COLIBRIUM ADDITIVE
a GE Aerospace company

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

L-PBF Ti6Al4V Grade 23

Parameters for Colibrium Additive's M2 Series 5

Titanium Ti6Al4V Grade 23 (ELI)

Ti6Al4V Grade 23, renowned for its exceptional strength-to-weight ratio, is ideal for additive manufacturing. It offers outstanding biocompatibility, making it perfect for medical implants. Its superior corrosion resistance ensures longevity and reliability in demanding environments. This alloy is widely used in the aerospace industry for critical components, in the medical field for durable implants, and in high-performance motorsports for lightweight, robust parts. Its versatile properties make Ti6Al4V Grade 23 a preferred choice across these advanced industries.

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M2 Series 5 Ti6Al4V

The parameters for the Colibrium Additive M2 Series 5 (1 kW) are designed to reach high productivity. The balanced 1 kW parameter has a layer thickness of 60 µm and provides nearly 20% higher productivity than the 60 µm 400 W counterpart, but still offers similar surface quality. The maximum productivity of 79 cm^3/h for a dual-laser system can be achieved with the productivity 1 kW parameter, which has a layer thickness of 120 µm. Both parameters exhibit outstanding tensile properties in stress relieved state and meet the ASTM F136-02a (ELI Grade 23)/ ASTM F3001 standard.

M2 Series 5 Ti6Al4V

Machine Configuration

M2 Series 5 (1 kW)

Single- or dual-laser architecture

Argon gas

Platform heating: 200°C

Powder Chemistry

Ti6Al4V Grade 23 (ELI) powder chemical composition according to ASTM F3001

Particle size: 15-45 µm

For more information, visit: AP&C

Thermal States

As-Built (AB)

Stress Relief (SR1)

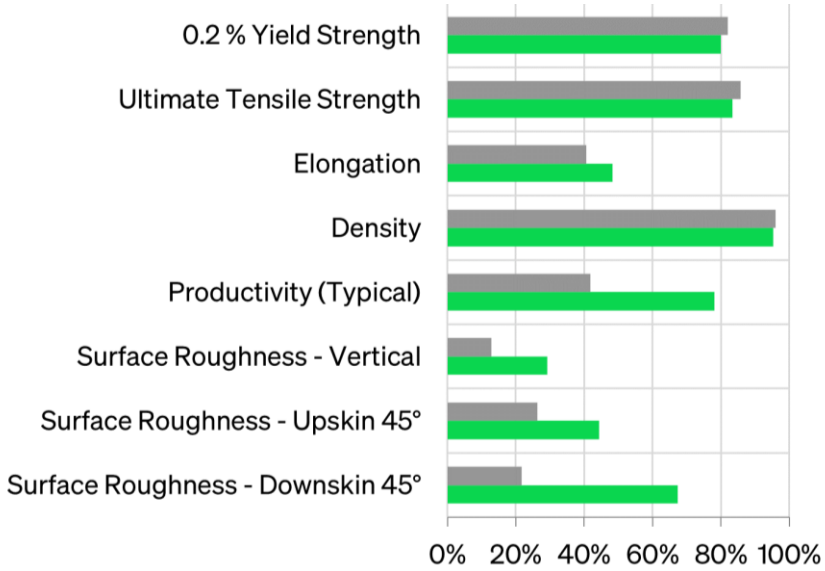
900°C for 1 hour in argon; furnace cooling

Stress Relief (SR2)

840°C for 2 hours in argon; furnace cooling

Parameter Availability and Thermal State Comparison

- Balanced 1 kW Parameter 364 AB
  1 kW, 60 µm layer thickness, rubber recoater
- Productivity 1 kW Parameter 397 AB
  1 kW, 120 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 titanium-based alloys, the ranges are as follows: 0.2%YS: 0-1250 MPa UTS: 0-1350 MPa, Elongation: 0-20%, Density: 99-100%, Productivity: 5-70 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 1 kW Parameter 364 - 1 kW / 60 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	44.7
Theoretical melting rate bulk per laser[2]	69.1

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

Tensile Performance at Room Temperature

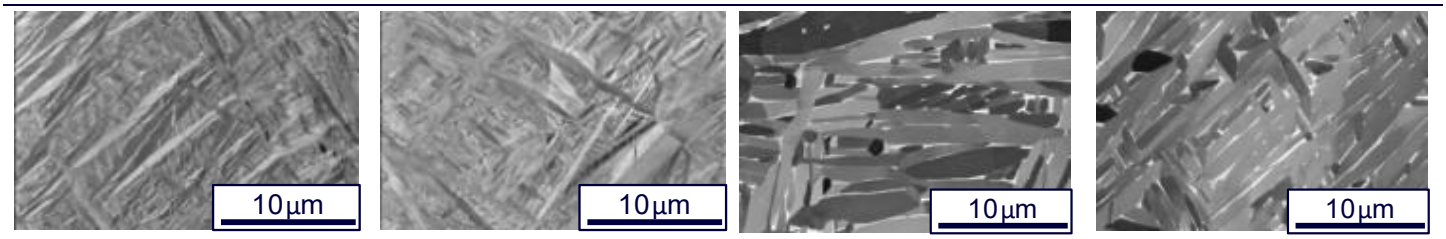
Thermal State	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)	
	H	V	H	V	H	V
As-Built	110	112	975	1070	1125	1190
SR1	117	111	905	830	1005	965
SR2	117	111	907	840	1025	990

Thermal State	Elongation (%)		Area Reduction (%)	
	H	V	H	V
As-Built	10.0	8.5	30	37
SR1	16.0	16.0	43	46
SR2	14.0	11.0	34	31

SR2 is recommended.

Microstructure

As-Built		SR2	
H	V	H	V



Scanning electron microscope images in As-Built and Stress Relief (SR2) condition as defined previously.

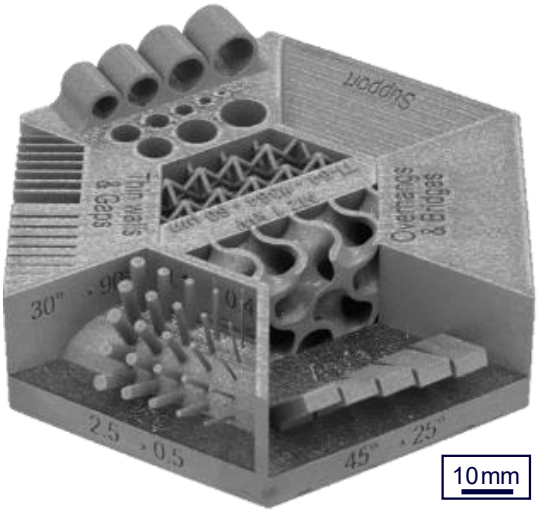
	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	15	13	10
Downskin	13	8	7

Surface Roughness, Ra (µm)	
H	18
V	10

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	347
SR1	99.9	99.9	328
SR2	99.9	99.9	335

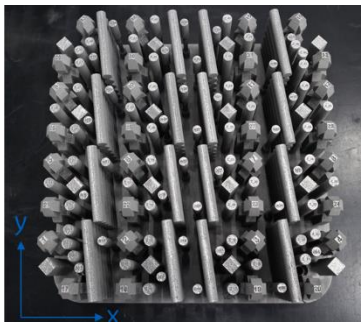
Minimum Feature Resolution

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.



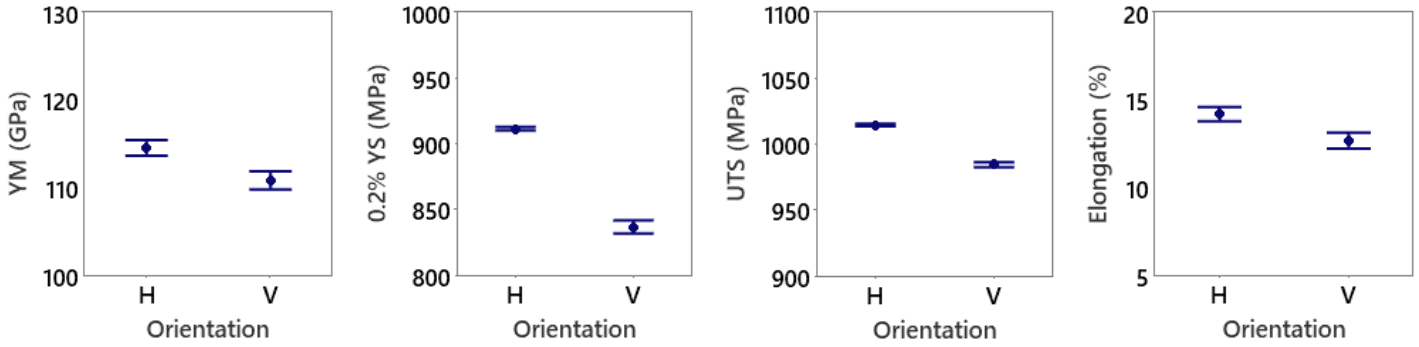
Feature	Result
Minimum Wall Thickness (mm)	0.18
Minimum Gap Width (mm)	0.12
Minimum Pin Diameter (mm)	0.20
Minimum Drill Hole Diameter, V (mm)	0.49
Minimum Drill Hole Diameter, H (mm)	0.34
Minimum Printable Angle (°)	25
Maximum Bridge Length (mm)	5

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.

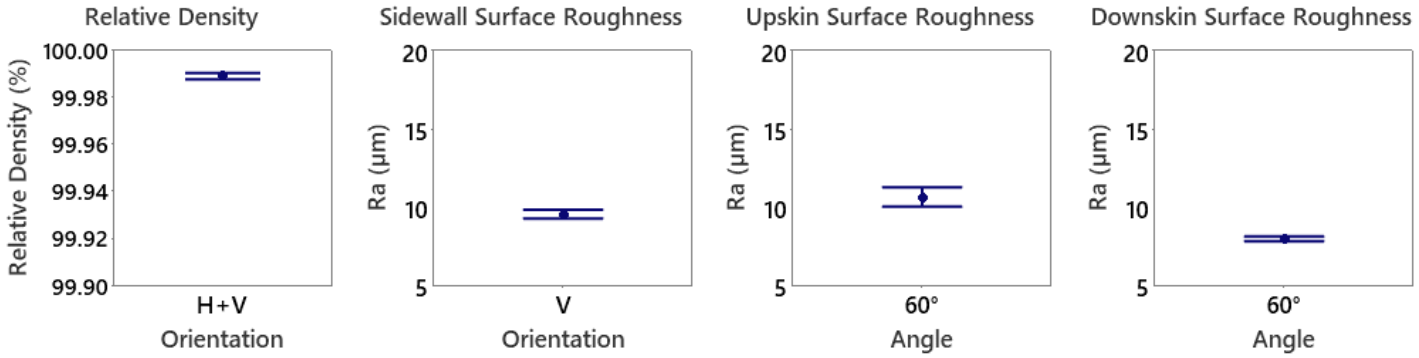


	Sample Size	Mean	Std. Dev.		Sample Size	Mean	Std. Dev.
YM (GPa) H/V - SR2	16/16	115/111	2/2	Rel. Density (%)	32	99.99	0.01
0.2% YS (MPa) H/V - SR2	16/16	911/837	2/9	Sidewall Roughness Ra (µm)	64	9.4	1.2
UTS (MPa) H/V - SR2	16/16	1015/984	2/3	60° Upskin Roughness Ra (µm)	64	10.6	2.5
Elongation (%) H/V - SR2	16/16	14.2/12.7	0.7/0.8	60° Downskin Roughness Ra (µm)	64	8.0	0.6

Results Platform Stability: Mechanical properties in SR2 condition



Results Platform Stability: Relative Density and Surface Quality



Productivity 1 kW Parameter 397 - 1 kW / 120 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	79.2
Theoretical melting rate bulk per laser[2]	90.7

[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	114	113	1005	990	1115	1130
SR1	116	113	900	830	1005	970

Thermal State	Elongation (%)		Area Reduction (%)	
	H	V	H	V
As-Built	11.0	8.0	35	28
SR1	15.5	14.5	41	45

Physical Properties at Room Temperature

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	21	17	13
Downskin	29	17	13

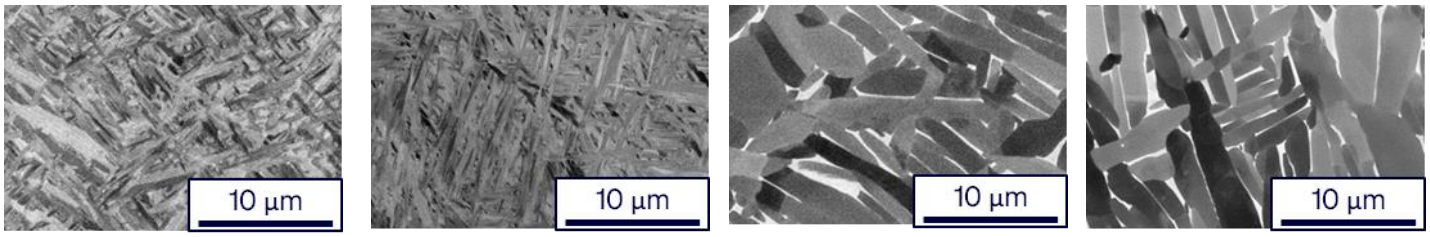
Surface Roughness, Ra (µm)	
H	17
V	16

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	350
SR1	99.9	99.9	335

Microstructure

Parameter 397

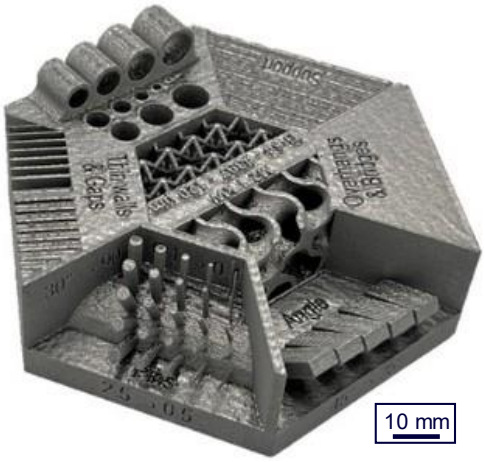
As-Built		SR1	
H	V	H	V



Scanning electron microscope images in As-Built and Stress Relief (SR1) condition as defined previously.

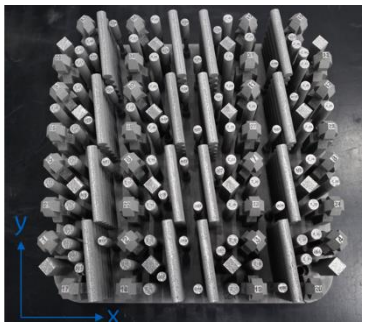
Minimum Feature Resolution

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.



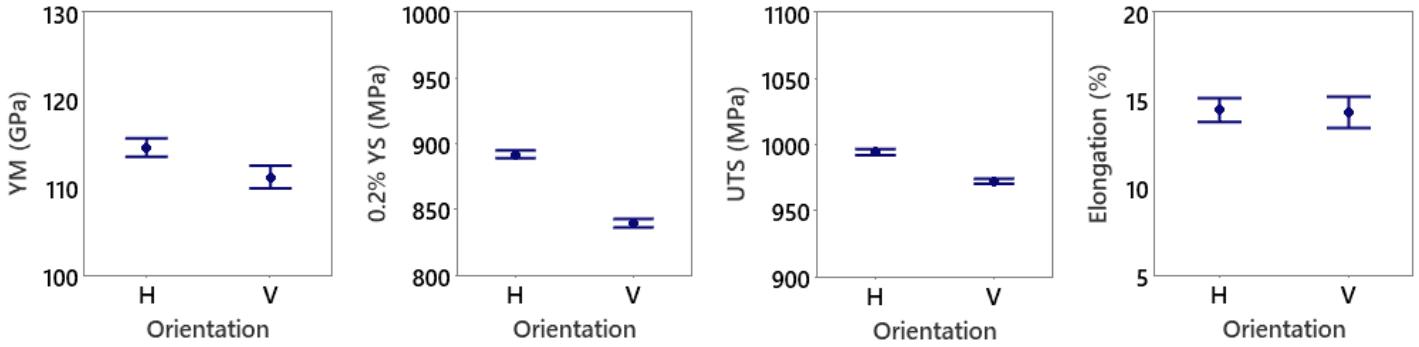
Feature	Result
Minimum Wall Thickness (mm)	0.22
Minimum Gap Width (mm)	0.11
Minimum Pin Diameter (mm)	0.35
Minimum Drill Hole Diameter, V (mm)	0.47
Minimum Drill Hole Diameter, H (mm)	0.35
Minimum Printable Angle (°)	25
Maximum Bridge Length (mm)	5

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.

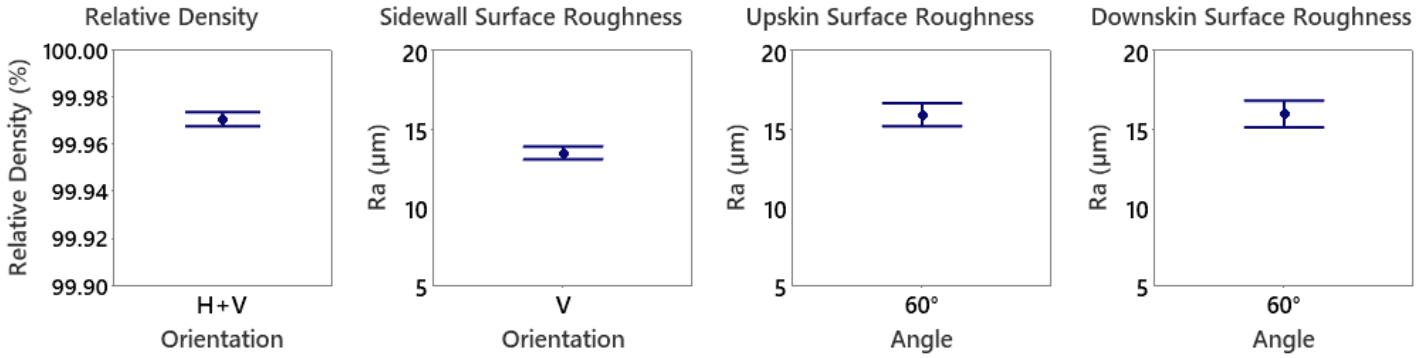


	Sample Size	Mean	Std. Dev.		Sample Size	Mean	Std. Dev.
YM (GPa) H/V - SR1	16/16	115/111	2/2	Rel. Density (%)	32	99.97	0.01
0.2% YS (MPa) H/V - SR1	16/16	892/839	6/6	Sidewall Roughness Ra (µm)	64	13.5	1.6
UTS (MPa) H/V - SR1	16/16	994/972	4/3	60° Upskin Roughness Ra (µm)	64	15.9	2.9
Elongation (%) H/V - SR1	16/16	14.4/14.3	1.3/1.7	60° Downskin Roughness Ra (µm)	64	15.9	3.4

Results Platform Stability: Mechanical properties in SR1 condition



Results Platform Stability: Relative Density and Surface Quality



Data Sheet Nomenclature and Notation

ELI: Extra Low Interstitials.

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.

All figures and data contained herein are approximate and/or typical only and are dependent on several factors including but not limited to process and machine parameters. The information provided on this material data sheet is illustrative only and cannot be considered binding.