Technical Whitepaper: Inconel 718 (UNS N07718) – The Metallurgy of Aerospace and Energy Excellence

Executive Summary

Inconel 718 (UNS N07718 / W.Nr. 2.4668) stands as the most widely used nickel-based superalloy in the modern industrial era. Developed specifically for high-strength duty in gas turbine engines, it maintains its mechanical integrity at temperatures ranging from cryogenic (-253°C) up to 700°C (1300°F). In 2026, the demand for Inconel 718 continues to grow, driven by hypersonic aviation and deep-water oil and gas extraction. This whitepaper details the strict metallurgical standards, melting protocols, and process controls required to achieve flight-critical reliability.

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1. Global Standard Compliance

Shanghai Hangbo Alloy Group produces and stocks Inconel 718 in strict accordance with international aerospace and industrial specifications.

Standard Body	Specification	Form / Product Type
ASTM (International)	**ASTM B637**	Precipitation-Hardened Bars, Forgings
ASME (Pressure Vessels)	**ASME SB-637**	Boilers & Pressure Vessel Code (Identical to B637)
AMS (Aerospace)	**AMS 5662 / AMS 5663**	Aerospace Material Specifications (Bars & Forgings)
API (Oil & Gas)	**API 6A718**	High-Strength Nickel Alloys for Sour Service
ISO (Global)	**ISO 15156-3**	Materials for use in H2S-containing environments

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2. Advanced Melting & Refining: The VIM-ESR-VAR Route

To achieve the fatigue life required for a turbine disk or a subsea valve stem, the primary melting of Inconel 718 must be followed by secondary and tertiary refining.

2.1 Vacuum Induction Melting (VIM)

VIM is used for the primary melt to ensure a clean, gas-free liquid metal. By melting in a vacuum, we eliminate dissolved Oxygen, Nitrogen, and Hydrogen, and allow for the precise addition of reactive elements like Titanium and Aluminum.

2.2 Electroslag Remelting (ESR)

For critical components, ESR provides an additional layer of purification. The ingot is remelted through a chemically active slag that removes non-metallic inclusions (oxides and sulfides) and produces a fine-grained, uniform solidification structure.

2.3 Vacuum Arc Remelting (VAR)

The "Triple Melt" (VIM+ESR+VAR) is the gold standard. VAR is the final step, used to eliminate "freckles" and macro-segregation. By controlling the arc gap and cooling rate in a water-cooled copper crucible, we produce an ingot with unparalleled chemical homogeneity, essential for predictable aging response.

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3. Strict Chemical Composition (ASTM B637 / AMS 5662)

Precise control of every element, including trace impurities, is non-negotiable.

Element	Symbol	Min (%)	Max (%)	Critical Role in Inconel 718
Nickel (+ Cobalt)	**Ni**	**50.00**	**55.00**	Matrix base; provides SCC resistance and toughness.
Chromium	**Cr**	**17.00**	**21.00**	Forms Cr■O■ passive layer for oxidation resistance.
Iron	**Fe**	**Balance**	**Balance**	Matrix support; cost-effective filler.
Niobium (+ Tantalum)	**Nb**	**4.75**	**5.50**	**The Key Element:** Forms γ'' [Ni■Nb] precipitates.
Molybdenum	**Mo**	**2.80**	**3.30**	Solid solution strengthening and pitting resistance.
Titanium	**Ti**	**0.65**	**1.15**	Forms γ' [Ni■(Al, Ti)] precipitates.
Aluminum	**Al**	**0.20**	**0.80**	Forms γ' and provides oxidation resistance.
Cobalt	**Co**	-	**1.00**	Impurity control; kept low for matrix stability.
Carbon	**C**	-	**0.08**	Necessary for grain boundary carbide formation.
Manganese	**Mn**	-	**0.35**	Deoxidizer; strictly limited for weldability.
Silicon	**Si**	-	**0.35**	Strictly limited to prevent brittle Laves phase.
Phosphorus	**P**	-	**0.015**	Trace impurity; causes weld cracking if high.
Sulfur	**S**	-	**0.015**	Causes "hot shortness" and weld defects.
Boron	**B**	-	**0.006**	Enhances creep-rupture life in trace amounts.
Copper	**Cu**	-	**0.30**	Trace impurity control.

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4. Mechanical & Physical Properties

Inconel 718 is unique among superalloys for its high yield strength up to 650°C (1200°F).

4.1 Mechanical Properties (Solution Treated + Aged)

Property	Value (at 20°C)	Value (at 650°C)	Requirement (ASTM B637)
Tensile Strength (UTS)	1241 MPa (180 ksi)	1034 MPa (150 ksi)	Min 1241 MPa
Yield Strength (0.2% Offset)	1034 MPa (150 ksi)	827 MPa (120 ksi)	Min 1034 MPa
Elongation (%)	12 – 25%	15%	Min 12%
Reduction of Area (%)	15 – 40%	-	Min 15%
Hardness (Rockwell C)	36 – 47 HRC	N/A	Range for application

4.2 Physical Properties

- **Density**: 8.19 g/cm³ (0.296 lb/in³)
- **Melting Range**: 1260°C – 1340°C
- **Coefficient of Thermal Expansion**: 13.0 x 10■■/°C (at 20-100°C)
- **Modulus of Elasticity**: 199 GPa (at 20°C)

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5. Process Control & Microstructure

The strength of 718 is not just in the chemistry, but in the thermal processing.

5.1 Strengthening Phases: γ' and γ''

- **Gamma Double-Prime (γ'')**: The primary strengthening phase. It is an orthorhombic Ni■Nb precipitate that provides massive resistance to dislocation movement.
- **Gamma-Prime (γ')**: A secondary face-centered cubic phase Ni■(Al, Ti).
- **Delta Phase (δ)**: A stable form of Ni■Nb. While δ does not provide strength, a controlled amount of globular delta phase at grain boundaries is mandatory to **pin the grains** and prevent grain growth during high-temperature forging.

5.2 Delta-Phase Processing (DPP)

High-end aerospace forgings use DPP to achieve a fine ASTM 8-10 grain size. This involves forging just below the delta solvus temperature (~1010°C), ensuring maximum fatigue resistance.

5.3 Heat Treatment Cycles

- **Standard (AMS 5663)**: 980°C Solution Anneal + 718°C Age (8h) + 621°C Age (10h).
- **NACE MR0175 Compliance**: Specialized cycle to ensure hardness < 40 HRC for sour gas service.

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6. Industrial Applications & Case Studies

6.1 Aerospace: Gas Turbine Disks

Scenario: Engine components exposed to high rotational stress and cyclic heating.

Why 718?: Exceptional low-cycle fatigue (LCF) resistance and high-temperature strength.

Case Study: Failure analysis of a high-pressure compressor disk revealed that improper forging above the delta solvus led to grain coarsening, reducing fatigue life by 40%. Corrective action mandated ESR+VAR triple-melt 718 with strict grain size control.

6.2 Oil & Gas: Subsea Completion Systems

Scenario: Wellhead components in H2S "sour" environments at 15,000 psi.

Compliance: Must meet NACE MR0175 / ISO 15156.

Case Study: A subsea valve stem failed due to Hydrogen Embrittlement. Audit found the material hardness was 48 HRC (Standard grade). Replacement with API 6A718-compliant Inconel 718 (max 40 HRC) solved the brittle fracture risk.

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7. Technical FAQ

Q: Can 718 be welded?
A: Yes, it is the most weldable superalloy due to delayed aging kinetics.

Q: Is it magnetic?
A: No, it remains non-magnetic even at cryogenic temperatures.

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