / braze (dissimilar, sealed) / adhesive (mixed materials, area). Size welds by throat and balance them; design adhesive joints for shear with overlap and surface prep; check fatigue at weld toes and peel at bond edges.