COLIBRIUM ADDITIVE
a GE Aerospace company

13 Al

22 Ti | 24 Cr | 26 Fe | 27 Co | 28 Ni | 29 Cu

L-PBF Nickel 718

Parameters for Colibrium Additive’s X Line 2000R

Nickel 718

Nickel chromium superalloys like 718 are often used in high-stress and high-temperature environments. The excellent high temperature strength and creep resistance derive from precipitation hardening of finely dispersed precipitates. Next to that Nickel 718 is a metal that is also highly resistant to the corrosive effects of hydrochloric acid and sulfuric acid. The favorable weldability of Nickel 718 makes this alloy suitable for additive manufacturing as well. Typical applications are high-quality components designed for thermally challenging environments such as rocket engines, gas-turbine hot sections, and heat exchangers.

X Line 2000R Nickel 718

The Nickel 718 parameters for the Colibrium Additive X Line 2000R are developed leveraging the performance of the previous X Line generations. The balanced parameters deliver a good balance between surface quality needs and productivity. Furthermore, the parameters offer a very good density leading to high strength and elongation - succeeding the minimum tensile properties specified in ASTM F3055 for additive manufactured parts in the heat treated state. The parameter performance was validated both in nitrogen and argon atmosphere. A large variety of heat treatments have been evaluated, in order to offer the best solution depending on the mechanical properties' requirements.

X Line 2000R Nickel 718

Machine Configuration

X Line 2000R

Dual-laser architecture

Argon/Nitrogen gas

Platform heating: 200°C

Powder Chemistry

Nickel 718 powder chemical composition according to ASTM B 637 UNS N07718

Particle size: 15-53 µm

Thermal States

As-Built (AB)

Solution Anneal + Age (SOLN1+AGE)

SOLN1: 980°C, 1 hour in argon; AGE: 720°C, 8 hours, furnace cooling down to 620°C; 620°C, 8 hours, cooling in air

Solution Anneal + Age (SOLN2+AGE)

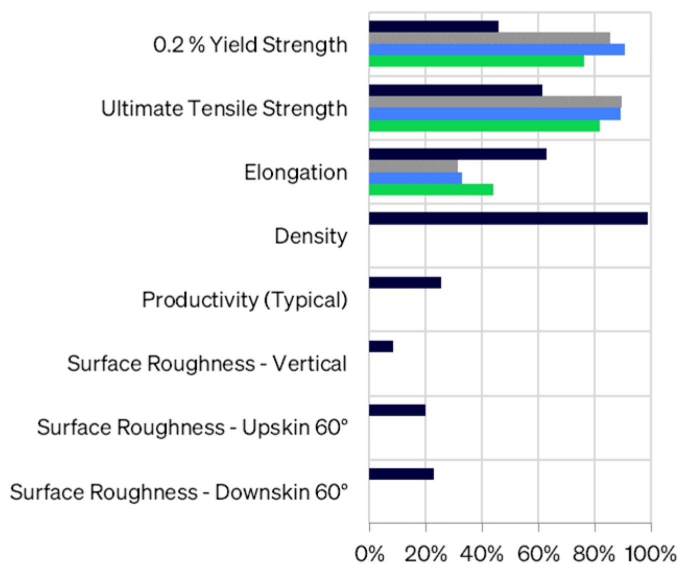
SOLN2: 1065°C, 1 hour in argon; AGE: 720°C, 8 hours, furnace cooling down to 620°C; 620°C, 8 hours, cooling in air

Vacuum Stress Relieve + HIP + Solution + Age (VSR+HIP+SOLN1+AGE)

VSR: 950 °C, 2 hours in argon; HIP: 1160°C, 4 hours, 100 MPa; SOLN1: 980°C, 1 hour in argon; AGE: 720°C, 8 hours, furnace cooling down to 620°C; 620°C, 8 hours, cooling in air

Parameter Availability and Thermal State Comparison

- Balanced 253/254 AB
  400 W, 60 µm layer thickness, carbon brush
- Balanced 253/254 SOLN1+AGE
  400 W, 60 µm layer thickness, carbon brush
- Balanced 253/254 SOLN2+AGE
  400 W, 60 µm layer thickness, carbon brush
- Balanced 253/254 VSR+HIP+SOLN1+AGE
  400 W, 60 µm layer thickness, carbon brush



Bar plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For nickel-based alloys, the ranges are as follows: 0.2%YS: 0-1400 MPa, UTS: 0-1600 MPa, Elongation: 0-50%, Density: 99-100%, Productivity: 5-60 cm^3/h, Surface Quality (all): 5-40 µm. 0% in the bar plot indicates the lower range value, 100% indicates the upper range value.

Balanced Parameter 253/254 - 400 W / 60 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	30.5
Theoretical melting rate bulk per laser[2]	22.5

[1] Using standard Factory Acceptance Test layout and 2 lasers
[2] Calculated (layer thickness × scan velocity × hatch distance)

Tensile Performance at Room Temperature

Thermal State	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)	
	H	V	H	V	H	V
As-Built	176	153	705	580	1020	950
SOLN1+AGE	186	173	1220	1170	1460	1405
SOLN2+AGE	189	172	1305	1235	1460	1390
VSR+HIP+SOLN1+AGE	195	184	1080	1050	1330	1290

Thermal State	Elongation (%)	
	H	V
As-Built	30.5	32.5
SOLN1+AGE	16.5	15.0
SOLN2+AGE	17.0	16.0
VSR+HIP+SOLN1+AGE	22.0	22.0

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	15	12	10
Downskin	43	13	9

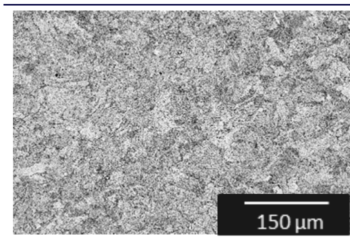
Surface Roughness, Ra (µm)	
H	34
V	8

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	276
SOLN1+AGE	---	---	468
SOLN2+AGE	---	---	475
VSR+HIP+SOLN1+AGE	---	---	443

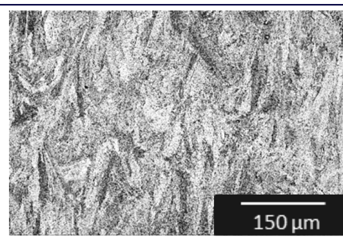
Microstructure

As-Built

H

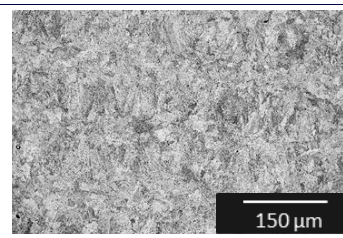


V



SOLN1+AGE

H



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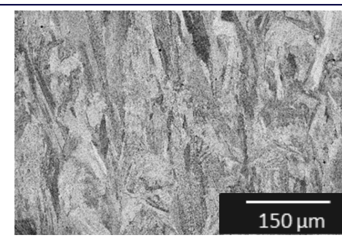
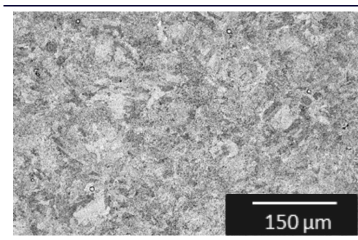


SOLN2+AGE

H



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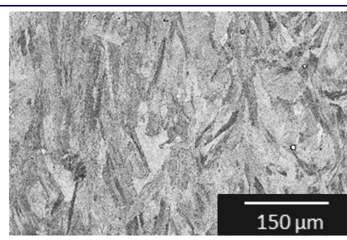
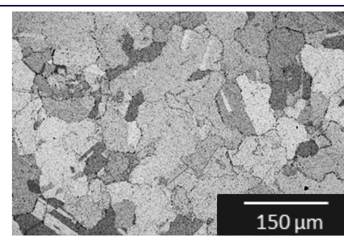


VSR+HIP+SOLN1+AGE

H



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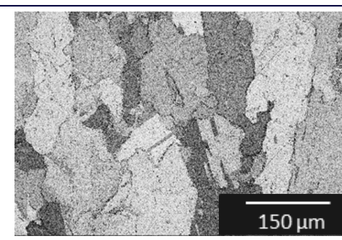
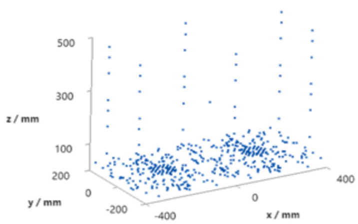
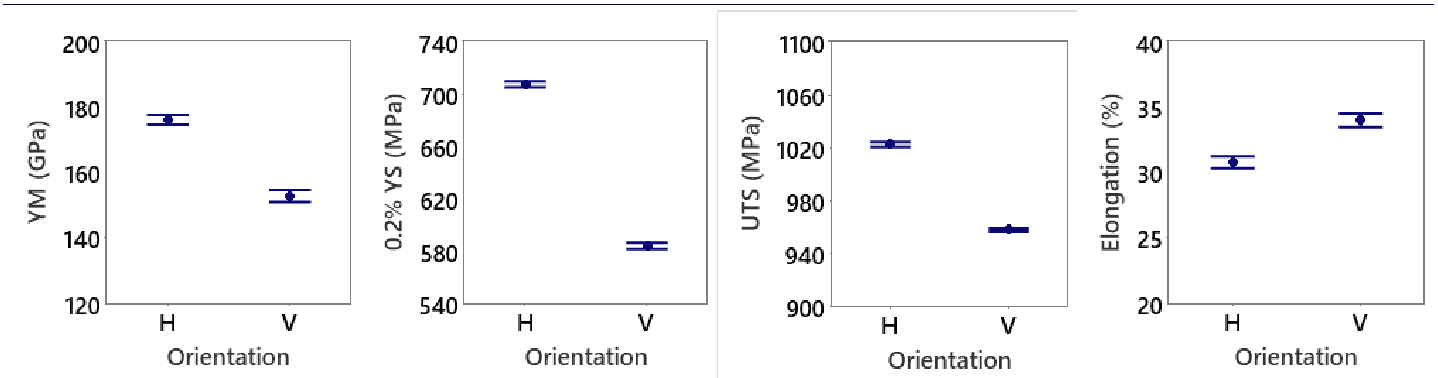


Scanning electron microscope images in As-Built, SOLN1+AGE, SOLN2+AGE and VSR+HIP+SOLN+AGE condition as defined previously.

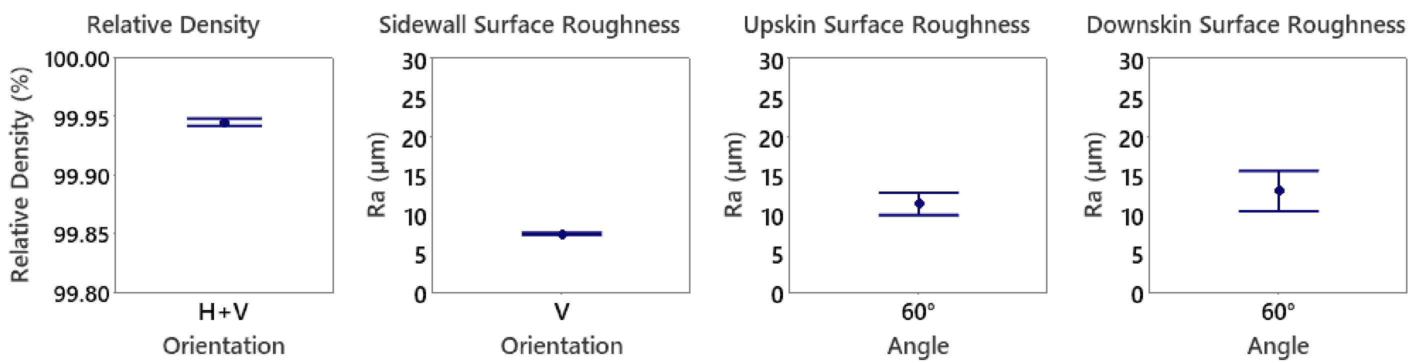
Within 3 platform stability builds relative density, roughness and tensile properties across different positions and orientations are evaluated. To illustrate the position dependency of the X Line 2000R, the samples were homogenously distributed across the platform and height. Regarding surface quality all sides of the specimen, so all orientations with respect to gas flow and optical system, are included in the analysis. Data shown below are dependent on part & print layout as well as batch chemistry variations and thus might deviate from “typical values” given on previous pages.

		Sample Size	Mean	Std. Dev.		Sample Size	Mean	Std. Dev.
	YM (GPa) H/V - AB	82/88	176/156	7/9	Rel. Density (%)	267	99.94	0.03
	0.2% YS (MPa) H/V - AB	82/88	707/583	11/12	Sidewall Roughness Ra (µm)	549	8	2
	UTS (MPa) H/V - AB	82/88	1022/957	9/5	60° Upskin Roughness Ra (µm)	16	11	3
	Elongation (%) H/V - AB	82/88	30.7/33.9	2.0/2.4	60° Downskin Roughness Ra (µm)	16	13	5

Results Platform Stability: Mechanical properties in AB condition



Results Platform Stability: Relative Density and Surface Quality



Data Sheet Nomenclature and Notation

H: Horizontal, perpendicular to build direction.
V: Vertical, parallel to build direction.
Other angles are measured from horizontal.

Roughness measurements have been performed according to DIN EN ISO 4287 and DIN EN ISO 4288. In general analysis of the surface quality is strongly dependent on the methodology used and therefore deviations might be observed depending on methodology used. Vertical and horizontal sidewalls have been characterized using a tactile system, overhangs using an optical system.

Tensile evaluations were performed according to ASTM E8 or E21, depending on test temperature.