Metallurgy of ATI 718Plus Alloy

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Alloys for turbine engines have high demands in terms of reliability, weight, performance, and service life. They must also be stable at high temperatures and should be easy to process and weld. Therefore, a material with the following properties is required:

- Service temperature up to 650°C (1200°F)
- Good processibility
- Good weldability
- Good low-cycle fatigue properties and low crack propagation rates at high temperatures
- Reasonable cost

A promising new alloy with a good combination of properties addressing all of these requirements is the ATI 718Plus Alloy. It closes the gap between alloys 718 and Waspaloy, as it combines the good processibility and weldability of alloy 718, with the temperature capability of Waspaloy.

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This article details the properties and processing characteristics of 718Plus alloy, showing how its composition and metallurgy enable achievement of the above properties.

Chemistry for higher temperature

Alloy 718Plus has been designed to raise the maximum service temperature of alloy 718 by approximately 55C° (100°F). A comparison of the chemical compositions of both alloys (Table 1) shows that iron is partly replaced by cobalt and tungsten. In addition, the aluminum and titanium contents and ratios in 718Plus alloy have been changed from those in alloy 718, thus changing the primary hardening phase to γ from γ''. The γ' phase in 718Plus alloy has higher temperature stability than γ'' in alloy 718.

The precipitation kinetics of γ' in 718Plus alloy is slightly faster than the precipitation of γ'' in alloy 718, but slower than the γ' precipitation in Waspaloy. This can be mainly attributed to the 5.4 wt% Nb in 718Plus alloy, compared with none in Waspaloy, as niobium significantly lowers diffusion rates.

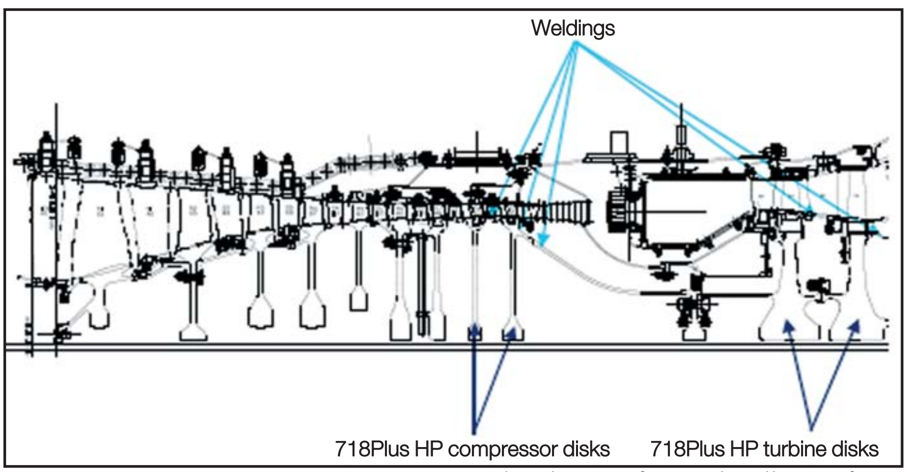

Fig. 1 — Potential applications for 718Plus alloy in a future high pressure core section.

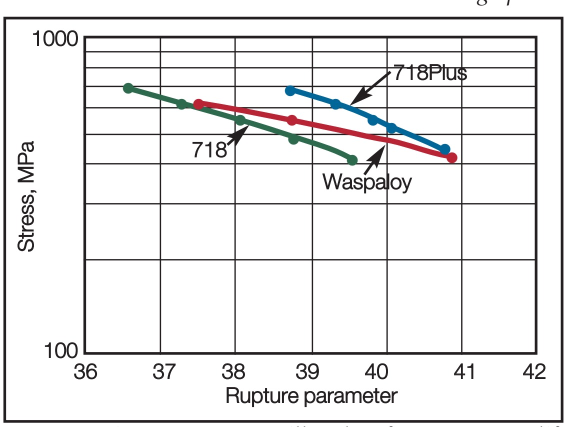

Fig. 2 — Larson-Miller plot of stress-rupture life of alloy 718Plus.

Mechanical properties

Nickel-base superalloys are intended for extended periods of service at high temperatures. Therefore, they must exhibit a variety of demanding properties, some of which may be partly conflicting: High strength and high ductility; Good crack-propagation resistance; No notch sensitivity; Good low-cycle fatigue and creep life.

• **Strength:** High strength is important at room temperature as well as at high temperatures. In comparison to 718, 718Plus alloy retains strength up to 704°C (1300°F). This is due to the high temperature stability of its γ' phase. The use of alloy 718 is limited by the rapid transformation of metastable γ'' into its stable conformation δ phase at a temperature of 650°C (1200°F). This transformation is accompanied by a significant drop in mechanical properties. The tensile strength of alloys 718 and 718Plus are comparable at room temperature, but higher for 718Plus alloy at 650°C and 704°C (1200 and 1300°F), respectively (Table 2). Over the entire temperature range, tensile ductility of the compared alloys is very good.

• **Creep stress rupture resistance:** The temperature capability of an alloy is also measured by its resistance to creep and stress rupture. Stress rup-

Table 1 — Chemistry of 718Plus, IN718, and Waspaloy, wt%

Element	C	Cr	Mo	W	Co	Fe	Ni	Nb	Ti	Al	P	B
718Plus	0.025	18.0	2.8	1.0	9.0	10.0	B	5.45	0.7	1.45	0.014	0.006
IN718	0.025	18.1	2.9	—	—	18.0	B	5.40	1.0	0.45	0.007	0.004
Waspaloy	0.035	19.4	4.3	—	13.3	—	B	—	3.0	1.30	0.006	0.006

Table 2 — Comparison of mechanical properties

Temp.	20°C, 68°F			649°C, 1200°F			704°C, 1300°F		
Alloys	YS, MPa	UTS, MPa	El., %	YS, MPa	UTS, MPa	El., %	YS, MPa	UTS, MPa	El., %
718Plus[A]	1204.6	1508.6	21.9	1023.2	1305.2	23.7	1005.3	1174.2	24.1
IN718[B]	1201.8	1459.0	20.2	1008.0	1133.5	20.8	936.3	1049.2	20.3
Waspaloy[C]	1086.7	1441.1	27.0	979.1	1341.8	22.8	884.6	1087.3	38.6

A — Heat Treatment 718Plus: 954 °C/1 h/AC + 788 °C/2 h/FC to 649 °C/8 h/AC
B — Heat Treatment IN718: 980 °C/1 h/AC + 720 °C/8 h/FC to 620 °C/8 h/AC
C — Heat Treatment Waspaloy: 1020 °C/4 h/OQ + 850 °C/4 h/AC + 760 °C/16 h/AC

A large number of full-size production ingots have been produced.

ture data taken from Allvac forged billet is compared to published data for alloys 718 and Waspaloy in Fig. 2. The 718Plus alloy curve corresponds almost exactly to a 55C° (100°F) increase in temperature capability compared to alloy 718. In the low-temperature, high-stress test region, 718Plus alloy shows the most significant advantage over Waspaloy. The stress rupture life curves converge in the high-temperature, low-stress regime, but a limited amount of creep testing suggests that steady-state creep rates for 718Plus alloy may still be significantly lower than those of Waspaloy, up to at least 704°C (1300°F).

• **Notch sensitivity:** For aerospace applications, it is important that an alloy not show notch sensitivity. The tendency for notch breaks in both alloys 718 and 718Plus is influenced by the precipitation of δ phase on the grain boundaries. The quantity, as well as the morphology of δ, depends on prior thermomechanical processing and heat treatment conditions that are well understood for both alloys. The precipitation of a small amount of short rod-shaped δ particles on the majority of grain boundaries retards intergranular cracking and thus prevents stress-rupture notch sensitivity.

• **Weldability:** Processing characteristics, including machinability and, in particular, weldability, are also important to ensure cost-effective application. Extensive welding is typical in the manufacture and repair of jet engine components. Welding trials have shown the weldability of 718Plus alloy to be very similar to that of alloy 718, which is considered to be the most weldable of all of the superalloys. Both alloys are substantially more weldable than Waspaloy. Good weldability is a result of the slow precipitation kinetics of alloys 718 and 718Plus discussed above.

Manufacturing base

An extensive manufacturing technology base has been established for 718Plus alloy. A large number of full-size production ingots have been produced by conventional vacuum induction melting (VIM) plus vacuum arc remelting (VAR). Material has also been produced by VIM plus electroslag remelting (ESR), and by triple melting (VIM+ESR+VAR). A full range of mill products has been produced, including billet, round, rectangular and shaped bar, sheet and foil, weld wire, and even investment castings. Rolled seamless rings, welded rings, and forged disks and blades have been produced. Three AMS specifications (AMS 5541, 5542 and 5964) covering 718Plus alloy have been issued, along with several company-specific specifications.

Numerous evaluations of this new alloy are ongoing at OEMs, forgers, fabricators, and government agencies. Because of the critical nature of aircraft jet engines, extensive testing and evaluation is required to qualify a new material, but 718Plus alloy will find its first flying application soon as an engine structural component. Extensive applications are expected in the future driven by the excellent properties of the alloy and its relatively moderate cost.

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