

INCONEL 718 VS. 625

Mechanical Properties & Machinability Guide by ForceBeyond

When engineering components for extreme environments—where towering temperatures, immense stress, and highly corrosive agents destroy standard metals—engineers routinely turn to nickel-based superalloys. Within this elite family, **Inconel 718** and **Inconel 625** stand as the industry standards.

While they share a nickel-chromium foundation, their strengthening mechanisms, mechanical limits, and machinability profiles are fundamentally different. Choosing the wrong alloy can lead to premature part failure or catastrophically inflated machining costs.

This ForceBeyond guide breaks down the critical differences between Inconel 718 and 625, helping design engineers and procurement teams make the right material selection for precision castings, forgings, and CNC machined parts.

1. Metallurgy & Strengthening Mechanisms

The core difference between these two alloys lies in how they derive their strength.

- **Inconel 625 (Solid-Solution Strengthened):** This alloy relies on the heavy addition of molybdenum and niobium to its nickel-chromium matrix. It is typically used in its annealed state. Because it does not rely on complex precipitation aging, it retains immense ductility and offers extraordinary resistance to pitting, crevice corrosion, and chloride-ion stress-corrosion cracking.
- **Inconel 718 (Precipitation-Hardenable):** Inconel 718 contains higher levels of niobium, titanium, and aluminum. When subjected to a highly controlled heat treatment (aging), these elements form microscopic precipitates (gamma prime and gamma double prime) throughout the matrix. This mechanism locks the crystal lattice in place, giving 718 a massive advantage in tensile and yield strength over 625.

2. Mechanical Properties Comparison

If your design requires maximum static strength, creep resistance, and fatigue performance under high loads, Inconel 718 is the superior choice. If your priority is aqueous corrosion resistance, marine durability, or extreme ductility for sheet forming, Inconel 625 takes the lead.

Note: Properties below reflect the standard usable conditions: Inconel 625 in the annealed state, and Inconel 718 in the aged/precipitation-hardened state.

Property	Inconel 625 (Annealed)	Inconel 718 (Aged)
Tensile Strength (UTS)	830 – 930 MPa	1,240 – 1,550+ MPa
Yield Strength (0.2% Offset)	410 – 510 MPa	1,030 – 1,310 MPa
Elongation at Break	45% – 60% (High Ductility)	12% – 25%
Typical Hardness	150 – 220 HB (~20 HRC)	36 – 48 HRC
Max Service Temp (Stress)	~980°C (1,796°F) - Non-rotating	~700°C (1,292°F) - High stress
Fatigue Resistance	Good	Superior (High Cycle)

ForceBeyond Engineering Insight:

Inconel 625 actually has a higher maximum service temperature for oxidation resistance (up to 980°C/1796°F). However, Inconel 718 is the mandatory choice for high-stress components at elevated temperatures (up to 700°C/1292°F), such as rotating turbine discs, because 625 will deform under high loads at those heats.

3. Machinability: The Shop Floor Reality

Both alloys are notoriously difficult to machine, but they do not behave identically. Inconel alloys conduct heat poorly, meaning the extreme heat generated during cutting stays trapped at the tool edge rather than flowing into the chip.

- **Inconel 625 Machinability Rating:** ~15% - 17% (Relative to 1212 steel).
- **Inconel 718 Machinability Rating:** ~8% - 12%.

Why Inconel 718 is harder to machine: As the cutting tool deforms Inconel 718, the alloy's austenitic structure rapidly work-hardens. The cut surface can instantly reach 400+ Brinell, ruining the cutting tool on the very next pass if the feed rate drops.

Best Practices for CNC Machining Inconel

1. **"Low Speed, High Feed" Strategy:** You must maintain a constant, aggressive feed rate. Never let the tool dwell or rub on the surface.

2. **Tooling:** Use high-performance, positive-rake solid carbide tools with PVD coatings (like TiAlN or AlTiN). For high-speed continuous finishing on 718, SiAlON ceramic inserts are ideal.
3. **Coolant:** High-pressure, through-spindle coolant is mandatory to blast heat away from the cutting zone and evacuate chips.
4. **Process Routing:** Whenever possible, rough-machine Inconel 718 in its softer, annealed state before sending it to heat treatment.

4. Primary Applications

When to specify Inconel 625:

- Marine and subsea oil & gas equipment (valves, pump casings) exposed to seawater.
- Chemical processing equipment handling volatile acids.
- Aerospace exhaust systems and ducting (high heat, highly corrosive, but lower mechanical stress).

When to specify Inconel 718:

- Jet engine and gas turbine components (turbine blades, discs, shafts).
- High-strength aerospace fasteners and structural members.
- Downhole tooling for oil and gas extraction requiring immense tensile strength.

Ready to manufacture your Inconel components?

Working with superalloys requires specialized knowledge, rigid machinery, and strict quality control. At **ForceBeyond**, we deliver world-class precision CNC machining, investment casting, and forging services tailored to the demands of Inconel 718 and 625.

Contact the ForceBeyond engineering team today to review your prints and optimize your next superalloy project for manufacturability.

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