COLIBRIUM ADDITIVE
a GE Aerospace company

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

L-PBF CpTi

Parameters for Colibrium Additive's M2 Series 5

Titanium CpTi

In general, titanium and its alloys have been used extensively in many industries due to their low density, high corrosion resistance and oxidation resistance. Commercially pure titanium (CpTi), due its biocompatibility and lack of potentially harmful alloying elements, is especially useful for medical devices and non-load bearing devices such as medical implants or trauma plates. Titanium alloys are used in additive manufacturing to produce a wide range of industrial components, including blades, fasteners, rings, discs, hubs, and vessels.

M2 Series 5 CpTi

The parameters for the Colibrium Additive M2 Series 5 were developed to achieve good surface quality on one hand and good productivity on the other. The surface parameter uses 30 µm layer thickness that produces optimal surface roughness in the range of 10 µm without the need for bead blasting or shot peening. The balanced 60 µm parameter showed similar vertical surface quality with approximately 1.6 times increased productivity.

Moreover, the microstructures of both parameters show extremely low amount of porosity.

The parameter has outstanding tensile properties exceeding the limits for conventional processed CpTi according to ASTM B348 Grade 2 in the stress relieved state.

M2 Series 5 CpTi

Machine Configuration

M2 Series 5

Single- or dual-laser architecture

Argon gas

Powder Chemistry

CpTi powder chemical composition according to ASTM B348 Grade 2

Particle size: 15-45 µm

For more information, visit: AP&C

Thermal States

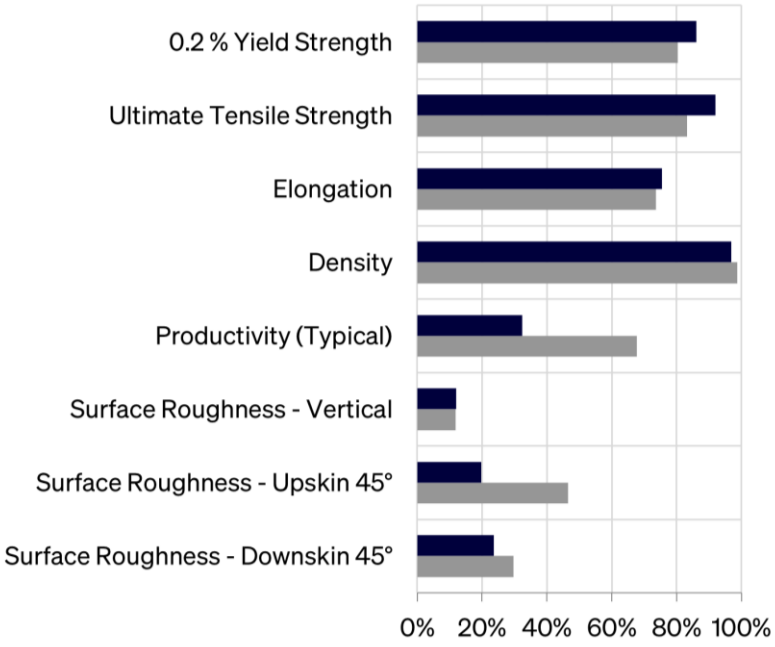
As-Built (AB)

Stress Relief (SR)

625°C for 1.25 hour in argon; furnace cooling

Parameter Availability and Thermal State Comparison

- Surface Parameter 174 (AB)
  400 W, 30 µm layer thickness, rubber recoater
- Balanced Parameter 223 (AB)
  400 W, 60 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 commercial pure titanium, the ranges are as follows: 0.2%YS: 0-700 MPa UTS: 0-800 MPa, Elongation: 0-30%, Density: 99-100%, Productivity: 5- 35 cm³/h, Surface Quality (all): 5-40 µm. 0% in the bar plot indicates the lower range value, 100% indicates the upper range value.

Surface Parameter 174 - 400 W / 30 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	14.7
Theoretical melting rate bulk per laser[2]	16.6

[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	111	107	615	585	720	745
SR	108	115	475	520	595	620

Thermal State	Elongation (%)		Area Reduction (%)	
	H	V	H	V
As-Built	23	22	61	64
SR	25	25	53	59

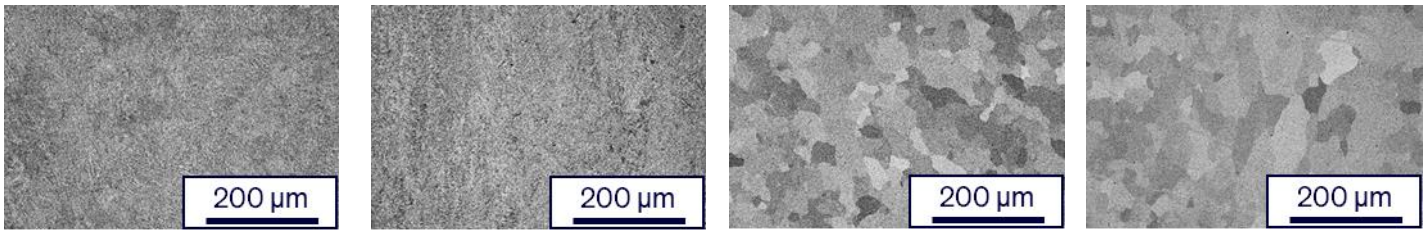
	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	12	10	7
Downskin	14	10	7

Surface Roughness, Ra (µm)	
H	10
V	10

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	234
SR	99.9	99.9	213

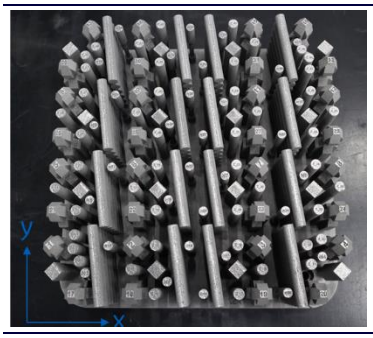
Microstructure

As-Built		SR	
H	V	H	V



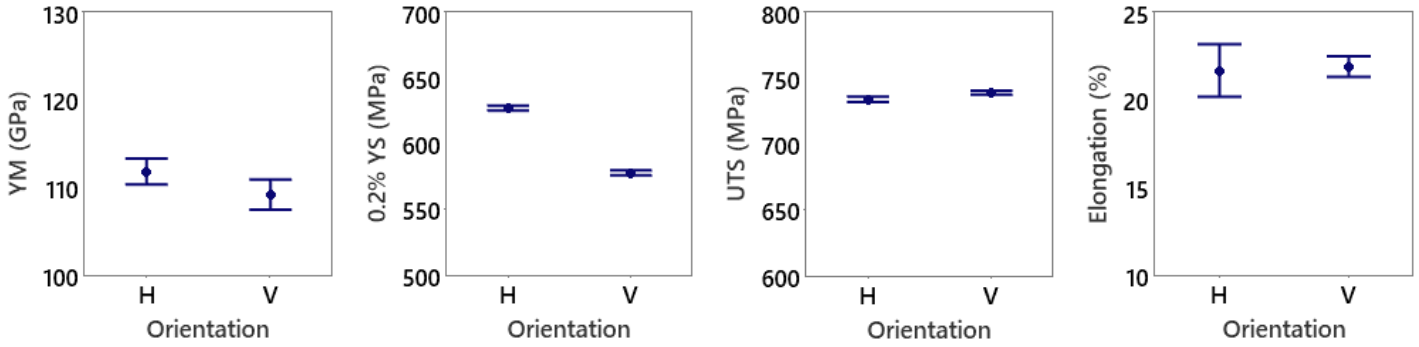
Scanning electron microscope images in As-Built and Stress Relief (SR) condition as defined previously.

The platform stability build evaluates relative density, roughness and tensile properties across different positions and orientations. To illustrate the position dependency of the 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.

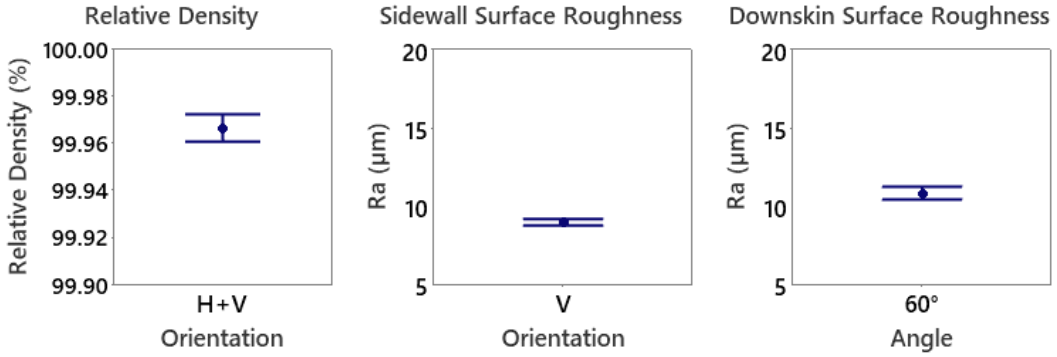


	Sample Size	Mean	Std. Dev.		Sample Size	Mean	Std. Dev.
YM (GPa) H/V - SR	16/16	112/109	3/3	Rel. Density (%)	32	99.97	0.02
0.2% YS (MPa) H/V - SR	16/16	627/578	4/4	Sidewall Roughness Ra (µm)	64	9.0	0.8
UTS (MPa) H/V - SR	16/16	734/739	4/3	60° Downskin Roughness Ra (µm)	64	10.8	1.6
Elongation (%) H/V - SR	16/16	21.7/21.9	2.8/1.1				

Results Platform Stability: Mechanical properties in SR condition



Results Platform Stability: Relative Density and Surface Quality



Balanced Parameter 223 - 400 W / 60 µm

Typical Build Rate

	(cm^3/h)
Typical build rate with coating[1]	25.3
Theoretical melting rate bulk per laser[2]	25.9

[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	560	560	665	665

Thermal State	Elongation (%)		Area Reduction (%)	
	H	V	H	V
As-Built	22.0	21.5	49	58

Physical Properties at Room Temperature

	Overhang Surface Roughness, Ra (µm)		
	45°	60°	75°
Upskin	22	17	13
Downskin	16	12	9

Surface Roughness, Ra (µm)	
H	15
V	10

Thermal State	Relative Density (%)		Hardness (HV10)
	H	V	H
As-Built	99.9	99.9	234

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.