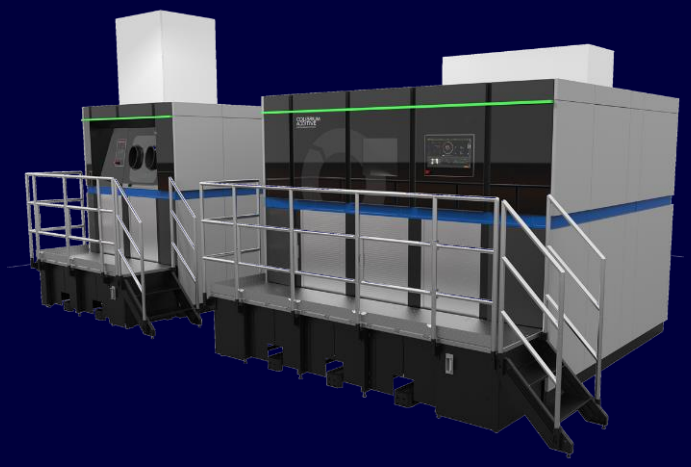
COLIBRIUM ADDITIVE
a GE Aerospace company

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

L-PBF Stainless Steel 316L

Parameter for Colibrium Additive's M Line



Stainless Steel 316L

316L is a chromium-nickel-molybdenum austenitic stainless steel having a higher corrosion resistance compared to the most common stainless steel 304 without any significant disadvantages in costs. By the addition of molybdenum this steel is particularly suitable for components within harsh chemical environments containing chlorides and other halides. Typical applications can be found across a wide range of industries like plant engineering, oil & gas industry, automotive, medical technology, and jewelry and components for molds. 316L is easily weldable and offers excellent ductility and high creep strength at elevated temperatures.

M Line Stainless Steel 316L

The 316L parameter for the Colibrium Additive M Line is developed leveraging the performance of the previous machine generations. The base parameter delivers good surface quality while maintaining a very good density, mechanical strength and productivity.

M Line Stainless Steel 316L

Machine Configuration

M Line

Quad-laser architecture

Nitrogen/Argon gas

Powder Chemistry

316L powder chemical composition according to ASTM F3184 – UNS S31603 / ASTM A276

Particle Size: 15-45 µm

Thermal States

As-Built (AB)

Stress Relief (SR) according to AMS2759/11A

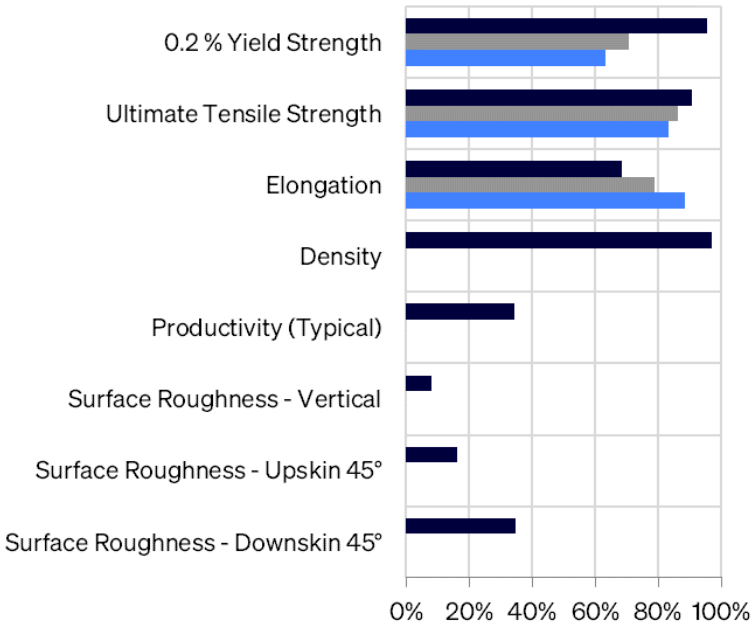
SR: 1h at 899°C, with air cooling

Solution Annealed according to AMS2759/4D (SOLN)

SOLN: 1h at 1066°C, with air cooling

Parameter Availability and Thermal State Comparison

- Base Parameter 358/359 AB
  400 W, 50 µm layer thickness, rubber recoater
- Base Parameter 358/359 SR
  400 W, 50 µm layer thickness, rubber recoater
- Base Parameter 358/359 SOLN
  400 W, 50 µm layer thickness, rubber recoater



Bar Plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For 316L, the ranges are as follows: 0.2% YS: 0-600 MPa, UTS: 0-750 MPa, Elongation: 0-60 %, 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.

Base Parameter 358/359 - 400 W / 50 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	24.0
Theoretical melting rate bulk per laser[2]	17.8

[1] Using standard Factory Acceptance Test layout and 4 lasers

[2] Calculated (layer thickness × scan velocity × hatch distance)

Tensile Performance at Room Temperature

Thermal State	Sample Size	YM (GPa)	0.2% YS (MPa)	UTS (MPa)	Elongation (%)	Area Reduction (%)
As-Built H	12	185	605	710	37.5	69
As-Built H – ST	12	180	600	705	37.5	68
As-Built V	64	155	545	655	44.5	73
SR H	12	190	440	675	43.5	68
SR H – ST	12	190	435	670	43.5	68
SR V	36	195	415	625	51.5	73
SOLN H	30	195	385	645	48.5	65
SOLN H – ST	---	---	---	---	---	---
SOLN V	30	200	375	605	57.5	71

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	11	8	7
Downskin	18	8	7

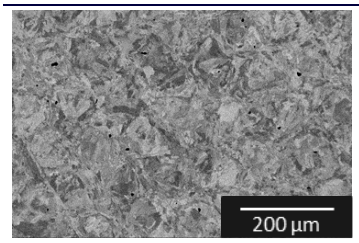
Surface Roughness, Ra (µm)	
H	---
V	8

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	222
SR	---	---	195
SOLN	---	---	183

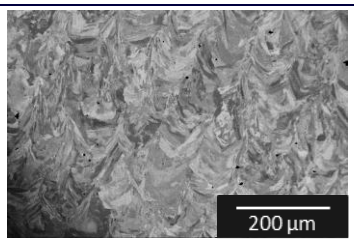
Microstructure

As-Built

H

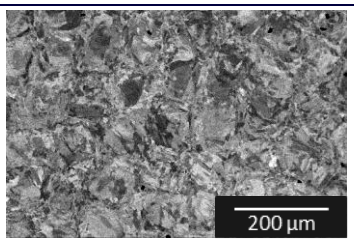


V



SR

H



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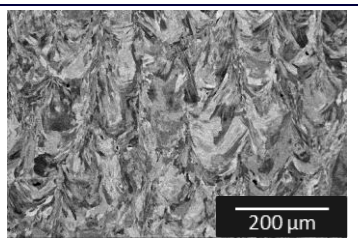
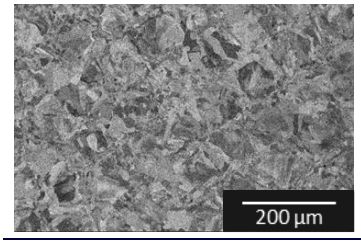


SOLN

H



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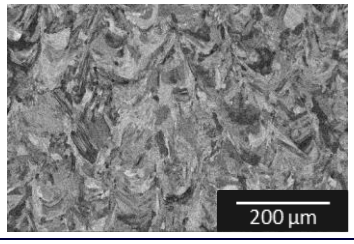
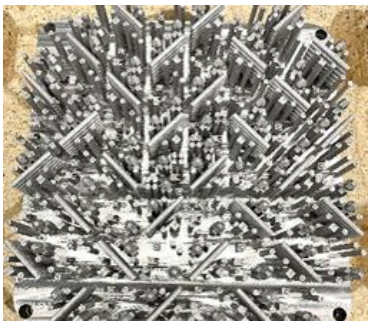


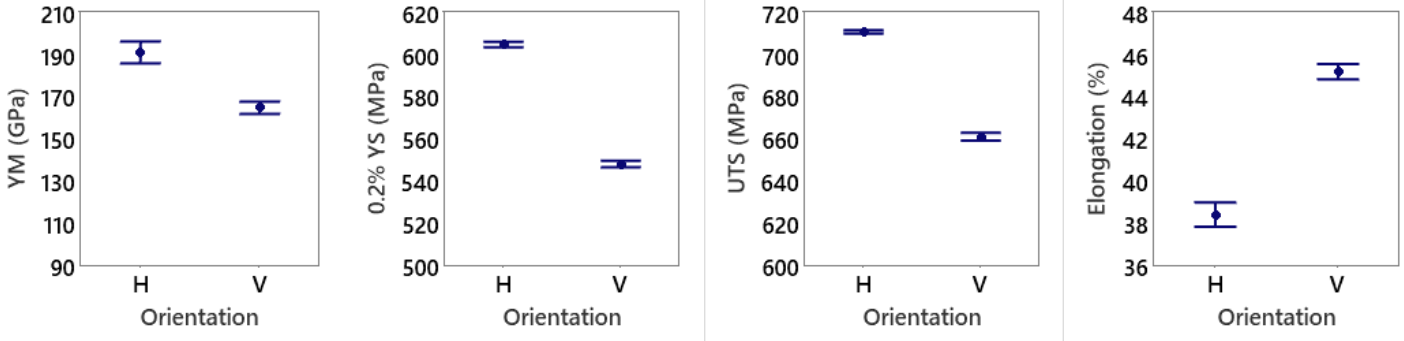
Scanning electron microscope images in As-Built, Stress Relief and Solution Annealed condition as defined previously.

The platform stability build evaluates relative density, roughness and tensile properties across different positions and orientations. To illustrate the position dependency of the M Line, the samples were homogenously distributed across the platform on 30 different positions. 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.

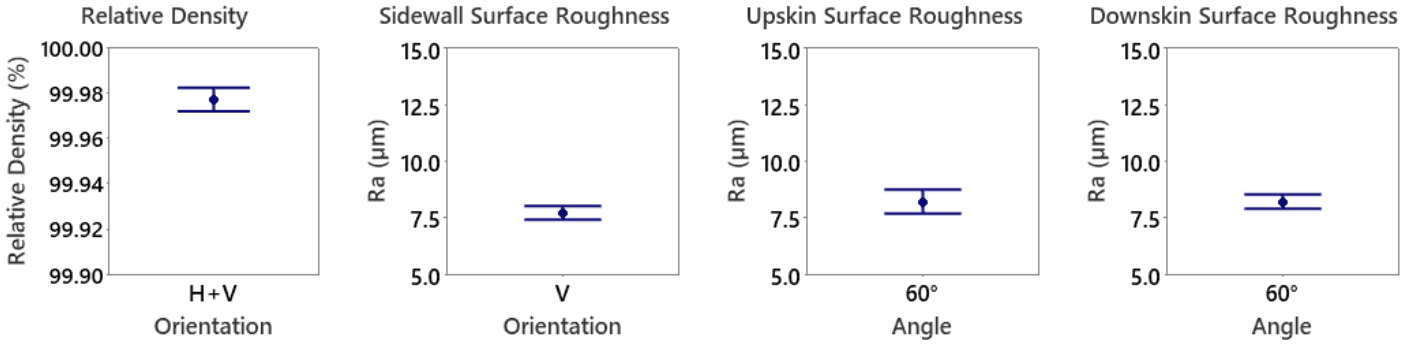


	Sample Size	Mean	Std. Dev.		Sample Size	Mean	Std. Dev.
YM (GPa) H/V – AB	30/30	190/164	14/8	Rel. Density (%)	60	99.98	0.02
0.2% YS (MPa) H/V – AB	30/30	604/547	4/5	Sidewall Roughness Ra (µm)	30	8	1
UTS (MPa) H/V – AB	30/30	710/660	3/6	60° Upskin Roughness Ra (µm)	30	9	1
Elongation (%) H/V – AB	30/30	38.3/45.1	1.6/1.0	60° Downskin Roughness Ra (µm)	30	9	1

Results Platform Stability: Mechanical properties in AB condition



Results Platform Stability: Relative Density and Surface Quality



Data Sheet Nomenclature and Notation

H: Horizontal, X or Y.
V: Vertical, Z.
Other angles are measured from horizontal.

ST: Stitched, parts built by multiple optical systems

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.