13 Al

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

M2 Series 5 Aluminum AlSi7Mg

Parameters for GE Additive's Concept Laser M2 Series 5

Data in this material datasheet represents material built with a 30, 60 and 90 µm layer thicknesses and in an argon or nitrogen atmosphere on a Concept Laser M2 Series 5 single-laser or dual-laser machine. The 30 and 60 µm layer thicknesses require build plate heating. The 90 µm layer thickness requires a Concept Laser M2 Series 5 1 kW single-laser or dual-laser machine. Values listed are typical.

Aluminum

Lightweight aluminum alloys for additive manufacturing are traditionally used in many industrial, aerospace and automotive applications. They possess high strength-to-weight ratios, and they also demonstrate good resistance to metal fatigue and corrosion. Due to the geometrically complex structures possible with additive manufacturing, further weight reduction is often possible with little or no compromise in strength and overall performance. One key advantage of aluminum alloy powders is that they typically offer better build rates than other metal powders.

M2 Series 5 AlSi7Mg

The parameters for the Concept Laser M2 Series 5 are developed leveraging the performance of the previous M2 generations of AlSi7Mg parameters. The surface parameter is a 30 µm parameter that produces the best surface roughness, having less than 10 µm without bead blast or shot peening. The productivity parameter has a layer thickness of 60 µm and provides double the productivity of the surface parameter, with the trade off of double the surface finish. Exceptional high productivity – reaching 71 cm³/h for a 1 kW dual-laser system – can be reached by the high productivity parameter having a layer thickness of 90 µm. All parameters can be used with either a rubber or steel recoater blade and succeed the minimum tensile properties specified in AMS 4289 in the heat treated state.

M2 Series 5 Aluminum AlSi7Mg

With appropriate approval* AlSi7Mg can be used for lightweight components in aerospace and industrial applications.

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POWDER CHEMISTRY

Aluminum AlSi7Mg powder chemical composition according to AMS 4289. For additional information on AlSi7Mg powder, visit AP&C.

MACHINE CONFIGURATION

- Concept Laser M2 Series 5 (single-laser or dual-laser) or M2 Series 5 1 kW (single-laser or dual-laser)
- Argon and Nitrogen gas
- Stainless steel or rubber recoater blade

AVAILABLE PARAMETERS

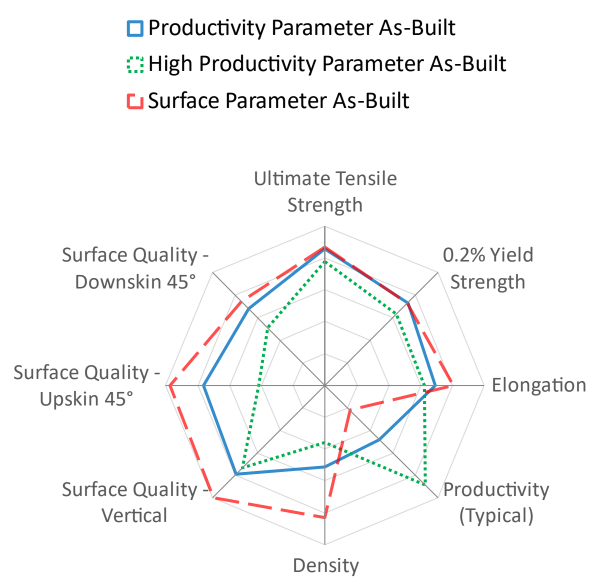
	Layer thickness	Recoater	Gas
M2 Series 5 - Surface Parameter 139 129 / 290**	30 µm	steel rubber	argon
- Productivity Parameter 128 / 289** 138 / 292**	60 µm	steel rubber	argon
- Hybrid Parameter 182	30/60 µm	rubber	argon
M2 Series 5 1 kW **-** High Productivity Parameter 203	90 µm	steel	nitrogen

**Productivity optimized version (productivity bundle required)

THERMAL STATES

1. As-Built
2. T6 Heat Treatment
   SOLN: 530 °C, 6 hours, water quench, AGE: 160°C, 5 hours
3. Vacuum Stress Relief + Hot Isostatic Press + Solution + Age (VSR+HIP+SOLN+AGE)
   VSR: 440°C, 1 hour in vacuum, HIP: 538°C, 8 hours at 100MPa, SOLN: 543°C, 8 hours, rapid quench, AGE: 160°C, 8 hours

PARAMETER COMPARISON (THERMAL STATE AS-BUILT)



Spider Plot is generated by normalizing typical material data (containing both horizontal and vertical) against a range defined for each material family. For **Aluminum Alloys,** the ranges are as follows: UTS: 0-450 MPa, 0.2%YS: 0-300 MPa, Density: 99-100 %, Elongation: 0-30 %, Productivity: 5-80 cm³/h, Surface Quality (all): 40-5 µm

	Standard (cm³/h)	Productivity optimized (cm³/h)
Typical build rate[1] w/coating	12.7	17.5
Theoretical melting rate[2] bulk per Laser	19.4	19.4

[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	7	6	5
Downskin	17	8	6

	Surface Roughness Ra** (µm)
H	16
V	6

Thermal State	Relative Density (%) H	V	Hardness (HV5) H	V	Poisson's Ratio H	V
As-Built	99.8	99.8	105	--	--	--
VSR+HIP+SOLN+AGE	--	--	--	--	--	--

HORIZONTAL

Thermal State	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

VERTICAL

Thermal State	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Test Temperature: RT

Thermal State	Modulus of Elasticity (GPa) H	V	0.2% Yield Strength (MPa) H	V	Ultimate Tensile Strength (MPa) H	V	Elongation (%) H	V	Reduction of Area (%) H	V
As-Built	72	68	225	200	385	390	17.5	14.0	--	--
VSR+HIP+SOLN+AGE	--	--	--	--	--	--	--	--	--	--

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 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.

TYPICAL BUILD RATE

M2 Series 5 — Productivity Parameter

	Standard (cm³/h)	Productivity optimized (cm³/h)
Typical build rate[1] w/coating	27.5	38.6
Theoretical melting rate[2] bulk per Laser	39.3	39.3

[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	14	15	13
Downskin	17	12	11

Surface Roughness Ra** (µm)	
H	14
V	13

	Relative Density (%)		Hardness (HV5)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.5	99.5	104	--	--	--
VSR+HIP+SOLN+AGE	99.9	99.9	--	--	0.352	--

HORIZONTAL

Thermal State	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

VERTICAL

Thermal State	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

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	70	67	225	210	385	385	12	8.5	14.0	10.5
VSR+HIP+SOLN+AGE	67	68	270	255	340	325	11.5	11.5	28.0	27.0

Test Temperature: 150°C	Modulus of Elasticity (GPa)		0.2% YS (MPa)		UTS (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	--	--	--	--	--	--	--	--	--	--
VSR+HIP+SOLN+AGE	55	56	215	210	250	245	15.5	14.5	39.5	38.0

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V: VERTICAL (Z) orientation

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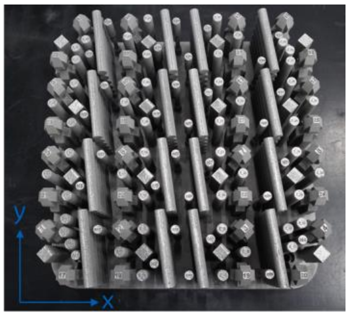
The platform stability build evaluates porosity, roughness and tensile properties across different positions and orientations. To illustrate the position dependency of the M2 Series 5, the samples were homogenously distributed across the platform on 16 different positions. Regarding surface quality all sides of the specimen, so all orientations with respect to gas flow and optical system, are included in the analysis. Data shown below are dependent on part & print layout as well as batch chemistry variations and thus might deviate from "typical values" given on previous pages.

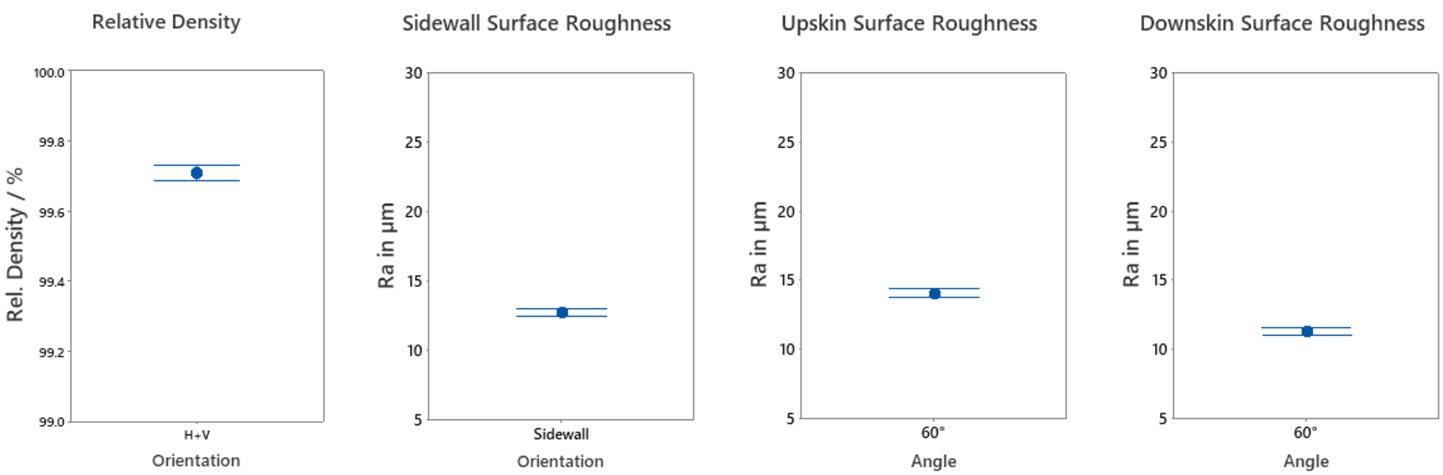
BUILD JOB DESIGN AND SUMMARIZED DATA (AS-BUILT)



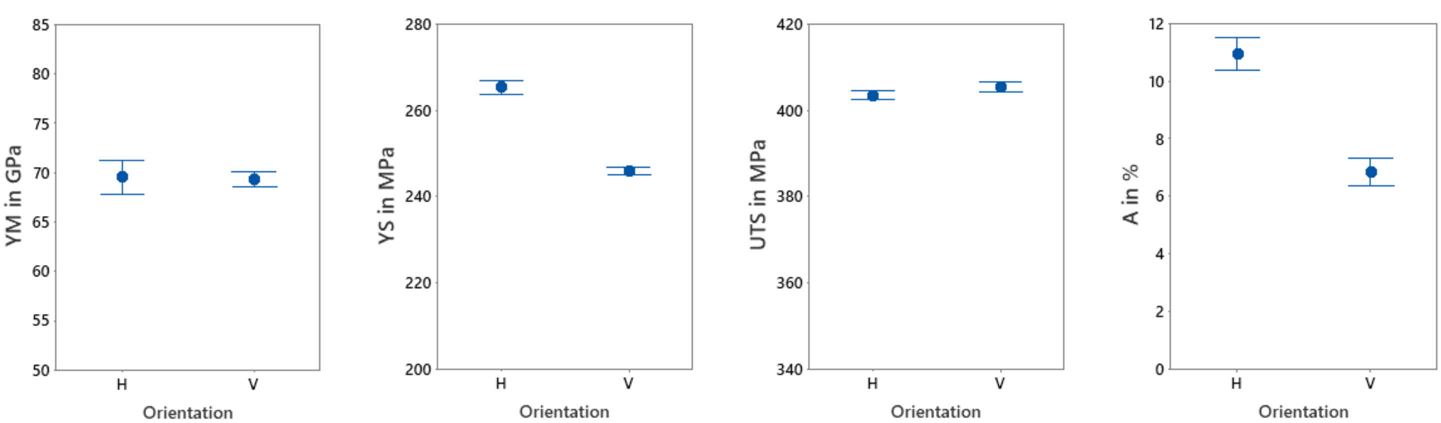
	Sample Size	Mean	St.Dev.
Rel. Density in %	32	99.71	0.06
Sidewall Roughness Ra in µm	64	13	1
Upside Roughness Ra in µm (60°)	64	14	1
Downside Roughness Ra in µm (60°)	64	11	1

	Sample Size	Mean	St.Dev.
YM in GPa (H/V)	16/16	70/69	3/1
YS in MPa (H/V)	16/16	265/246	3/2
UTS in MPa (H/V)	16/16	403/405	2/2
Elongation in % (H/V)	16/16	10.9/6.9	1.1/0.9

RESULTS – RELATIVE DENSITY AND SURFACE QUALITY



RESULTS - MECHANICAL PROPERTIES IN AS-BUILT CONDITION



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

H: HORIZONTAL (XY) orientation
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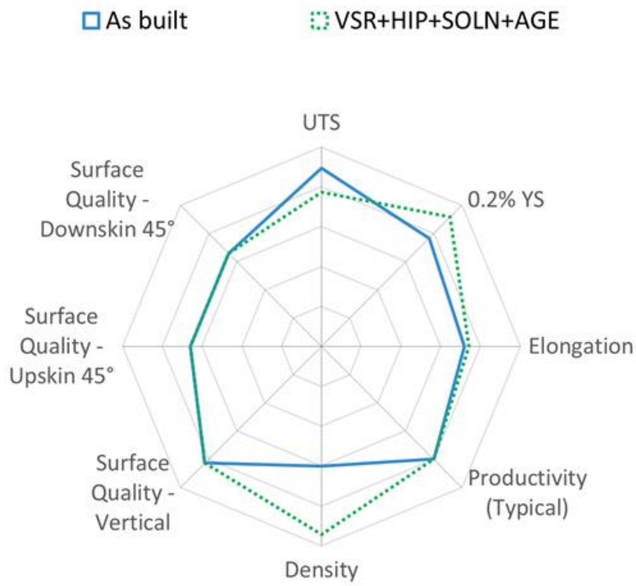

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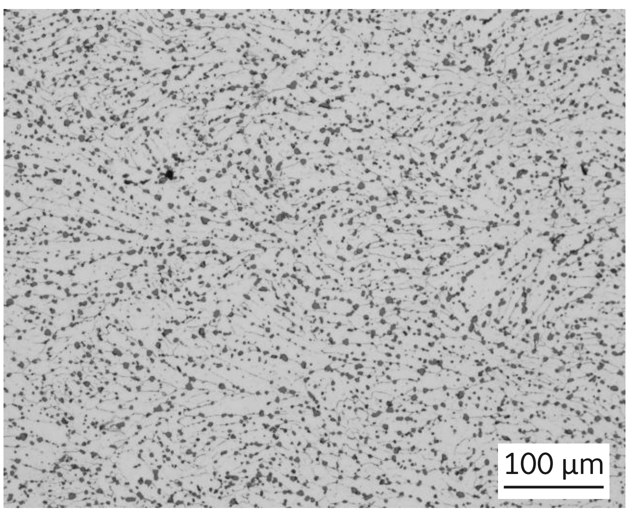
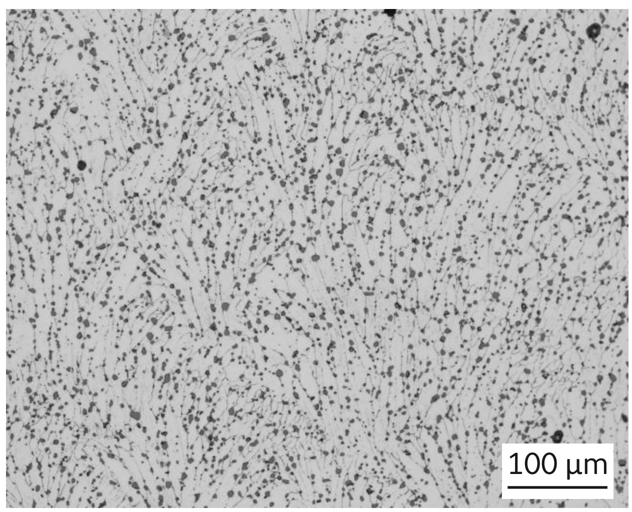
TYPICAL MICROSTRUCTURE



200X, VSR+HIP+SOLN+AGE, HORIZONTAL



200X, VSR+HIP+SOLN+AGE, VERTICAL

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V: VERTICAL (Z) orientation

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	(cm³/h)
Typical build rate[1] w/coating	13.9 *(13-35)*[3]
Theoretical melting rate[2] bulk per Laser	36.5

[1]Using standard Factory Acceptance Test layout and 2 lasers
[2]Calculated (layer thickness x scan velocity x 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.

PHYSICAL DATA AT ROOM TEMPERATURE

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

	Surface Roughness Ra** (µm)
H	20
V	6

	Relative Density (%)		Hardness (HV5)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.6	99.6	103	--	--	--
VSR+HIP+SOLN+AGE	--	--	--	--	--	--

HORIZONTAL **Thermal State**	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

VERTICAL **Thermal State**	Thermal Conductivity (W/m•K)	Coeff. Of Thermal Expansion (mm/mm/K)	Thermal Diffusivity (m²/s)	Specific Heat (J/K•kg)
As-Built	--	--	--	--
VSR+HIP+SOLN+AGE	154.0	13.7×10^{-6}	6.3×10^{-5}	917

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	70	69	220	200	380	380	14.0	10.0	--	--
T6	--	--	--	--	--	--	--	--	--	--

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	(cm³/h)
Typical build rate[1] w/coating	71.0
Theoretical melting rate[2] bulk per Laser	106.3

[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	26	21	17
Downskin	23	15	14

	Surface Roughness Ra** (µm)
H	23
V	15

	Relative Density (%)		Hardness (HV5)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.4	99.4	97	--	--	--
T6	--	--	93	--	--	--

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	71	70	190	185	350	345	10	6	--	--
T6	69	69	235	225	295	285	5	6.5	--	--

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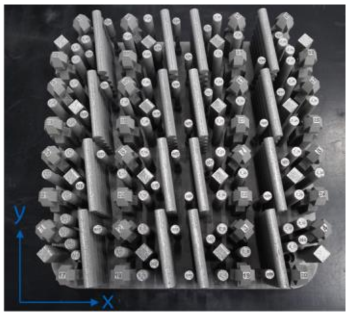
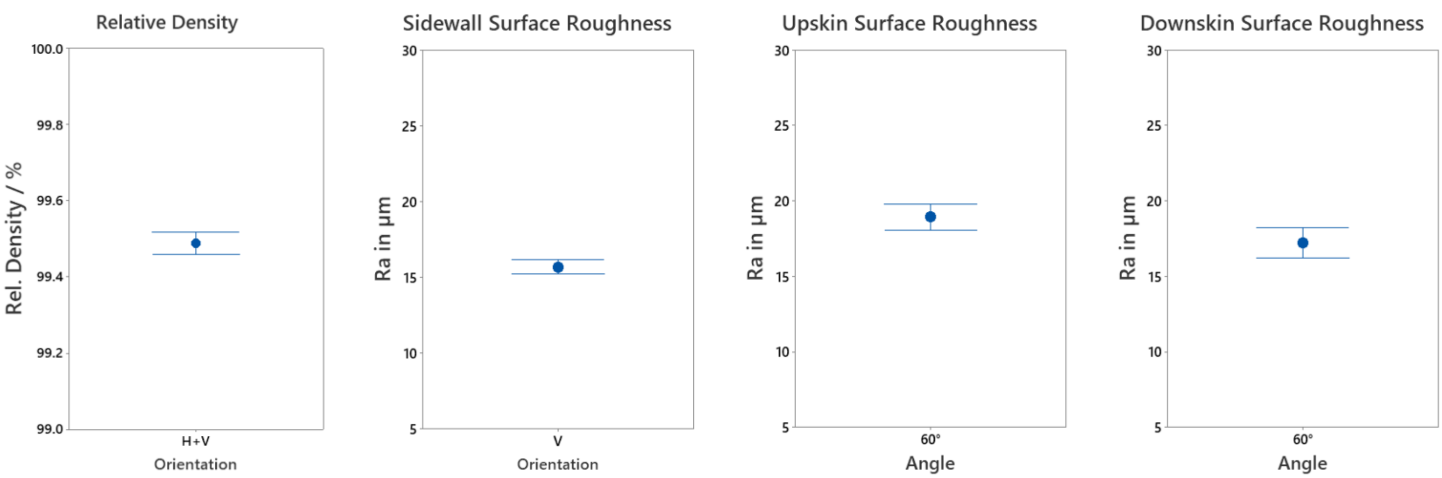


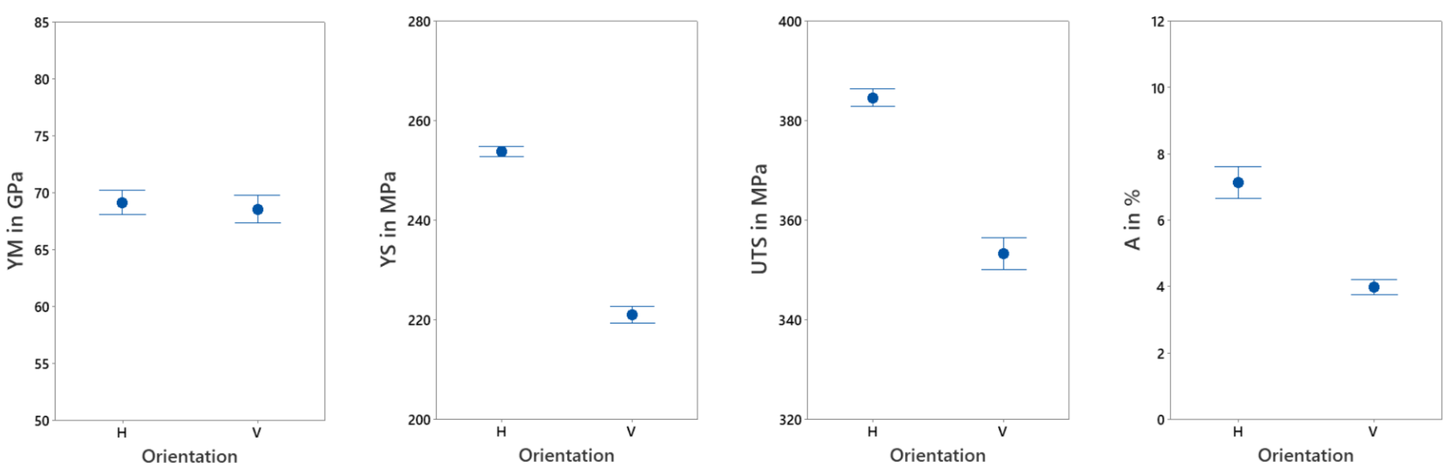
	Sample Size	Mean	St.Dev.
Rel. Density in %	32	99.49	0.08
Sidewall Roughness Ra in µm	64	16	2
Upside Roughness Ra in µm (60°)	64	19	4
Downside Roughness Ra in µm (60°)	64	17	4

	Sample Size	Mean	St.Dev.
YM in GPa (H/V)	16/16	69/69	2/2
YS in MPa (H/V)	16/16	254/221	2/3
UTS in MPa (H/V)	16/16	385/353	3/6
Elongation in % (H/V)	16/16	7.1/4.0	0.9/0.4

RESULTS – RELATIVE DENSITY AND SURFACE QUALITY



RESULTS - MECHANICAL PROPERTIES IN AS-BUILT CONDITION



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