13 Al

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

M2 Series 5 Steel 316L

Parameters for GE Additive's Concept Laser M2 Series 5

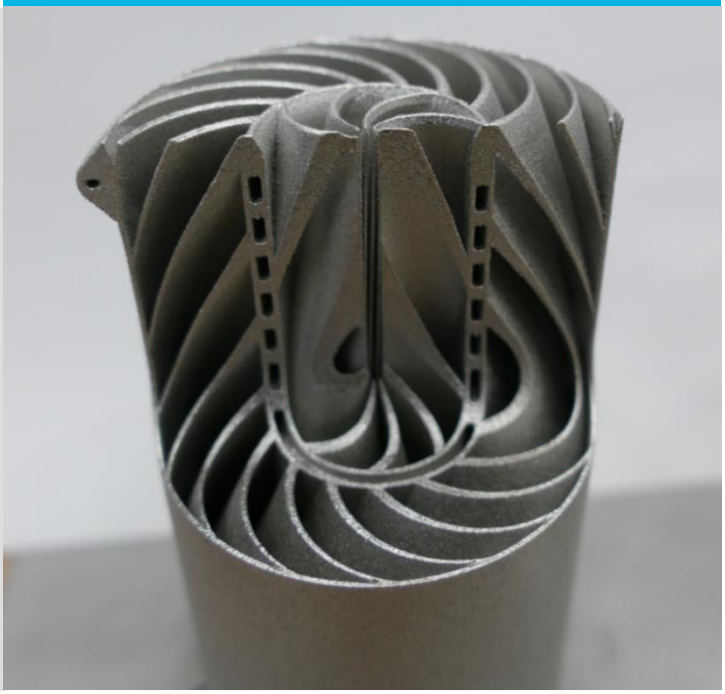
Data in this material datasheet represent material built with 25 and 50 µm layer thicknesses and in a nitrogen atmosphere on a Concept Laser M2 Series 5 single-laser or dual-laser machine. Values listed are typical.

316L Stainless Steel

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.

M2 Series 5 Steel 316L

The 316L parameters for the Concept Laser M2 Series 5 are developed leveraging the performance of the previous M2. The base parameter deliver good surface quality while maintaining a very good density, mechanical strength and productivity. For highest all-around surface quality, particularly within overhang downskin and upskin regions, the surface parameter has been developed.
All parameters succeed the minimum tensile properties specified in ASTM F3184 for additive manufactured parts in the stress relieved state.



M2 Series 5 Steel 316L

With corresponding approval* Steel 316L can be used for manufacturing components for acid- and corrosion-resistant applications in the following fields: plant engineering, automotive, medical technology, and jewelry and components for molds.

Data in this material datasheet represent material built with 25 and 50 µm layer thicknesses in a nitrogen atmosphere on a Concept Laser M2 Series 5 single-laser or dual-laser machine. Values listed are typical.

POWDER CHEMISTRY

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

MACHINE CONFIGURATION

- Concept Laser M2 Series 5 (single-laser or dual-laser)
- Nitrogen gas
- Rubber/Steel recoater blade

AVAILABLE PARAMETERS

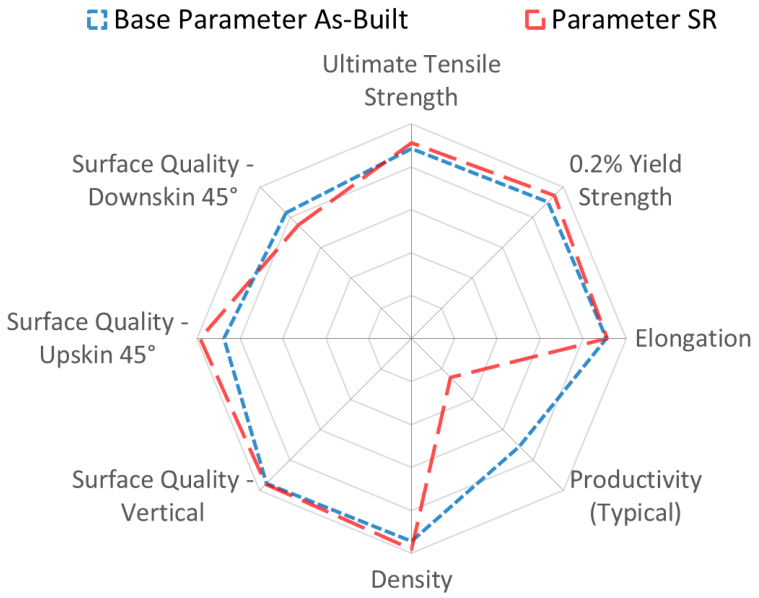
- **Base Parameter 244 / 294**** 50 µm layer thickness, rubber recoater
- **Base Parameter 245 / 295**** 50 µm layer thickness, steel recoater
- **Surface Parameter 165 / 293**** 25 µm layer thickness, rubber recoater

**productivity optimized version (productivity bundle required)

THERMAL STATES

1. As-Built
2. Stress Relief according to AMS2759 (SR1)
   SR: 1h at 899°C, with air cooling
3. Stress Relief (SR2)
   SR: 3h to 550°C, hold 6h at 550°
4. Solution Anneal (SOLN)
   SOLN: 4h at 1100°C, with water quench

PARAMETER COMPARISON



Spider Plot is generated by normalizing typical material data (containing both horizontal and vertical data) against a range defined for each material family. For **Stainless Steels**, the ranges are as follows: UTS: 0-750 MPa, 0.2%YS: 0-600 MPa, Elongation: 0-60 %, Density: 99-100 %, Productivity: 5-30 cm³/h, Surface Quality (all): 50-5 µm

TYPICAL BUILD RATE

Base Parameter

	Standard (cm³/h)	Productivity optimized (cm³/h)
Typical build rate[1] w/coating	20.5	21.3
Theoretical melting rate[2] bulk per Laser	18.0	18.0

[1]Using standard Factory Acceptance Test layout and 2 lasers

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

PHYSICAL DATA AT ROOM TEMPERATURE

	Surface Roughness Ra** - Overhang (µm)		
	45°	60°	75°
Upskin	11	8	6
Downskin	13	11	8

	Surface Roughness Ra** (µm)
H	9
V	7

	Relative Density (%)		Hardness (HV10)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.9	99.9	212	--	--	--
SR1	--	--	--	--	--	--
SR2	--	--	--	--	--	--
SOLN	--	--	147	--	--	--

TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Test Temperature: RT

	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	176	150	565	510	690	630	38.5	43.5	70.0	72.5
SR1									--	--
SR2	186	155	555	490	720	665	36.5	41.5	--	--
SOLN	187	170	255	250	600	585	57.0	59.5	69.0	70.0

H: HORIZONTAL (XY) orientation
V: VERTICAL (Z) orientation

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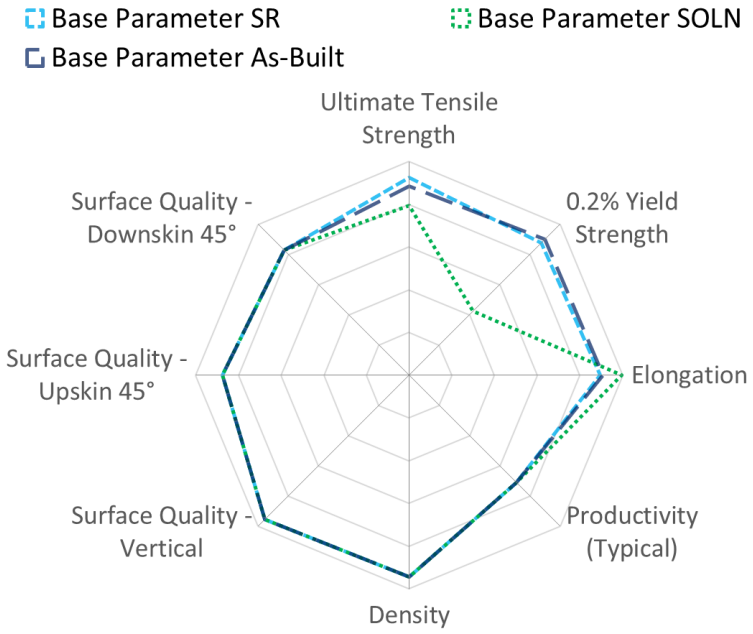
** Roughness measurements have been performed according to DIN EN ISO 4287 and DIN EN ISO 4288. In general analysis of the surface quality is strongly dependent on the methodology used and deviations might be caused by different measurement set up. Vertical and horizontal sidewalls have been characterized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

THERMAL STATE COMPARISON

Base Parameter



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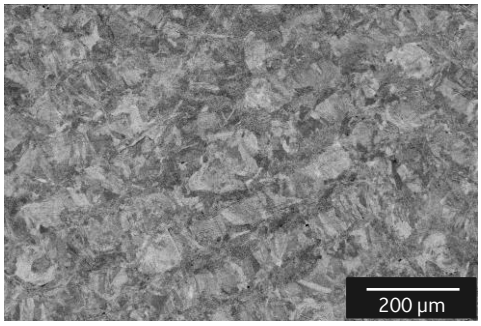
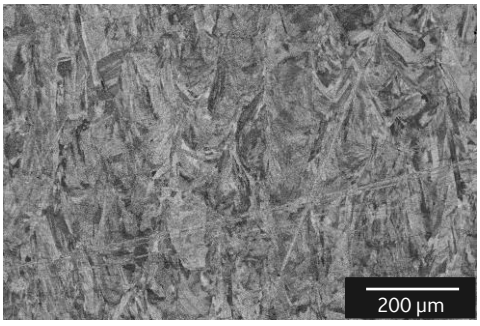
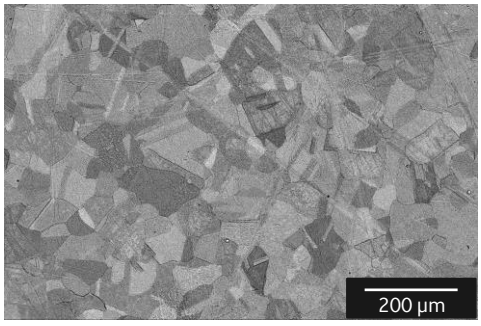
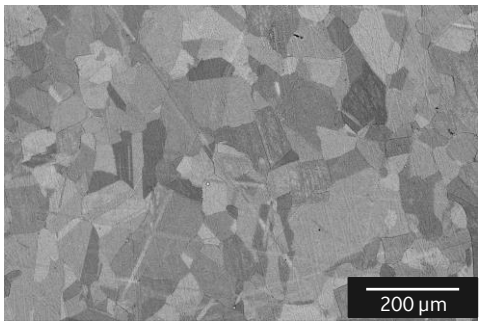
SEM IMAGES (low magnification)

Balanced Parameter

	Horizontal	Vertical
As-Built		
SOLN		

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V: VERTICAL (Z) orientation

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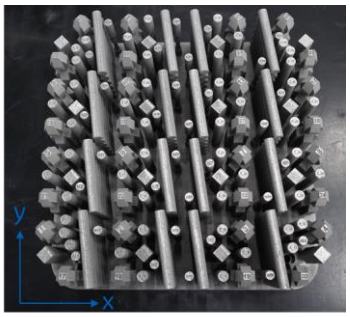
PLATFORM STABILITY

Base Parameter

The platform stability build evaluates porosity, 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 is dependent on part & print layout as well as batch chemistry and thus might deviate from “typical values” given on previous pages.

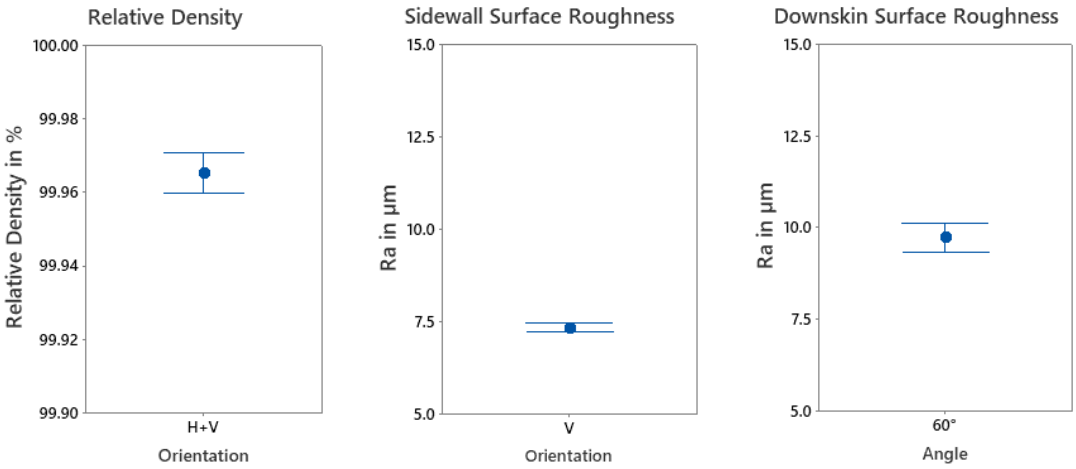
BUILD JOB DESIGN AND SUMMARIZED DATA (AS-BUILT)



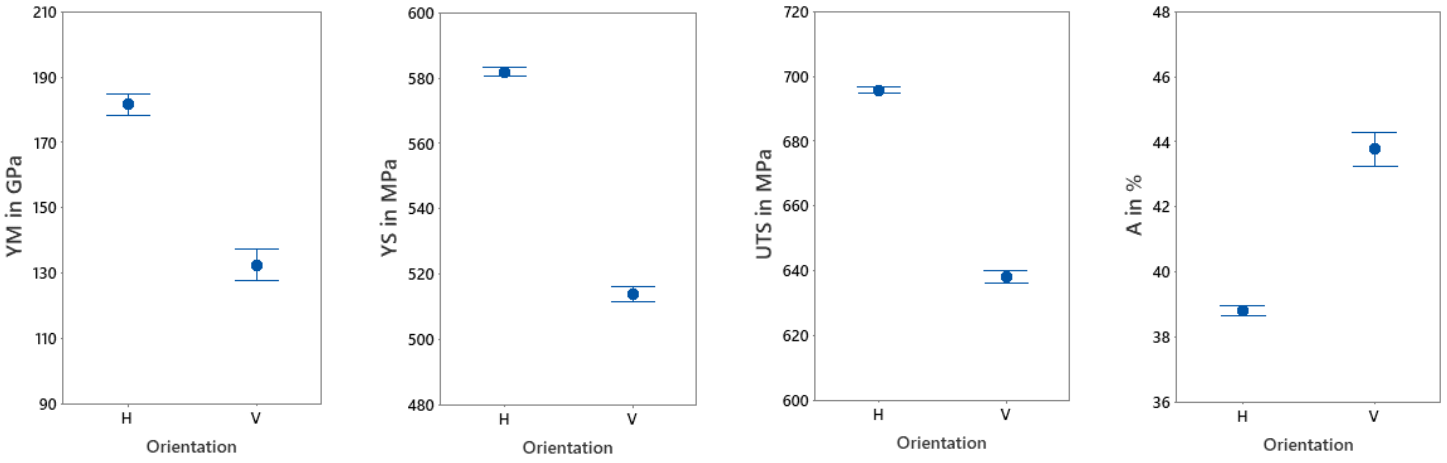
	Sample Size	Mean	St.Dev.
Rel. Density in %	32	99.97	0.02
Sidewall Roughness Ra in µm	64	7	1
Upskin Roughness Ra in µm (60°)	--	--	--
Downskin Roughness Ra in µm (60°)	64	10	2

	Sample Size	Mean	St.Dev.
YM in GPa (H/V)	16/16	182/132	6/9
YS in MPa (H/V)	16/16	582/514	3/4
UTS in MPa (H/V)	16/16	696/638	2/4
Elongation in % (H/V)	16/16	38.8/43.8	0.3/1.0

RESULTS – RELATIVE DENSITY AND SURFACE QUALITY



RESULTS - MECHANICAL PROPERTIES IN AS-BUILT CONDITION



Data points represent the mean value, intervals the 95% confidence level.

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TYPICAL BUILD RATE

Surface Parameter

	Standard (cm³/h)	Productivity optimized (cm³/h)
Typical build rate[1] w/coating	7.7	9.3
Theoretical melting rate[2] bulk per Laser	7.2	7.2

[1]Using standard Factory Acceptance Test layout and 2 lasers

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

PHYSICAL DATA AT ROOM TEMPERATURE

	Surface Roughness Ra** - Overhang (µm)		
	45°	60°	75°
Upskin	6	5	5
Downskin	17	7	6

	Surface Roughness Ra** (µm)
H	9
V	7

	Relative Density (%)		Hardness (HV10)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.9	99.9	220	--	--	--
SR	--	--	220	--	--	--

TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Test Temperature: RT	Modulus of Elasticity (GPa)		0.2% Yield Strength (MPa)		Ultimate Tensile Strength (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	208	172	645	550	740	600	34.5	65.0	--	--
SR	205	189	610	520	765	600	31.5	52.1	--	--

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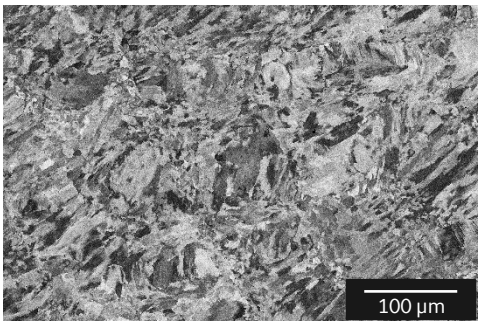
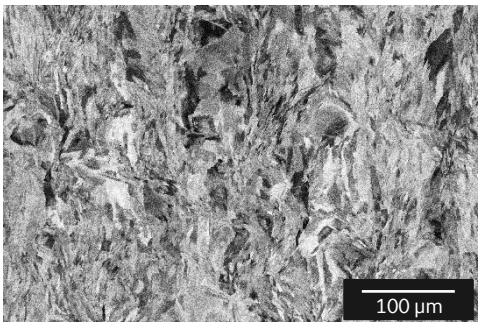
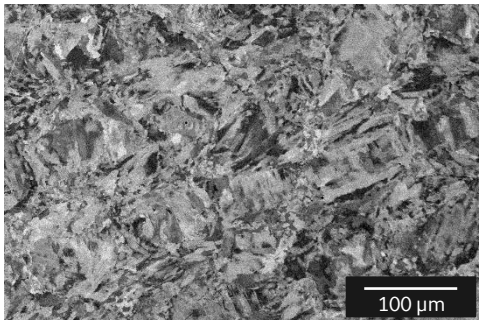
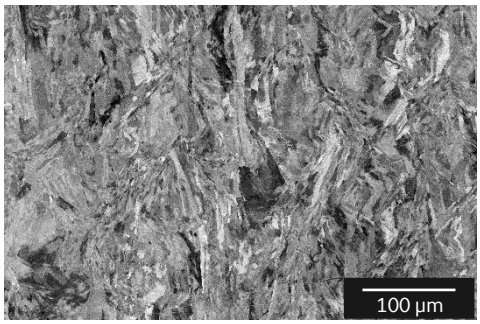
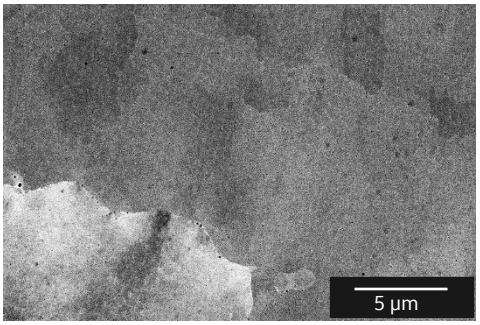
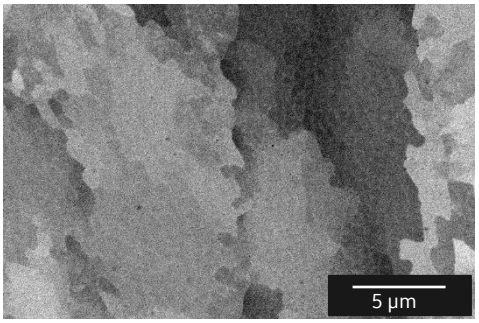
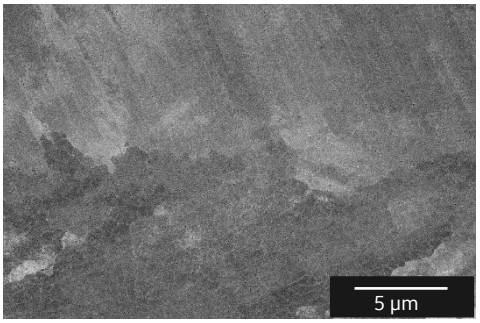
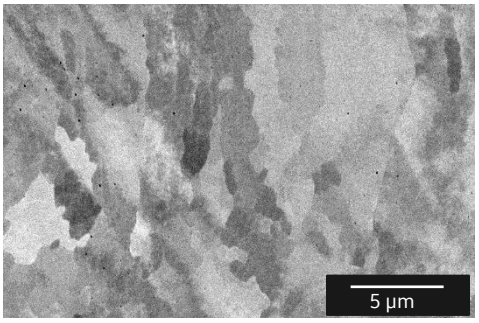
SEM IMAGES (low magnification)

	Horizontal	Vertical
As-Built		
SR		

SEM IMAGES (high magnification)

	Horizontal	Vertical
As-Built		
SR		

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