COLIBRIUM ADDITIVE
a GE Aerospace company

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

L-PBF Maraging Steel M300

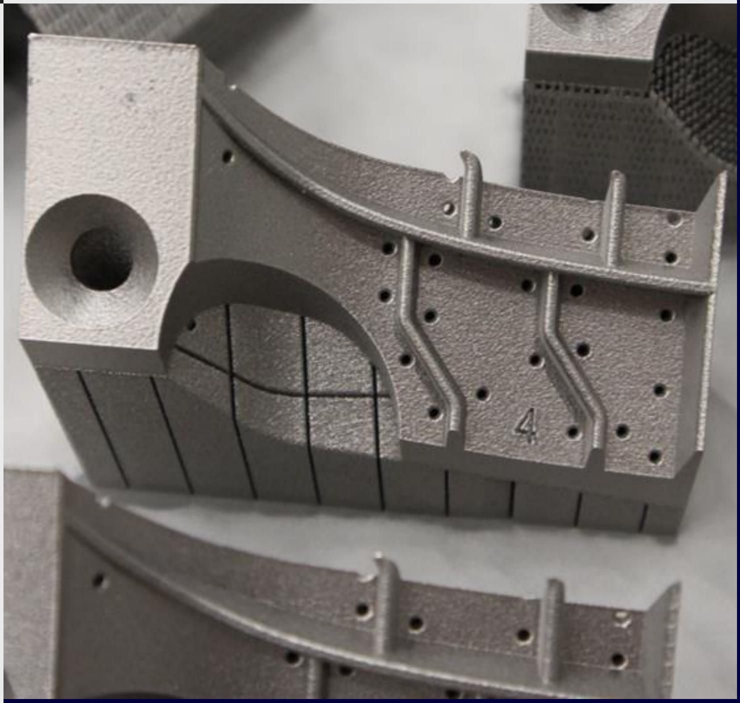
Parameters for Colibrium Additive's M2 Series 5

Maraging Steel M300

Maraging steel M300 has a chemical composition according to 1.2709 and similar to ASTM A646/A646M with exception of Mn, Ni, Co, Ti content. Maraging steels are a class of low-carbon high strength alloys that achieve high strength from intermetallic precipitates while maintaining good ductility. Because of their high strength and hardenability, maraging steels lend themselves to a variety of applications, including manufacturing tool components, structural components, and die casting and injection molding tools.

M2 Series 5 M300

The M300 parameters for the Colibrium Additive M2 Series 5 are developed leveraging the performance of the previous M2 generations. The balanced parameter delivers good surface quality, while maintaining a very good density, mechanical strength and productivity. To gain highest all-around surface quality and best part resolution the surface parameter has been developed. To maximize the build rate, the productivity parameter can be used, which is processable using rubber or steel recoater. The hybrid parameter combines surface & productivity parameter and can significantly increase the productivity of parts having a high volume/surface ratio and still meeting highest surface quality requirements.



M2 Series 5 M300

Machine Configuration

M2 Series 5

Single- or dual-laser architecture

Nitrogen gas

Powder Chemistry

Maraging Steel M300 powder chemical composition et al. according to 1.2709 and similar to ASTM A646/A646M with exception of Mn, Ni, Co, Ti content.

Particle size: 10-45 µm

Thermal States

As-Built (AB)

Solution Annealed + Age (SOLN+AGE)

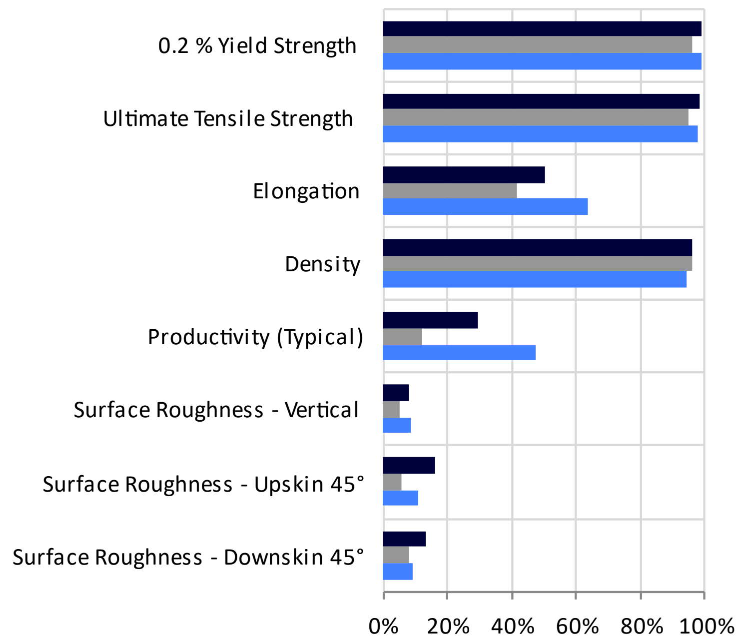
SOLN: 940 °C for 2 hours in argon; cooling in air; AGE: 490 °C for 6 hours in argon; cooling in air

Stress Relief (SR)

840°C for 2 hours in argon; furnace cooling

Parameter Availability and Thermal State Comparison

- Balanced Parameter 298 SOLN+AGE
  400 W, 40 µm layer thickness, rubber recoater
- Surface Parameter 299 SOLN+AGE
  400 W, 25 µm layer thickness, rubber recoater
- Productivity Parameter 300/301 SOLN+AGE
  400 W, 50 µm layer thickness rubber/steel 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 M300, the ranges are as follows: 0.2%YS: 0-2200 MPa UTS: 0-2300 MPa, Elongation: 0-6%, Density: 99-100%, Productivity: 5-40 cm³/h, Surface Quality (all): 3-40 µm. 0% in the bar plot indicates the lower range value, 100% indicates the upper range value

Balanced Parameter 298 - 400 W / 40 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	15.4
Theoretical melting rate bulk per laser[2]	15

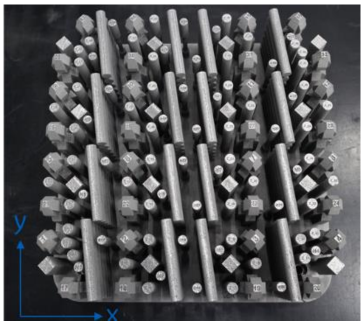
[1] Using standard Factory Acceptance Test layout and 2 lasers
[2] Calculated (layer thickness × scan velocity × hatch distance)

Tensile Performance at Room Temperature

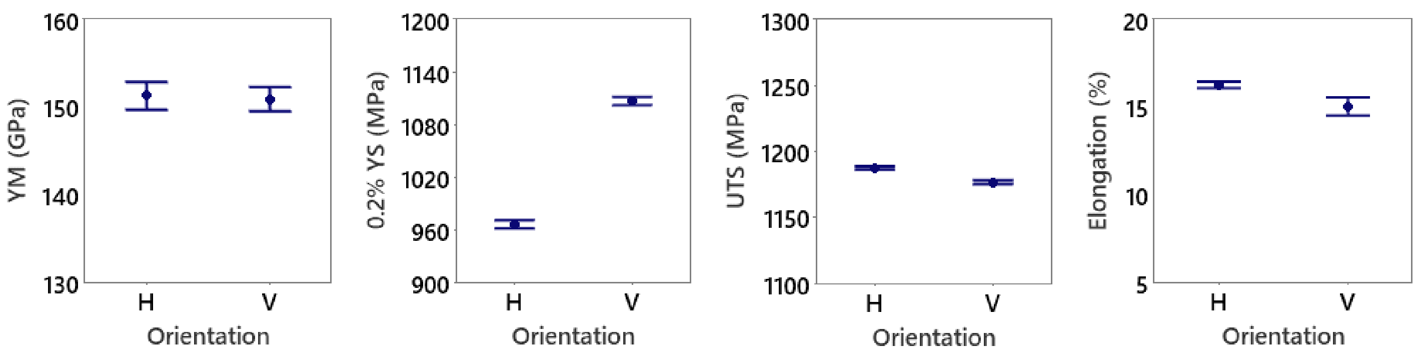
Thermal State	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)	
	H	V	H	V	H	V
As-Built	152	153	820	1095	1115	1180
SOLN+AGE	183	184	2175	2175	2255	2255

Thermal State	Elongation (%)	
	H	V
As-Built	15	13.5
SOLN+AGE	3	3

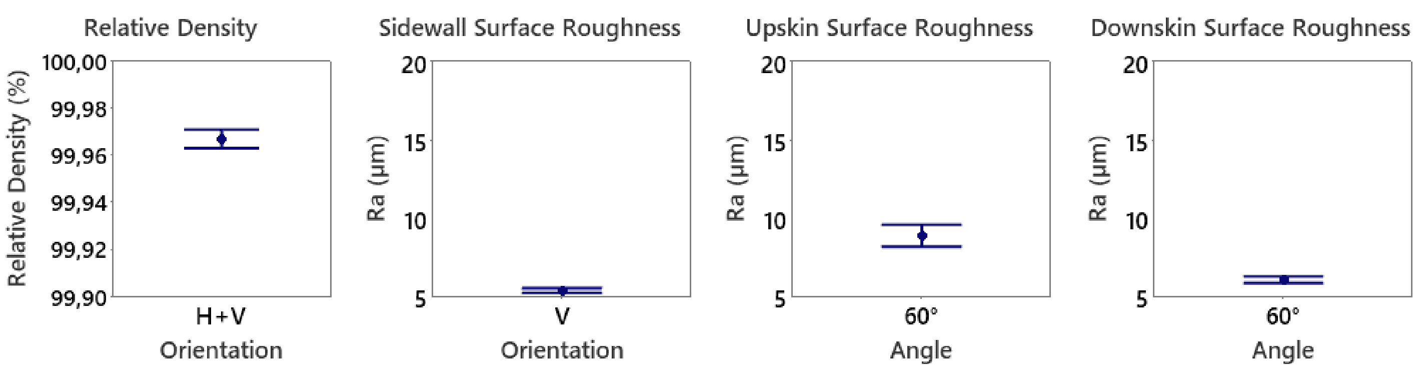
The platform stability build evaluates relative density, roughness and tensile properties across different positions and orientations. To illustrate the position dependency of the M2 Series 5, the samples were homogenously distributed across the platform on 16 different positions. Regarding surface quality 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	16/16	151/151	3/3	Rel. Density (%)	32	99.97	0.01
	0.2% YS (MPa) H/V - AB	16/16	966/1107	9/8	Sidewall Roughness Ra (µm)	64	5.3	0.6
	UTS (MPa) H/V - AB	16/16	1187/1176	2/3	60° Upskin Roughness Ra (µm)	64	8.9	2.8
	Elongation (%) H/V - AB	16/16	16.2/15	0.3/1	60° Downskin Roughness Ra (µm)	64	6.1	0.8

Results Platform Stability: Mechanical properties in As-Built condition



Results Platform Stability: Relative Density and Surface Quality



Surface Parameter 299 - 400 W / 25 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	9.3
Theoretical melting rate bulk per laser[2]	7.2

[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	150	165	950	1135	1140	1195
SOLN+AGE	190	192	2100	2115	2175	2190

Thermal State	Elongation (%)	
	H	V
As-Built	13.5	13.0
SOLN+AGE	3.0	2.0

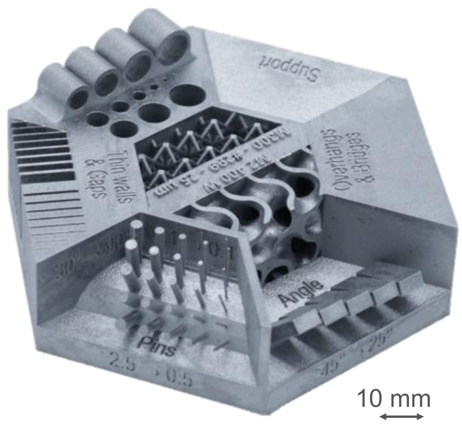
Physical Properties at Room Temperature

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	6	5	4
Downskin	6	5	4

Surface Roughness, Ra (µm)	
H	9
V	5

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	356
SOLN+AGE	---	---	636

The minimum feature resolution part was designed to demonstrate parameter capability to produce specific features such as minimum wall thickness, minimum gap width, minimum pin diameter, minimum drill hole diameter (horizontal and vertical), minimum unsupported downskin angle, and maximum unsupported bridge length.



Feature	Result
Minimum Wall Thickness (mm)	0.16
Minimum Gap Width (mm)	0.13
Minimum Pin Diameter (mm)	0.26
Minimum Drill Hole Diameter, V (mm)	0.45
Minimum Drill Hole Diameter, H (mm)	0.35
Minimum Printable Angle (°)	25
Maximum Bridge Length (mm)	5

Hybrid Parameter 171 - 400 W / 25/50 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	8.6 (8-20)[3]
Theoretical melting rate bulk per laser[2]	7.2

[1] Using standard Factory Acceptance Test layout and 2 lasers
[2] Calculated (layer thickness × scan velocity × hatch distance)
[3] The hybrid parameter build rate is strongly dependent on application design, in particular wall thickness. For this parameter, a larger increase in productivity (faster build rate) can be expected for parts having high volume/surface ratios

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	149	162	970	1145	1160	1200
SOLN+AGE	188	189	2090	2100	2165	2175

Thermal State	Elongation (%)	
	H	V
As-Built	14.0	13.0
SOLN+AGE	3.5	3.5

Physical Properties at Room Temperature

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	6	5	4
Downskin	7	5	5

Surface Roughness, Ra (µm)	
H	10
V	5

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	363
SOLN+AGE	---	---	641

Productivity Parameter 300/301 - 400 W / 50 μm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	21.6
Theoretical melting rate bulk per laser[2]	18.7

[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	156	162	840	1035	1105	1155
SOLN+AGE	187	187	2200	2220	2270	2290

Thermal State	Elongation (%)	
	H	V
As-Built	14.5	12.5
SOLN+AGE	3.0	2.5

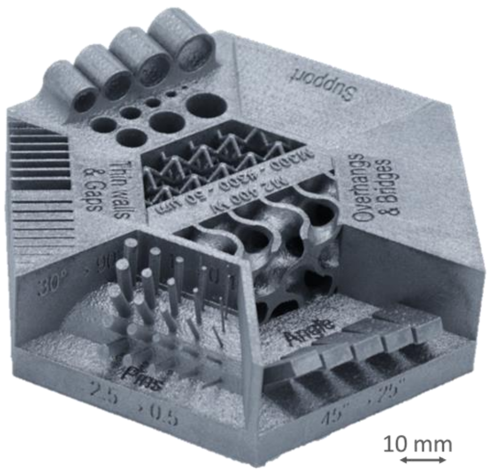
Physical Properties at Room Temperature

	Overhang Surface Roughness, Ra (μm)		
	45°	60°	75°
Upskin	8	6	5
Downskin	11	7	5

Surface Roughness, Ra (μm)	
H	9
V	6

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	356
SOLN+AGE	---	---	636

The minimum feature resolution part was designed to demonstrate parameter capability to produce specific features such as minimum wall thickness, minimum gap width, minimum pin diameter, minimum drill hole diameter (horizontal and vertical), minimum unsupported downskin angle, and maximum unsupported bridge length.



Feature	Result
Minimum Wall Thickness (mm)	0.14
Minimum Gap Width (mm)	0.11
Minimum Pin Diameter (mm)	0.23
Minimum Drill Hole Diameter, V (mm)	0.45
Minimum Drill Hole Diameter, H (mm)	0.41
Minimum Printable Angle (°)	25
Maximum Bridge Length (mm)	5

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.

Minimum features have been characterized using a coordinate measuring machine (CMM) and an optical microscope.