Metal
Solutions

TRL 3
Core

EOS StainlessSteel 316L VPro
High Volume Production

EOS StainlessSteel 316L VPro
High Volume Production

This material together with the HiPro process parameters were designed for high volume production. They offer a high productivity of 316L parts on the EOS M 290.

Main Characteristics

- → Part properties similar to conventionally manufactured 316L
- → Up to 11 mm³/s build rate
- → Very cost efficient
- → Variable options in development

Typical Applications

316L is a very widely used material in multiple applications and industries. This AM process parameter is developed specifically for volume production, yet enabling complex structures. Hence, it has high potential to replace press and sinter production.

Headquarters

EOS GmbH
Electro Optical Systems
Robert-Stirling-Ring 1
D-82152 Krailling/Munich
Germany
Phone +49 89 893 36-0
Fax +49 89 893 36-285

www.eos.info
info@eos.info

Key parameters

Current TRL	3
Target TRL	open
System	EOS M 290
Material	EOS StainlessSteel 316L VPro
Process	HiPro with 60 µm layer thickness

	EOS StainlessSteel 316L		EOS StainlessSteel 316L VPro
	Surface 20 µm	FlexLine 40 µm	VPro 60 µm
Productivity	●	● ●	● ● ● ● ●
Cost per part	●	● ●	● ● ● ● ●
Mechanical properties	● ● ● ● ●	● ● ● ● ●	● ● ●
Detail resolution	● ● ● ● ●	● ● ● ●	● ●
Density	● ● ● ● ●	● ● ● ● ●	● ● ●

Further EOS Offices

EOS France
Phone +33 437 49 76 76

EOS Greater China
Phone +86 21 602307 00

EOS India
Phone +91 44 39 64 80 00

EOS Italy
Phone +39 02 33 40 16 59

EOS Japan
Phone +81 45 670 0250

EOS Korea
Phone +82 2 6330 5800

EOS Nordic & Baltic
Phone +46 31 760 46 40

EOS of North America
Phone +1 877 388 7916

EOS Singapore
Phone +65 6430 0463

EOS UK
Phone +44 1926 675 110

Typical part properties

	Rm	Rp0.2	A
Mechanical properties vertical	540 MPa	410 MPa	19,5 %
Mechanical properties horizontal	530 MPa	430 MPa	13,5 %
Surface roughness vertical	Typical 10 Ra		

Status 07/2019 (V1.0, 2019-02)

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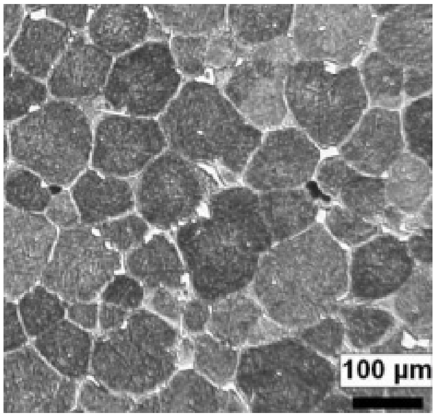
M2 Tool Steel

Material Composition	Amount
Chromium	3.75 - 4.50
Manganese	0.15 - 0.40
Molybdenum	4.50 - 5.50
Phosphorus	0.030 max
Sulfur	0.030 max
Silicon	0.20 - 0.45
Vanadium	1.75 - 2.20
Tungsten	5.50 - 6.75
Carbon	0.78 - 1.05
Iron	Balance

Printed Part

Binder Jet Properties	Heat Treated
Density	8.03 - 8.08 g/cc (98.5 - 99.5%)
Hardness	62 - 65 HRC
Literature Value	**Hardness (HRC)**
MIM M2 Tool Steel (sintered) - 1	55 - 63
MIM M2 Tool Steel (heat treated) - 1	60 - 65

Notes: (1) Metal Injection Molding: MIM: Indo-MIM®. Retrieved from https://www.indo-mim.com/mim-downloads/



Microstructure

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EOS NickelAlloy IN718

EOS NickelAlloy IN718 is a heat and corrosion resistant nickel alloy powder intended for processing on EOS DMLS systems.

This document provides information and data for parts built using EOS NickelAlloy powder (EOS art.-no. 9011-0020) on the following specifications:

- EOS DMLS system: M400 SF
- EOSYSTEM: EOSPRINT v.1.2/HCS v.2.2.40
- EOS Parameter set IN718_040_FlexM400_1.11

Description

Parts built from EOS NickelAlloy IN718 have chemical composition corresponding to UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, DIN NiCr19Fe19NbMo3. This kind of precipitation-hardening nickel-chromium alloy is characterized by having good tensile, fatigue, creep and rupture strength at temperatures up to 700 °C (1290 °F).

This material is ideal for many high temperature applications such as gas turbine parts, instrumentation parts, power and process industry parts etc. It also has excellent potential for cryogenic applications.

Parts built from EOS NickelAlloy IN718 can be easily post-hardened by precipitation-hardening heat treatments. In both as-built and age-hardened states the parts can be machined, spark eroded, welded, micro shot-peened, polished and coated if required. Due to the layerwise building method, the parts have a certain anisotropy.

Electro Optical Systems Finland Oy
Lemminkäisenkatu 36
FIN-20520 Turku
Telephone: +358 20 765 9144
Telefax: +358 20 765 9141

EOS GmbH - Electro Optical Systems
Robert-Stirling-Ring 1
D-82152 Krailling / München
Telephone: +49 (0)89 / 893 36-0
Telefax: +49 (0)89 / 893 36-285
Internet: www.eos.info

Technical Data

Powder properties

Material composition

Element	Min	Max
Ni	50	55
Cr	17.0	21.0
Nb	4.75	5.5
Mo	2.8	3.3
Ti	0.65	1.15
Al	0.20	0.80
Co	-	1.0
Cu	-	0.3
C	-	0.08
Si, Mn	-	0.35
P, S	-	0.015
B	-	0.006
Fe	-	Balance

Max. particle size

Particles > 63µm [1]	max. 0.3 wt.-%

[1] Sieve analysis according to DIN ISO 4497 or ASTM B214.

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General process data

Layer thickness	40 µm
Volume rate [2]	4.2 mm^3/s (15.2 cm^3/h)

[2] The volume rate is a measure of build speed during laser exposure of the skin area. The total build speed depends on this volume rate and many other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings.

Physical and chemical properties of parts

Part density [3]	min. 8.15 g/cm3
Surface roughness after shot peening [4]	Ra < 6.5 µm; Rz < 50.0 µm

[3] Weighing in air and water according to ISO 3369.
[4] Measurement according to ISO 4287. The numbers were measured at the horizontal (up-facing) and all vertical surfaces of test cubes. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

Tensile data at room temperature [5, 6]

	As built	Heat treated [7]
Ultimate tensile strength, Rm	1040 MPa	1470 MPa
Yield strength, Rp0.2	710 MPa	1200 MPa
Elongation at break A	26 %	15 %

[5] The numbers are average values and are determined from samples with horizontal and vertical orientation.
[6] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), original gauge length 25 mm (1 inch).
[7] Heat treatment procedure conform to Aerospace Material Specification AMS 2774D and AMS 5662:
1. Solution Anneal at 954 °C (1750 °F) for 1 hour per 25mm (0.98 inch) of thickness, air (/argon) cool.
2. Ageing treatment; hold at 718 °C (1325 °F) 8 hours, furnace cool to 621 °C (1150 °F) and hold at 621 °C (1150 °F) for total precipitation time of 18 hours., air (/argon) cool.

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D-82152 Krailling / München
Telephone: +49 (0)89 / 893 36-0
Telefax: +49 (0)89 / 893 36-285
Internet: www.eos.info

Abbreviations

min.	minimum
max.	maximum
wt.	weight

Legal notes

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Electro Optical Systems Finland Oy
Lemminkäisenkatu 36
FIN-20520 Turku
Telephone: +358 20 765 9144
Telefax: +358 20 765 9141

EOS GmbH - Electro Optical Systems
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Telephone: +49 (0)89 / 893 36-0
Telefax: +49 (0)89 / 893 36-285
Internet: www.eos.info

Material Data Sheet

Al-Alloy AlSi10Mg[1]

General

AlSi10Mg is a hardenable aluminum-based alloy with a density of circa 2.67 g/cm^3. It is applicable for thin-walled components and parts with complex geometries. AlSi10Mg is highly suitable for processing and characterized by a good resistance in corrosive atmospheres as well as a high electrical conductivity. The combination of achievable high strengths while maintaining dynamic load capacity enable it to be used for highly stressed parts. With this profile of properties, AlSi10Mg is currently the most common aluminum-based alloy. Components made of AlSi10Mg are ideal to use in areas such as aerospace engineering and the automotive industry.

Material Structure

SLM® processed aluminum-based alloy components exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat treatment, the components' properties can be adapted to meet specific requirements. Due to high solidi cation rates, a typical heat treatment of aluminum alloys (T6) is not necessary for SLM® parts. Therefore, only a stress relief heat treatment at 300 °C for 2 h is recommended after the SLM® process.

Chemical composition [Mass fraction in %][2]

Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Pb	Sn	Other total
Balance	9.00 – 11.00	0.55	0.05	0.45	0.20 – 0.45	0.10	0.15	0.05	0.05	0.05	0.15

Powder properties

Particle size[2]	20 – 63 µm	Particle shape[3]	Spherical
Mass density[4]	≈ 2.67 g/cm^3	Thermal conductivity[5]	130 – 150 W/(m·K)

Al-Alloy AlSi10Mg[1]

30 µm / 400 W[6]				As-built		Heat-treated[14]	
Build-up rate[9]	[cm^3/h]			24.5 cm^3/h			
Component density[10]	[%]			≥ 99.5 %			

Tensile test[11]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	454	5	276	16
			V	474	5	280	14
Offset yield strength	$R_{p0,2}$	[MPa]	H	297	7	166	12
			V	271	7	158	7
Elongation at break	A	[%]	H	8	1	19	3
			V	6	1	17	2
Reduction of area	Z	[%]	H	9	1	36	4
			V	7	2	31	3
Young's modulus	E	[GPa]	H	73	4	62	16
			V	74	2	66	7

Hardness test[12]		M	SD	M	SD
Vickers hardness	HV5	124	7	82	1

Roughness measurement[13]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	8	2	5	1	4	1
Mean roughness depth	Rz	[µm]	55	13	34	6	26	4

Al-Alloy AlSi10Mg[1]

60 µm / 400 W[7]				As-built		Heat-treated[14]	
Build-up rate[9]	[cm³/h]			35.6 cm³/h			
Component density[10]	[%]			≥ 99.0 %			

Tensile test[11]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	443	6	264	5
			V	432	28	273	5
Offset yield strength	$R_{p0,2}$	[MPa]	H	277	7	151	8
			V	259	5	154	6
Elongation at break	A	[%]	H	8	1	19	3
			V	5	1	14	3
Reduction of area	Z	[%]	H	7	2	30	5
			V	4	1	19	6
Young's modulus	E	[GPa]	H	72	5	57	14
			V	71	3	58	14

Hardness test[12]		M	SD	M	SD
Vickers hardness	HV5	127	4	80	1

Roughness measurement[13]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	13	2	8	1	5	1
Mean roughness depth	Rz	[µm]	80	13	49	7	30	4

Al-Alloy AlSi10Mg[1]

60 µm / 700 W[8]			As-built	Heat-treated[14]
Build-up rate[9]	[cm³/h]		67.9 cm³/h	
Component density[10]	[%]		≥ 99.0 %	

Tensile test[11]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	421	4	261	12
			V	424	10	270	11
Offset yield strength	$R_{p0,2}$	[MPa]	H	251	6	141	13
			V	235	5	142	10
Elongation at break	A	[%]	H	8	1	16	3
			V	6	1	13	2
Reduction of area	Z	[%]	H	7	1	20	3
			V	6	1	17	3
Young's modulus	E	[GPa]	H	72	5	59	14
			V	72	3	57	8

Hardness test[12]		M	SD	M	SD
Vickers hardness	HV5	123	7	76	1

Roughness measurement[13]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	16	4	9	3	7	1
Mean roughness depth	Rz	[µm]	96	22	52	18	41	7

Material Data Sheet

Al-Alloy AlSi10Mg[1]

The properties and mechanical characteristics apply to powder that is tested and sold by SLM Solutions, and that has been processed on SLM Solutions machines using the original SLM Solutions parameters in compliance with the applicable operating instructions (including installation conditions and maintenance). The part properties are determined based on specified procedures. More details about the procedures used by SLM Solutions are available upon request.

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[1] Material according to DIN EN 1706:2013, EN AC-43000, EN AC-AlSi10Mg(a).

[2] With respect to powder material.

[3] According to DIN EN ISO 3252:2001.

[4] Material density varies by ± 0,01 g/cm³ within the range of possible chemical composition variations.

[5] Literature value for conventionally manufactured material at 20 °C.

[6] Material data file: AlSi10Mg_SLM_MBP3.0_30_CE2_400W_Stripes_V1.2

[7] Material data file: AlSi10Mg_SLM_MBP3.0_60_CE2_400W_Stripes_V1.3

[8] Material data file: AlSi10Mg_SLM_MBP3.0_60_CE2_700W_Stripes_V1.3

[9] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance

[10] Optical density determination at test specimens by light microscopy.

[11] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); testing machine: ZwickRoell ProLine; load range: 100 kN; testing speed: 0,008 1/s; testing temperature: room temperature. Test samples were turned before tensile test.

[12] Hardness testing according to DIN EN ISO 6507-1:2018.

[13] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm. Glass-bead blasting is an additional post-processing step after corundum blasting.

[14] Heat treatment: 2 h at 300 °C, air quenching.

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Material Data Sheet

Co-Alloy CoCr28Mo6 / 2.4979 / F75[1]

General

Cobalt-chromium alloys are characterized by their especially high hardness as well as high ductility. Additionally, they are corrosion resistant. Due to their high bio-compatibility, cobalt-chromium alloys are among the standard alloys used in medical and dental technologies. They are used to produce dental as well as knee and hip prostheses. Their resistance to heat makes them well-suited for use in high-temperature areas, such as in jet are very hard, there are limitations when it comes engines. Since cobalt-chromium components to cutting processes. The SLM® process provides a comparatively economic and quick option to manufacture cobalt-chromium components.

Material Structure

SLM®-processed CoCr28Mo6 shows a homogenous, nearly void-free structure. The mechanical properties are within material specification. Through subsequent processing such as heat treatment (e.g. solution annealing), the components' properties can be adapted to meet specific requirements.

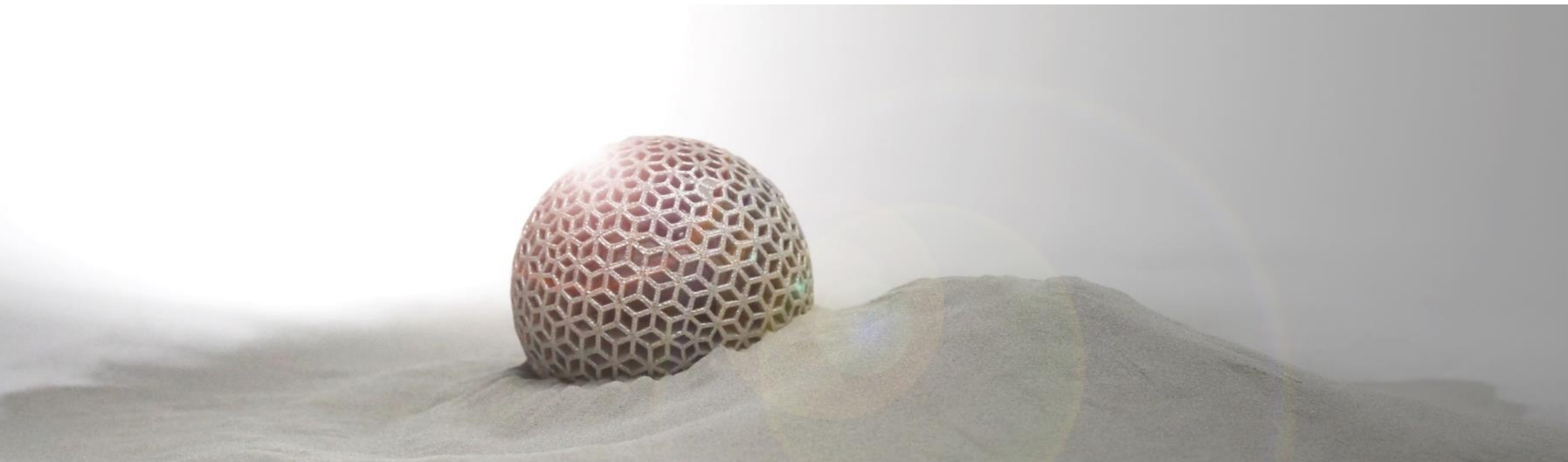
Chemical composition [Mass fraction in %][7]

Co	Cr	Mo	Mn	Si	Fe	Ni	C	Al	B	N	P
Balance	27.00 – 30.00	5.00 – 7.00	1.00	1.00	0.75	0.50	0.35	0.10	0.01	0.25	0.02

S	W	Ti
0.01	0.20	0.10

Powder properties

Particle size[7]	10 – 45 µm	Particle shape[8]	Sphärisch
Mass density[2]	8.47 g/cm³	Thermal conductivity	11 - 14 W/(m·K)



Co-Alloy CoCr28Mo6 / 2.4979 / F75[1]

Layer thickness 30 µm[3]		As-built
Aufbaurate[6]	[cm³/h]	11.0 cm³/h
Bauteildichte[7]	[%]	≥ 99.5 %

Tensile test[9]				M	SD
Tensile strength	R_m	[MPa]	H	1269	13
			V	1177	32
Offset yield strength	$R_{p0,2}$	[MPa]	H	824	31
			V	639	28
Elongation at break	A	[%]	H	13	2
			V	23	4
Reduction of area	Z	[%]	H	10	4
			V	19	3
Young’s modulus	E	[GPa]	H	205	49
			V	190	16

Hardness test[10]		M	SD
Vickers hardness	HV10	385	6

Roughness measurement[10]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	16	3	7	1	6	1
Mean roughness depth	Rz	[µm]	99	13	50	9	41	4

Co-Alloy CoCr28Mo6 / 2.4979 / F75[1]

Layer thickness 60 µm[4]		As-built
Aufbaurate[6]	[cm³/h]	11.0 cm³/h
Bauteildichte[7]	[%]	≥ 99.5 %

Tensile test[9]				M	SD
Tensile strength	R_m	[MPa]	H	1247	9
			V	1155	25
Offset yield strength	$R_{p0,2}$	[MPa]	H	851	19
			V	667	13
Elongation at break	A	[%]	H	18	1
			V	27	4
Reduction of area	Z	[%]	H	14	5
			V	21	3
Young's modulus	E	[GPa]	H	217	33
			V	199	8

Hardness test[10]		M	SD
Vickers hardness	HV10	377	5

Roughness measurement[11]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	15	4	7	2	6	1
Mean roughness depth	Rz	[µm]	91	17	46	11	41	4

Co-Alloy CoCr28Mo6 / 2.4979 / F75[1]

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[1] Material according to ASTM F75.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: CoCr_SLM_MBP3.0_30_CE2_400W_Stripes_V1.0

[4] Material data file: CoCr_SLM_MBP3.0_60_CE2_400W_Stripes_V1.0

[5] Optical density determination by light microscopy.

[6] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[7] With respect to powder material.

[8] According to DIN EN ISO 3252:2001.

[9] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0°, 90°.

[10] Hardness testing according to DIN EN ISO 6507-1:2018.

[11] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

Material Data Sheet

Cu-Alloy CuNi2SiCr

General

The low-alloyed copper-alloy CuNi2SiCr is a thermally hardenable alloy with a high stiffness, even at elevated temperatures. In addition, CuNi2SiCr offers a balanced combination of electrical and thermal conductivity as well as a very high resistance to wear. Due to the addition of nickel and silicon, this alloy has a high corrosion resistance, especially against stress-corrosion cracking.

This property profile predestines CuNi2SiCr for use under mechanical, thermal or tribological stresses with simultaneously good conductivity. Typical areas of application are, for example, toolmaking, conductive contacts in electrical engineering or valves. This copper alloy is also completely free of beryllium.

Material Structure

Components made of low-alloyed copper alloys with the SLM® process have a homogenous, almost pore-free structure, which allows mechanical values to be in range of the material specification. CuNi2SiCr crystallizes in a face-centered cubic lattice structure. The component properties can be adapted to individual requirements by subsequent heat treatment. Precipitation strengthening – comprising the heat treatment steps solution annealing, quenching and artificial aging – leads to improved strength properties and increases electrical conductivity likewise. Strengthening of CuNi2SiCr is based on the temperature-dependent solubility of the intermetallic phases Ni_2Si and Ni_5Si_2 ($Ni_{31}Si_{12}$)

Chemical composition [Mass fraction in %][6]

Cu	Ni	Si	Cr	Nb + Ta	O	Fe	Mn	Pb	C	N	Others Total
Balance	2.0 – 3.0	0.5 – 0.8	0.2 – 0.5	/	/	0.15	0.1	0.02	/	/	0.1

Powder properties

Particle size[7]	20 – 63 µm	Particle shape[8]	Spherical
Mass density[1]	8.84 g/cm3	Thermal conductivity	

Cu-Alloy CuNi2SiCr

30 µm / 400 W[2]				As-built		Heat-treated [12]	
Build-up rate [6]	[cm³/h]			11.7 cm³/h			
Component density[4]	[%]			> 99.5 %			

Tensile test[9]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	314	2	666	5
			V	281	4	613	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	260	4	580	5
			V	239	2	543	4
Elongation at break	A	[%]	H	36	2	18	1
			V	40	1	23	2
Reduction of area	Z	[%]	H	79	4	41	4
			V	88	3	65	9
Young's modulus	E	[GPa]	H	98	8	114	6
			V	95	5	105	2

Hardness test[10]		M	SD	M	SD
Vickers hardness	HV10	105	1	214	3

Conductivity measurement[5]			
Electrical conductivity	[MS/m]	8	23
	[%IACS]	14	40

Roughness measurement[11]			As-built		Corundum blasted		Corundum- and Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	15	1	5	1	4	1
Mean roughness depth	Rz	[µm]	86	4	32	5	28	2

Cu-Alloy CuNi2SiCr

60 µm / 700 W[3]				As-built		Heat-treated [12]	
Build-up rate [6]	[cm³/h]			25.7 cm³/h			
Component density[4]	[%]			> 99.5 %			

Tensile test[9]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	318	4	674	20
			V	280	4	633	13
Offset yield strength	$R_{p0,2}$	[MPa]	H	249	3	584	15
			V	226	3	551	9
Elongation at break	A	[%]	H	37	2	18	1
			V	34	2	22	1
Reduction of area	Z	[%]	H	67	5	40	3
			V	85	3	71	5
Young's modulus	E	[GPa]	H	102	14	110	9
			V	87	4	102	2

Hardness test[10]		M	SD	M	SD
Vickers hardness	HV10	109	3	225	1

Conductivity measurement[5]			
Electrical conductivity	[MS/m]	8	22
	[%IACS]	14	38

Roughness measurement[11]			As-built		Corundum blasted		Corundum- and Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	21	1	11	2	7	1
Mean roughness depth	Rz	[µm]	121	8	63	10	45	7

Material Data Sheet

Cu-Alloy CuNi2SiCr

The properties and mechanical characteristics apply to powder that is tested and sold by SLM Solutions, and that has been processed on SLM Solutions machines using the original SLM Solutions parameters in compliance with the applicable operating instructions (including installation conditions and maintenance). The part properties are determined based on specified procedures. More details about the procedures used by SLM Solutions are available upon request.

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[1] Material density varies within the range of possible chemical composition variations.

[2] Material data file: CuNi2SiCr_SLM_MBP3.0_30_400W_CE2_V1.0
Maximum oxygen content in the process: 500 ppm

[3] Material data file: CuNi2SiCr_SLM_MBP3.0_60_700W_CE2_V1.0
Maximum oxygen content in the process: 500 ppm

[4] Optical density determination by light microscopy.

[5] Electrical conductivity measurement according to DIN EN 2004-1, ASTM E 1004.

[6] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[7] With respect to powder material.

[8] According to DIN EN ISO 3252:2001.

[9] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0°, 90°.

[10] Hardness testing according to DIN EN ISO 6507-1:2018.

[11] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[12] Heat treatment: solution annealing at 930 °C, hold for 15 min, followed by water quenching. Aging at 540 °C for 2 h with subsequent cooling in air.

Material Data Sheet

Stainless Steel 15-5PH / 1.4545 / A564[1]

General

15-5PH is a stainless, martensitic, and hardenable Cr-Ni-Cu Steel with high strength and ductility as well as good weldability and forgeability. Typical fields of application are in medical, automotive, and aerospace areas. Through solution annealing and subsequent ageing, an increase in strength occurs. 15-5PH is applicable in a temperature range from -200 °C to 300 °C.

Material Structure

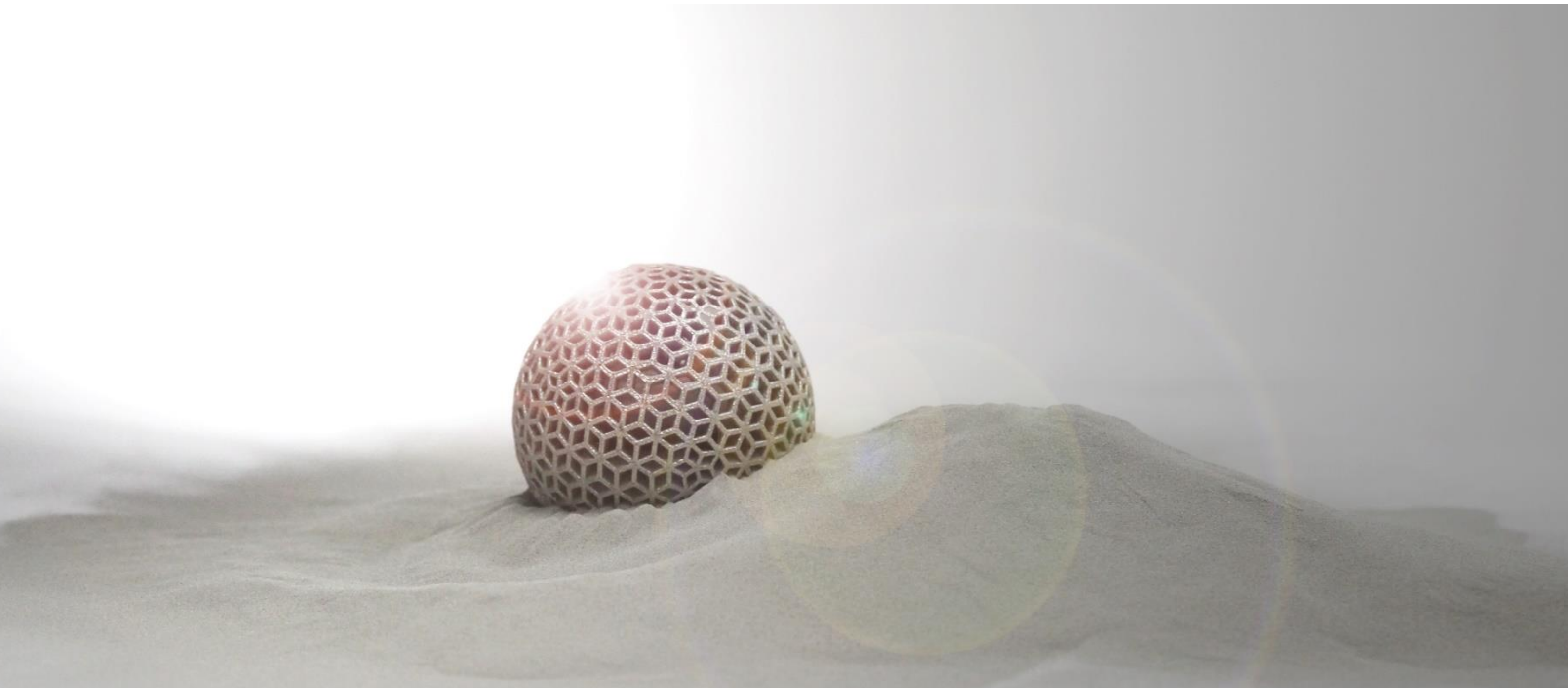
SLM®-processed components out of 15-5PH exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material speci cations. Through subsequent post processing such as heat treatment (e.g. precipitation hardening), the components' properties can be adapted to meet specific requirements.

Chemical composition [Mass fraction in %][8]

Fe	Cr	Ni	Cu	Nb + Ta	Mn	Si	P	S	C	N	O
Balance	14.50 – 15.50	3.50 – 5.50	2.50 – 4.50	0.15 – 0.45	1.00	1.00	0.04	0.03	0.07	0.10	0.10

Powder properties

Particle size[8]	10 – 45 µm	Particle shape[9]	Spherical
Mass density[2]	7.8 g/cm³	Thermal conductivity	11 W/(m·K)



Stainless Steel 15-5PH / 1.4545 / A564[1]

Layer thickness 30 µm[3]				As-built		Heat-treated [13]	
Build-up rate [7]	[cm³/h]			10.4 cm³/h			
Component density[6]	[%]			> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1237	6	1426	15
			V	1206	66	1426	17
Offset yield strength	$R_{p0,2}$	[MPa]	H	831	18	1244	58
			V	873	47	1289	13
Elongation at break	A	[%]	H	17	1	14	1
			V	14	1	12	1
Reduction of area	Z	[%]	H	57	2	37	1
			V	51	7	46	3
Young's modulus	E	[GPa]	H	174	8	199	31
			V	182	15	188	7

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	373	3	459	6

Roughness measurement[12]			As-built	
			M	SD
Roughness average	Ra	[µm]	10	2
Mean roughness depth	Rz	[µm]	62	11

Stainless Steel 15-5PH / 1.4545 / A564[1]

Layer thickness 50 µm[4]				As-built		Heat-treated [13]	
Build-up rate [7]	[cm³/h]			15.3 cm³/h			
Component density[6]	[%]			> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1263	7	1412	87
			V	1202	18	1485	4
Offset yield strength	$R_{p0,2}$	[MPa]	H	845	22	1281	43
			V	1003	21	1322	5
Elongation at break	A	[%]	H	17	1	12	1
			V	11	1	11	3
Reduction of area	Z	[%]	H	59	4	39	4
			V	41	18	37	13
Young's modulus	E	[GPa]	H	173	13	191	28
			V	191	9	209	9

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	367	4	-	-

Roughness measurement[12]			As-built	
			M	SD
Roughness average	Ra	[µm]	12	5
Mean roughness depth	Rz	[µm]	65	26

Stainless Steel 15-5PH / 1.4545 / A564[1]

Layer thickness 60 µm[5]				As-built		Heat-treated [13]	
Build-up rate [7]	[cm^3/h]			24.6 cm^3/h			
Component density[6]	[%]			> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1247	12	1451	14
			V	1205	4	1466	6
Offset yield strength	$R_{p0,2}$	[MPa]	H	778	42	1290	22
			V	870	61	1315	10
Elongation at break	A	[%]	H	14	1	8	3
			V	13	1	10	2
Reduction of area	Z	[%]	H	37	1	19	12
			V	51	7	36	5
Young's modulus	E	[GPa]	H	181	23	192	13
			V	182	19	195	6

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	318	43	452	2

Roughness measurement[12]			As-built	
			M	SD
Roughness average	Ra	[µm]	26	6
Mean roughness depth	Rz	[µm]	157	41

Material Data Sheet

Stainless Steel 15-5PH / 1.4545 / A564[1]

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[1] Material according to ASTM A564.
[2] Material density varies within the range of possible chemical composition variations.
[3] Material data file: 15-5PH_SLM_MBP3.0_30_CE2_400W_Stripes_V1.2
[4] Material data file: 15-5PH_SLM_MBP3.0_50_CE2_400W_Stripes_V1.2
[5] Material data file: 15-5PH_SLM_MBP3.0_60_CE2_400W_Stripes_V1.0
[6] Optical density determination by light microscopy.
[7] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.
[8] With respect to powder material.
[9] According to DIN EN ISO 3252:2001.
[10] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – B6x30); orientation: 0°, 90°; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature; test laboratory: EWIS GmbH. Test samples were turned before tensile test.
[11] Hardness testing according to DIN EN ISO 6507-1:2018.
[12] Roughness measurement according to DIN EN ISO 4288:1998; λc = 0,8 mm.
[13] Heat Treatment: 1) Solution annealing: 1050 °C, 1 h; air quenching 2) Ageing: 450 °C, 1 h; air quenching.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Stainless Steel 17-4PH / 1.4542 / A564[1]

General

17-4PH is a martensitic precipitation-hardenable Cr-Ni-Cu-steel possessing high strength and toughness. It provides an outstanding combination of good corrosion resistance and good mechanical properties at temperatures up to 320 °C. This versatile material is widely used in the aerospace, chemical, petrochemical, and general metalworking industries. The good mechanical characteristic values of stainless steel make it suitable for heavy-strain applications, thanks to its high wear resistance.

Material Structure

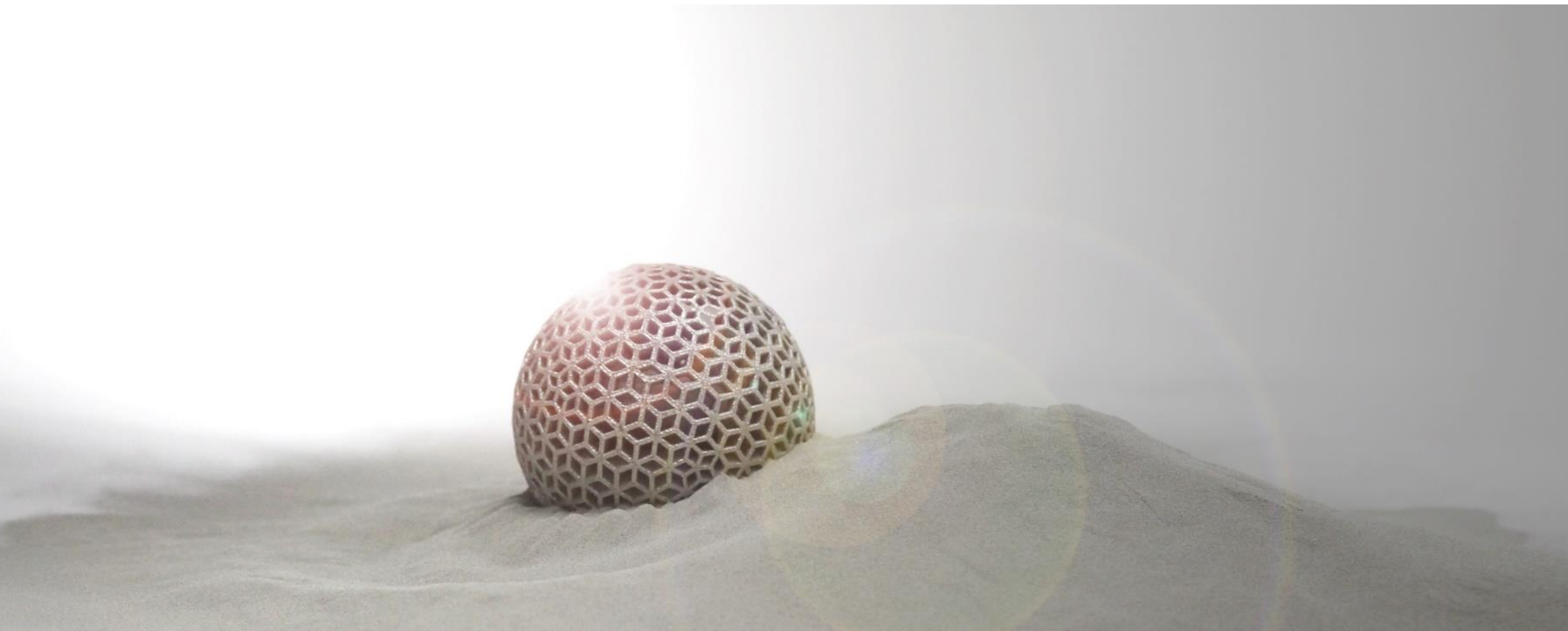
SLM®-processed steel components exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat treatment (e.g. precipitation hardening), the components' properties can be adapted to meet specific requirements.

Chemical composition [Mass fraction in %][7]

Fe	Cr	Ni	Cu	Mn	Si	Nb + Ta	C	N	O	P	S
Balance	15.00 – 17.50	3.00 – 5.00	3.00 – 5.00	1.00	0.07	0.15 – 0.45	0.07	0.10	0.04	0.040	0.015

Pulvereigenschaften

Particle size[7]	10 – 45 µm	Particle shape[8]	Spherical
Mass density[2]	7.8 g/cm³	Thermal conductivity	16 W/(m·K)



Stainless Steel 17-4PH / 1.4542 / A564[1]

Layer thickness 30 µm [3]				As-built		Heat-treated[12]	
Build-up rate[10]	[cm³/h]			16.85 cm³/h			
Component density[11]	[%]			≥ 99.5 %			

Tensile test[9]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	987	22	1359	9
			V	931	45	1308	88
Offset yield strength	$R_{p0,2}$	[MPa]	H	517	27	1024	11
			V	506	25	1091	27
Elongation at break	A	[%]	H	26	2	16	2
			V	28	2	14	6
Reduction of area	Z	[%]	H	56	2	27	10
			V	56	8	26	17
Young's modulus	E	[GPa]	H	171	28	154	5
			V	154	19	182	4

Hardness test[10]		M	SD	M	SD
Vickers hardness	HV10	226	2	352	22

Roughness measurement[11]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	9	2	6	1	5	1
Mean roughness depth	Rz	[µm]	60	10	36	9	30	6

Stainless Steel 17-4PH / 1.4542 / A564[1]

Layer thickness 50 µm [3]				As-built		Heat-treated[12]	
Build-up rate[10]	[cm³/h]			16.85 cm³/h			
Component density[11]	[%]			≥ 99.5 %			

Tensile test[9]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	966	13	1267	23
			V	907	5	1189	16
Offset yield strength	$R_{p0,2}$	[MPa]	H	508	17	897	54
			V	511	18	866	41
Elongation at break	A	[%]	H	26	1	20	1
			V	33	1	22	1
Reduction of area	Z	[%]	H	62	2	47	3
			V	66	2	53	5
Young's modulus	E	[GPa]	H	177	36	162	16
			V	148	3	151	5

Hardness test[10]		M	SD	M	SD
Vickers hardness	HV10	229	32	367	24

Roughness measurement[11]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	10	1	6	1	-	-
Mean roughness depth	Rz	[µm]	64	7	38	3	-	-

Material Data Sheet

Stainless Steel 17-4PH / 1.4542 / A564[1]

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[1] Material according to DIN EN 10088-1:2014, ASTM A564.

[2] Material density varies by ± 0,01 g/cm³ within the range of possible chemical composition variations.

[3] Material data file: 17-4PH_SLM_MBP3.0_30_CE2_400W_Stripes_V1.2

[4] Material data file: 17-4PH_SLM_MBP3.0_50_CE2_400W_Stripes_V1.1

[5] Optical density determination by light microscopy.

[6] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[7] With respect to powder material.

[8] According to DIN EN ISO 3252:2001.

[9] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – B6x30); orientation: 0°, 90°; heat treatment: none; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature. Test samples were turned before tensile test.

[10] Hardness testing according to DIN EN ISO 6507-1:2018.

[11] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[12] Heat treatment according to ASTM A564 (H900): 1. Solution annealing at 1040 °C for 30 min 2. Ageing at 480 °C for 60 min.

Material Data Sheet

Fe-Alloy 316L (1.4404)[1]

General

Components made of tool or stainless steels are known for great hardness with a high ductility. Through selective application of alloying elements, material properties can be precisely adjusted. This means that even corrosion-resistant steel alloys like 316L (1.4404) can be processed using SLM®. Applications for corrosion-resistant alloys are found in medical technologies, the automotive industry as well as in aerospace engineering. Tool steel is mainly used to produce tools and molds. Its layered structure enables components to be fitted with integrated cooling channels. The good mechanical characteristic values of stainless steel make it suitable for use in places that are exposed to heavy strain, because its high resistance to wear keeps abrasion to a minimum. Steel can also be used at high operating temperatures, which reduces the amount of wear on tools.

Material Structure

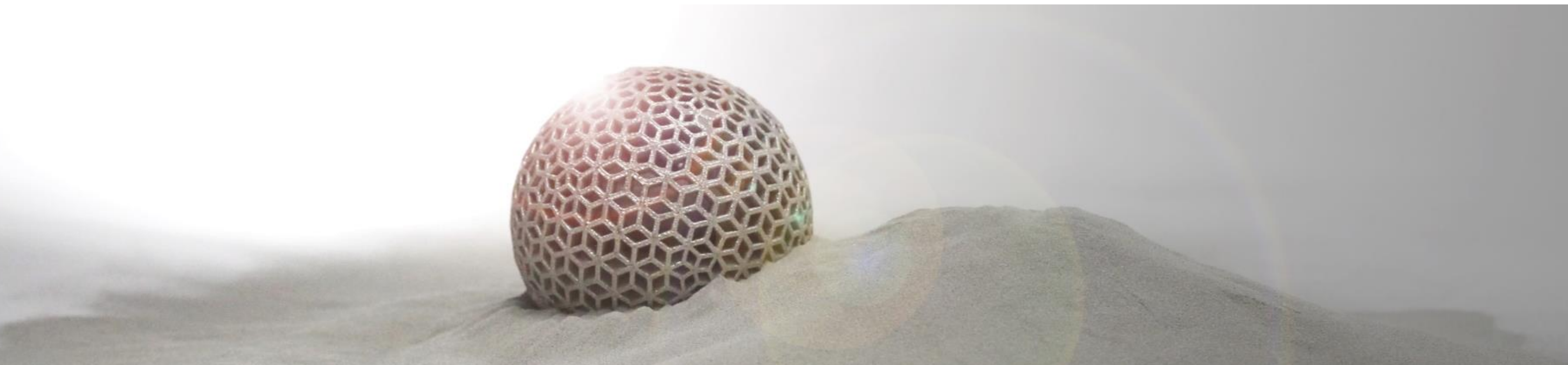
SLM®-processed stainless steel components exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat treatment (e.g. solution annealing), the components' properties can be adapted to meet specific requirements.

Chemical composition [Mass fraction in %][8]

Fe	Cr	Ni	Mo	Nb + Ta	Mn	Si	P	S	C	N	O
Balance	16.00-18.00	10.00-14.00	2.00-3.00	\	2.00	1.00	0.045	0.030	0.030	0.10	\

Pulvereigenschaften

Particle size[8]	10-45 µm	Particle shape[9]	Spherical
Mass density[2]	≈ 7.9 g/cm³	Thermal conductivity	15 W/(m·K)



Fe-Alloy 316L (1.4404)[1]

30 µm / 400 W[3]		As-built
Build-up rate [7]	[%]	10.4 cm³/h
Component density[6]	[%]	≥ 99.5 %

Tensile test[10]				M	SD
Tensile strength	R_m	[MPa]	H	692	4
			V	618	2
Offset yield strength	$R_{p0,2}$	[MPa]	H	591	16
			V	541	2
Elongation at break	A	[%]	H	39	1
			V	45	1
Reduction of area	Z	[%]	H	66	2
			V	72	2
Young's modulus	E	[GPa]	H	239	51
			V	178	9

Hardness test[11]		M	SD
Vickers hardness	HV10	221	4

Roughness measurement[12]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	8	2	6	2	5	1
Mean roughness depth	Rz	[µm]	68	10	40	6	30	5

Fe-Alloy 316L (1.4404)[1]

50 µm / 400 W[4]		As-built
Build-up rate[7]	[%]	15.3 cm³/h
Component Density [6]	[%]	≥ 99.5 %

Tensile test[10]				M	SD
Tensile strength	R_m	[MPa]	H	651	5
			V	640	8
Offset yield strength	$R_{p0,2}$	[MPa]	H	546	8
			V	529	14
Elongation at break	A	[%]	H	41	1
			V	43	1
Reduction of area	Z	[%]	H	70	2
			V	69	2
Young's modulus	E	[GPa]	H	181	29
			V	178	22

Hardness test[11]		M	SD
Vickers hardness	HV10	211	4

Roughness measurement[12]			As-built		Corundum blasted		Corundum- and Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	9	3	7	2	6	2
Mean roughness depth	Rz	[µm]	71	13	54	11	44	7

Fe-Alloy 316L (1.4404)[1]

60 µm / 400 W[5]		As-built
Build-up rate[7]	[%]	24.6 cm³/h
Component Density [6]	[%]	≥ 99.5 %

Tensile test[10]				M	SD
Tensile strength	R_m	[MPa]	H	674	5
			V	616	4
Offset yield strength	$R_{p0,2}$	[MPa]	H	556	12
			V	498	3
Elongation at break	A	[%]	H	40	1
			V	44	5
Reduction of area	Z	[%]	H	65	3
			V	66	7
Young's modulus	E	[GPa]	H	187	54
			V	173	12

Hardness test[11]		M	SD
Vickers hardness	HV10	214	5

Roughness measurement[12]			As-built		Corundum blasted		Corundum- and Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	12	5	10	3	9	2
Mean roughness depth	Rz	[µm]	83	18	63	7	57	6

Fe-Alloy 316L (1.4404)[1]

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[1] Material according to DIN EN 10088:2014, ASTM A276.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: 316L_SLM_MBP3.0_30_CE2_400W_Stripes_V3.0

[4] Material data file: 316L_SLM_MBP3.0_50_CE2_400W_Stripes_V3.0

[5] Material data file: 316L_SLM_MBP3.0_60_CE2_400W_Stripes_V3.0

[6] Optical density determination at test specimens by light microscopy.

[7] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[8] With respect to powder material.

[9] According to DIN EN ISO 3252:2001.

[10] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); testing machine: ZwickRoell ProLine; load range: 100 kN; testing speed: 0,008 1/s; testing temperature: room temperature. Test samples were turned before tensile test.

[11] Hardness testing according to DIN EN ISO 6507-1:2018.

[12] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm. Glass-bead blasting is an additional post-processing step after corundum blasting.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Tool Steel 1.2709 / A646 / M300[1]

General

Tool steels such as 1.2709 are primarily used for manufacturing tools and molds. They are characterized by a high hardness combined with a high ductility. Their specific mechanical properties allow usage in high-stressed components due to its high wear resistance. The maximum operating temperatures can further reduce wear. An SLM®-specific bene t is the layerwise manufacturing, which allows to implement cooling channels into the component.

Material Structure

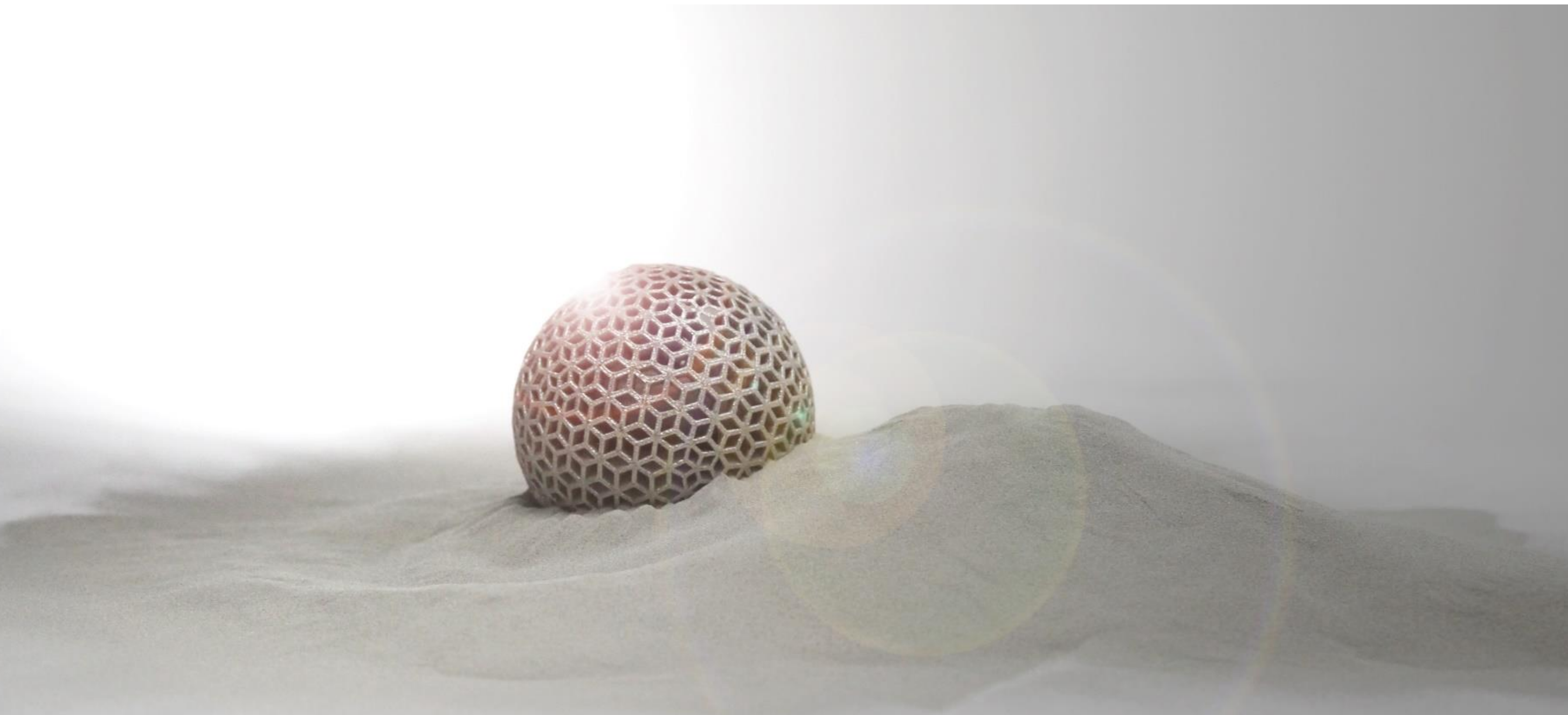
SLM®processed tool steel components exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat treatment (e.g. precipitation hardening, soft annealing), the components' properties can be adapted to meet specific requirements.

Chemical composition [Mass fraction in %][8]

Fe	Ni	Co	Mo	Ti	Al	Mn	Si	P	S	C	O
Balance	18.00 – 19.00	8.50 – 9.50	4.70 – 5.20	0.50 – 0.80	0.05 – 0.15	0.10	0.10	0.01	0.01	0.03	/

Powder properties

Particle size[8]	10 – 45 µm	Particle shape[9]	Spherical
Mass density[2]	8.0 g/cm³	Thermal conductivity	14.2 W/(m·K)



Tool Steel 1.2709 / A646 / M300[1]

Layer thickness 30 µm[3]				As-built		Heat-treated[13]	
Build-up rate[7]	[cm³/h]			10.0 cm³/h			
Component density [6]	[%]			≈ 99.5 %			
Tensile Test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	0°	1190	20	2038	20
			45°	1184	27	2107	20
			90°	1213	20	2111	20
Offset yield strength	$R_{p0,2}$	[MPa]	0°	999	8	1962	8
			45°	967	41	2023	15
			90°	1076	15	1937	17
Elongation at break	A	[%]	0°	14	5	8	2
			45°	12	5	4	2
			90°	10	2	4	2
Reduction of area	Z	[%]	0°	60	3	31	5
			45°	56	1	12	0
			90°	49	3	19	5
Young's modulus	E	[GPa]	0°	168	4	192	4
			45°	173	6	201	14
			90°	181	2	203	4
Hardness Test[11]				M	SD	M	SD
Vickers hardness	HV10			654	8	608	5
Roughness measurement[12]				As-built		Corundum blasted	
				M	SD	M	SD
Roughness average	Ra	[µm]		7	1	6	2
Mean roughness depth	Rz	[µm]		45	5	41	4

SLM SOLUTIONS

Tool Steel 1.2709 / A646 / M300[1]

Layer thickness 50 µm[4]				As-built		Heat-treated[13]	
Build-up rate[7]	[cm³/h]			10.0 cm³/h			
Component density [6]	[%]			≈ 99.5 %			
Tensile Test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	0°	1174	20	1940	34
			45°	1128	42	2040	14
			90°	1175	24	2021	28
Offset yield strength	$R_{p0,2}$	[MPa]	0°	965	25	1789	35
			45°	890	45	1971	14
			90°	970	32	1978	23
Elongation at break	A	[%]	0°	14	5	6	2
			45°	10	2	5	2
			90°	12	2	5	2
Reduction of area	Z	[%]	0°	55	11	28	4
			45°	56	2	8	1
			90°	57	5	22	7
Young's modulus	E	[GPa]	0°	170	8	198	40
			45°	187	11	199	5
			90°	182	6	199	2
Hardness Test11]				M	SD	M	SD
Vickers hardness	HV10			342	22	575	10

Roughness measurement[12]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	9	1	-	-
Mean roughness depth	Rz	[µm]	67	5	-	-

Tool Steel 1.2709 / A646 / M300[1]

Layer thickness 60 µm[5]				As-built		Heat-treated[13]	
Build-up rate[7]	[cm³/h]			10.0 cm³/h			
Component density [6]	[%]			≈ 99.5 %			

Tensile Test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	0°	1168	20	1975	20
			45°	1073	29	2018	21
			90°	1091	36	1921	20
Offset yield strength	$R_{p0,2}$	[MPa]	0°	931	25	1894	2
			45°	896	59	1944	30
			90°	943	53	1921	17
Elongation at break	A	[%]	0°	13	5	6	2
			45°	11	5	6	2
			90°	11	5	4	2
Reduction of area	Z	[%]	0°	49	7	22	1
			45°	47	4	20	5
			90°	44	11	13	8
Young's modulus	E	[GPa]	0°	172	11	190	9
			45°	167	13	186	10
			90°	167	10	185	8

Hardness Test11]		M	SD	M	SD
Vickers hardness	HV10	-	-	552	6

Roughness measurement[12]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	10	2	5	2
Mean roughness depth	Rz	[µm]	61	10	35	11

Material Data Sheet

Tool Steel 1.2709 / A646 / M300[1]

The properties and mechanical characteristics apply to powder that is tested and sold by SLM Solutions, and that has been processed on SLM Solutions machines using the original SLM Solutions parameters in compliance with the applicable operating instructions (including installation conditions and maintenance). The part properties are determined based on specified procedures. More details about the procedures used by SLM Solutions are available upon request.

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[1] Material according to ASTM A646 Grade Marage 300.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: 1.2709_SLM_MBP3.0_30_CE2_400W_Stripes_V1.2

[4] Material data file: 1.2709_SLM_MBP3.0_50_CE2_400W_Stripes_V1.3

[5] Material data file: 1.2709_SLM_MBP3.0_60_CE2_400W_Stripes_V1.0

[6] Optical density determination by light microscopy.

[7] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[8] With respect to powder material.

[9] According to DIN EN ISO 3252:2001.

[10] Tensile test according to ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); testing machine: Zwick Z100; load range: 100 kN; testing speed: 0,008 1/s; testing temperature: room temperature. Test samples were turned before tensile test.

[11] Hardness testing according to DIN EN ISO 6507-1:2018.

[12] Roughness measurement according to DIN EN ISO 4288:1998; λc = 0,8 mm.

(13) Heat treatment: aging 500 °C, 6 h; air-cooling.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Tool Steel 1.2344 / A681 H13 / H13[1]

General

Components made of tool steel such as 1.2344 (H13) are known for great hardness combined with high ductility. Through selective application of alloying components, the material properties can be precisely adjusted. Applications for corrosion resistant alloys are found in medical technologies, the automotive industry as well as in aerospace engineering. Tool steel is mainly used for producing tools and molds. Its layered structure enables components to be equipped with integrated cooling channels. The good mechanical characteristic values of tool and stainless steel make it suitable for use in places that are exposed to heavy strain, because its high wear to resistance keeps abrasion to a minimum.

Material Structure

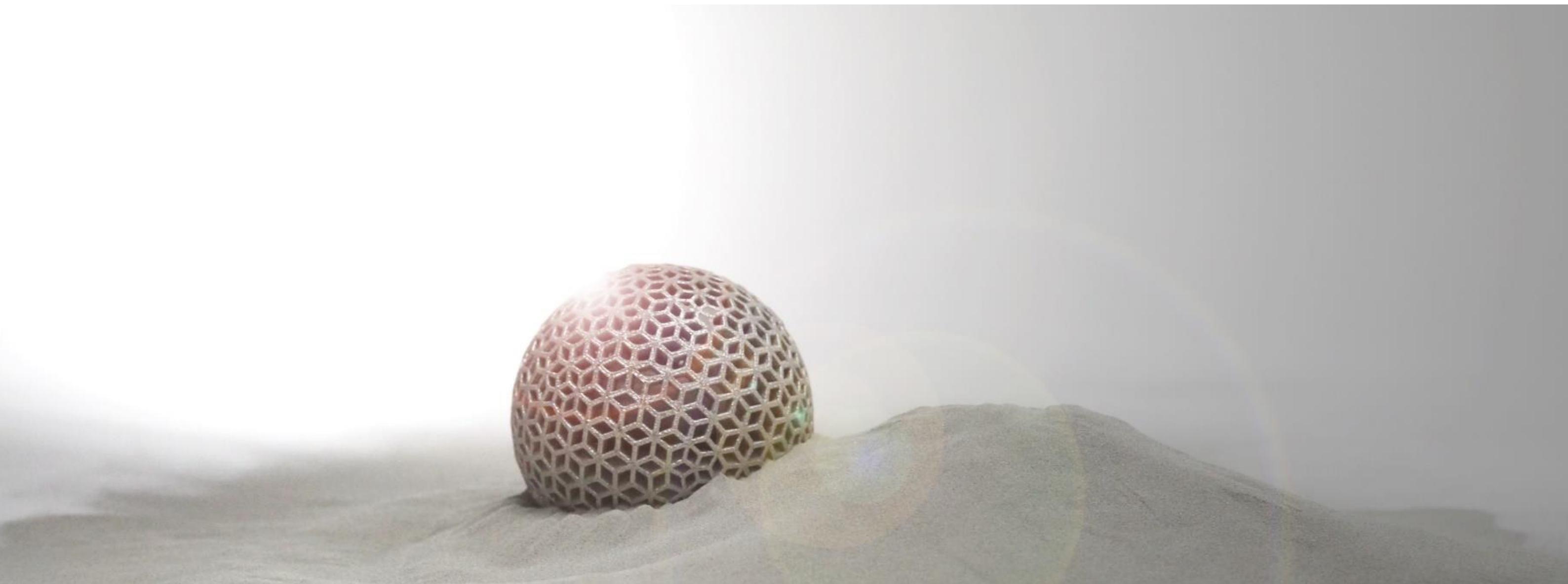
SLM®-processed tool steel components exhibit a homogeneous, nearly non-porous texture, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat treatment (e.g. precipitation hardening, soft annealing), the components' properties can be adapted to meet specific requirements.

Chemical composition [Mass fraction in %][7]

Fe	C	Cr	Mn	Mo	Ni + Cu	P	S	Si	V	N	O
Balance	0.32 – 0.45	4.75 – 5.50	0.20 – 0.60	1.10 – 1.75	0.75	0.03	0.03	0.80 – 1.25	0.80 – 1.20	/	/

Powder properties

Particle size[7]	10 – 45 µm	Particle shape[8]	Spherical
Mass density[2]	≈ 8.0 g/cm³	Thermal conductivity	/



Material Data Sheet

Tool Steel 1.2344 / A681 H13 / H13[1]

Layer thickness 30 µm[3]		As-built	Heat-treated [12]
Build-up rate [10]	[cm³/h]	10.4 cm³/h	
Component density[11]	[%]	≈ 99.5 %	

Tensile test[9]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1244	106	1719	239
			V	1360	86	1720	99
Offset yield strength	$R_{p0,2}$	[MPa]	H	987	39	1528	32
			V	-	-	-	-
Elongation at break	A	[%]	H	2	2	4	2
			V	1	2	9	2
Reduction of area	Z	[%]	H	-	-	14	5
			V	-	-	16	5
Young's modulus	E	[GPa]	H	203	23	-	-
			V	-	-	-	-

Tool Steel 1.2344 / A681 H13 / H13[1]

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[1] Material according to ASTM A681 H13.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: H13_SLM_MBP2.2_30_FS_Stripes_T200_400W_V5103

[4] Material data file: H13_SLM_MBP2.2_50_Stripes_T200_400W_V5103

[5] Optical density determination by light microscopy.

[6] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[7] With respect to powder material.

[8] According to DIN EN ISO 3252:2001

[9] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – B6x30); orientation: 0°, 90°; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature; test laboratory: EWIS GmbH. Test samples were turned before tensile test.

[10] Hardness testing according to DIN EN ISO 6507-1:2018.

[11] Roughness measurement according to DIN EN ISO 4288:1998; λc = 0,8 mm.

[12] Heat treatment: preheating to 750 °C for 2 h, followed by austenitizing at 1050 °C for 15 min. and quenching in warm oil (about 60 °C). Immediate double tempering at 300 °C for 2.5 h with interstage cooling down to room temperature.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Fe-Alloy Invar 36® / 1.3912[1]

General

Invar 36® is an iron-based alloy with 36 % nickel. A special feature of this material is its low coefficient of thermal expansion below its Curie temperature of 280°C. Invar 36® also has excellent mechanical properties and a low tendency to fatigue in cryogenic environment. Fields of application are components that require both a high reliability and a high dimensional stability. For example, Invar 36® is used for space equipment, clocks, valves in engines, bimetallic thermostats, optic and laser systems, and precision instruments.

Material Structure

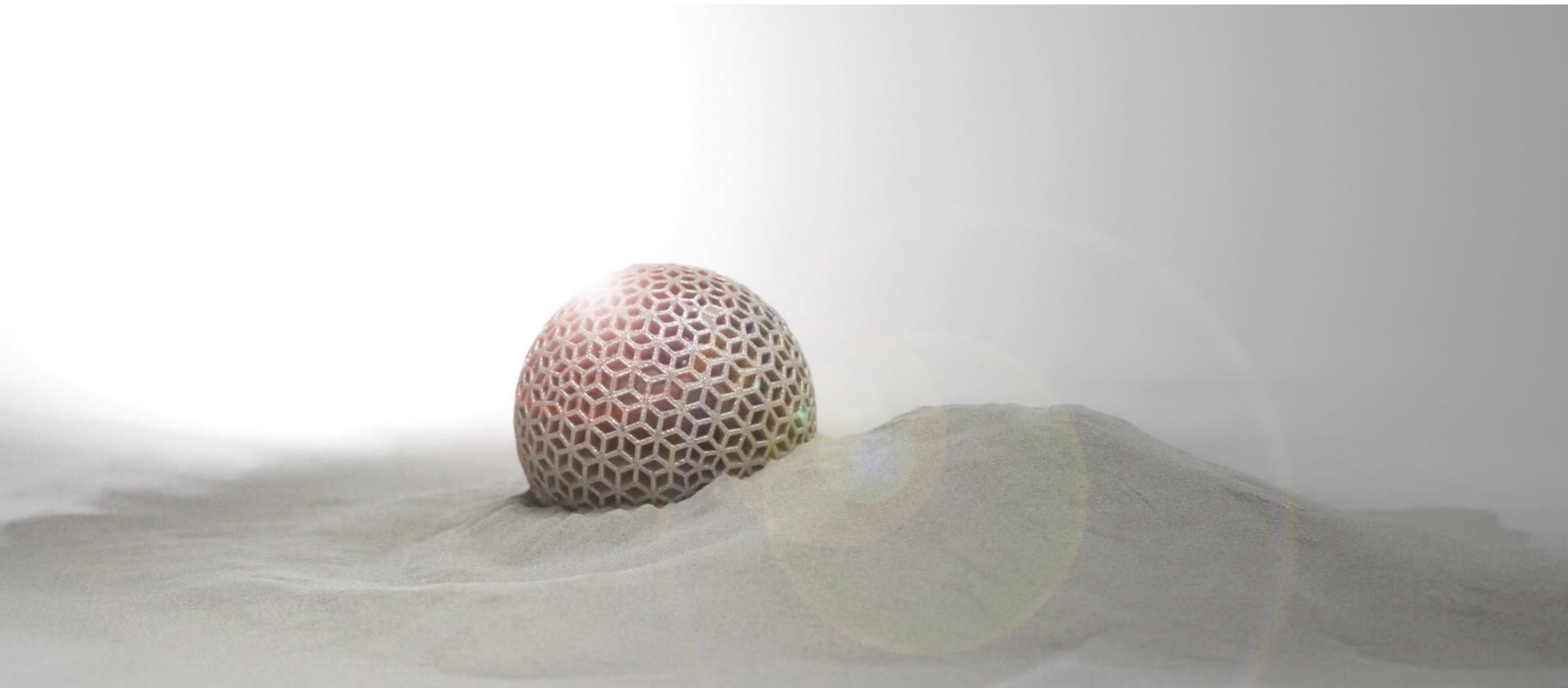
SLM®-processed components out of Invar 36® show a homogenous, nearly void free structure, with mechanical characteristic values in the range of material specifications. By post processing like heat treatment (e.g. stress-relief annealing, soft annealing, stabilizing annealing), material properties can be adjusted to individual required conditions.

Chemical composition [Mass fraction in %][6]

Fe	Ni	Cr	Mn	Si	C	Other each	Other total	P	C	N	O
Balance	35.00 – 37.00	0.50	0.50	0.50	0.10	0.20	0.50	/	/	/	/

Powder properties

Particle size[6]	10 – 45 µm	Particle shape[7]	Spherical
Mass density[1]	8.1 g/cm³	Thermal conductivity	12.8 W/(m·K)



Material Data Sheet

Fe-Alloy Invar 36® / 1.3912[1]

Layer thickness 30 µm[3]				As-built		Heat-treated [11]	
Build-up rate [5]	[cm³/h]			10.0 cm³/h			
Component density[4]	[%]			> 99.5 %			
Tensile test[8]				M	SD	M	SD
Tensile strength	R_m	[MPa]	0°	508	15	510	15
			45°	457	15	487	15
			90°	443	15	443	5
Offset yield strength	$R_{p0,2}$	[MPa]	0°	404	4	392	14
			45°	394	2	386	2
			90°	352	4	354	4
Elongation at break	A	[%]	0°	31	5	33	5
			45°	33	5	32	5
			90°	35	5	34	5
Reduction of area	Z	[%]	0°	71	1	71	3
			45°	72	3	71	5
			90°	80	2	79	2
Young's modulus	E	[GPa]	0°	153	11	138	13
			45°	125	17	151	13
			90°	131	8	126	5
Hardness test[9]				M	SD	M	SD
Vickers hardness	HV10			149	2	-	-
Roughness measurement[10]				As-built		Corundum blasted	
				M	SD	M	SD
Roughness average	Ra	[µm]		13	3	-	-
Mean roughness depth	Rz	[µm]		82	21	-	-

Material Data Sheet

Fe-Alloy Invar 36® / 1.3912[1]

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[1] Material according to DIN 1715-1:1983.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: Invar_SLM_MBP2.2_30_CE2_400W_Stripes_V1.0

[4] Optical density determination at test specimens by light microscopy.

[5] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[6] With respect to powder material.

[7] According to DIN EN ISO 3252:2001.

[8] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0°, 45°, 90°.

[9] Hardness testing according to DIN EN ISO 6507-1:2018.

[10] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[11] Heat treatment for stabilization of thermal expansion coefficient: 1) Annealing at 880 °C for 0,5 h and quenching in water 2) Annealing at 300 °C for > 1h and cooling with air 3) Heating to 100 °C and furnace cooling for 48 h.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Ni-Alloy IN625 / 2.4856 / B446[1]

General

Developed in the early 1960‘s, IN625 is still considered the material of choice for the majority of aircraft engine components with service temperatures below 650 °C. IN625 is a precipitation-hardenable nickel-chromium alloy containing also significant amounts of iron, niobium, and molybdenum along with lesser amounts of aluminum and titanium. It combines corrosion resistance and high strength with outstanding weldability including resistance to postweld cracking. This alloy has excellent creep-rupture strength at temperatures to 700 °C.

Material Structure

SLM®-processed components out of IN625 show a homogenous, nearly void free structure. The mechanical properties are in the range of material specifications. Through subsequent processing such as heat treatment (e.g. stress-relief annealing, solution annealing) or hot isostatic pressing (HIP), the material properties can be adjusted to individual required conditions.

Chemical composition [Mass fraction in %][8]

Ni	Cr	Mo	Nb	Fe	Co	Si	Mn	Ti	Al	C	S
Balance	20.00 – 23.00	8.00 – 10.00	3.15 – 4.15	5.00	1.00	0.50	0.50	0.40	0.40	0.1	0.015

P
0.015

Powder properties

Particle size[8]	10 – 45 µm	Particle shape[9]	Spherical
Mass density[2]	8.44 g/cm³	Thermal conductivity	9.8 W/(m·K)

Ni-Alloy IN625 / 2.4856 / B446[1]

20 µm / 400 W[3]				As-built		Heat-treated [13]	
Build-up rate [7]	[cm³/h]			6.48 cm³/h			
Component density[6]	[%]			> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1103	14	1085	11
			V	965	14	971	6
Offset yield strength	$R_{p0,2}$	[MPa]	H	784	32	704	24
			V	705	12	685	5
Elongation at break	A	[%]	H	28	1	31	1
			V	40	2	43	1
Reduction of area	Z	[%]	H	43	3	36	3
			V	43	3	47	5
Young's modulus	E	[GPa]	H	170	36	188	31
			V	162	18	196	10

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	310	5	299	3

Roughness measurement[12]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	4	1	3	1	2	1
Mean roughness depth	Rz	[µm]	37	3	21	1	14	1

Ni-Alloy IN625 / 2.4856 / B446[1]

30 µm / 400 W[4]				As-built		Heat-treated [13]	
Build-up rate [7]	[cm³/h]			10.37 cm³/h			
Component density[6]	[%]			> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1072	20	1069	16
			V	945	10	938	7
Offset yield strength	$R_{p0,2}$	[MPa]	H	737	28	699	20
			V	686	11	649	4
Elongation at break	A	[%]	H	31	1	33	1
			V	42	5	45	1
Reduction of area	Z	[%]	H	35	4	36	3
			V	44	8	49	3
Young's modulus	E	[GPa]	H	178	27	172	19
			V	153	18	190	9

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	303	7	297	4

Roughness measurement[12]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	4	1	3	1	2	1
Mean roughness depth	Rz	[µm]	37	3	21	1	14	1

Ni-Alloy IN625 / 2.4856 / B446[1]

60 µm / 400 W[5]			As-built		Heat-treated [13]	
Build-up rate [7]	[cm³/h]		23.33 cm³/h			
Component density[6]	[%]		> 99.5 %			

Tensile test[10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1057	5	1063	7
			V	995	8	1006	7
Offset yield strength	$R_{p0,2}$	[MPa]	H	708	15	664	9
			V	674	23	653	6
Elongation at break	A	[%]	H	33	1	34	1
			V	37	4	40	2
Reduction of area	Z	[%]	H	41	4	39	1
			V	36	5	43	4
Young's modulus	E	[GPa]	H	191	47	179	28
			V	166	30	208	7

Hardness test[11]		M	SD	M	SD
Vickers hardness	HV10	291	4	284	5

Roughness measurement[12]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	8	1	5	1	4	1
Mean roughness depth	Rz	[µm]	56	6	34	4	24	3

Ni-Alloy IN625 / 2.4856 / B446[1]

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[1] Material according to DIN 17744:2002, ASTM B446.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: IN625_SLM_MBP3.0_20_CE2_400W_Stripes_V2.2

[4] Material data file: IN625_SLM_MBP3.0_30_CE2_400W_Stripes_V2.1

[5] Material data file: IN625_SLM_MBP3.0_60_CE2_400W_Stripes_V2.1

[6] Optical density determination by light microscopy.

[7] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[8] With respect to powder material.

[9] According to DIN EN ISO 3252:2001.

[10] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – B6x30); orientation: 0°, 90°; heat treatment: none; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature; test laboratory: EWIS GmbH. Test samples were turned before tensile test.

[11] Hardness testing according to DIN EN ISO 6507-1:2018.

[12] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[13[Specimens were heated up to 870 °C with subsequent holding for 1 h, followed by air-cooling. According to AMS 5599.

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+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Ni-Alloy IN718 / 2.4668 [1]

General

IN718 is a precipitation-hardenable nickel-chromium alloy with a density of circa 8.2 g/cm³. Developed in the early 1960's, this alloy is still considered the material of choice for the majority of aircraft engine components with service temperatures below 700 °C. IN718 combines a very good corrosion resistance at high and low temperatures and a good corrosion resistance at temperatures to 1000 °C with outstanding weldability including resistance to postweld cracking. Furthermore, the alloy has excellent tensile, fatigue, creep, and rupture strength at temperatures up to 700 °C. Besides components for (gas) turbines, IN718 can be used for engine components, rocket parts, and in high temperature environments in general.

Material Structure

SLM®-processed components out of IN718 show a homogenous, nearly non-porous structure. The mechanical properties are in the range of material specifications. Through subsequent processing such as heat treatment (e.g. precipitation hardening), material properties can be adjusted to the individual required conditions.

Chemical composition [Mass fraction in %][2]

Ni	Cr	Fe	Ta + Nb	Mo	Ti	Al	Cu	C	Si	Mn	B
50.00 – 55.00	17.00 – 21.00	Balance	4.75 – 5.50	2.80 – 3.30	0.65 – 1.15	0.20 – 0.80	0.30	0.08	0.35	0.35	0.006

Co	P	S
1.00	0.015	0.015

Powder properties

Particle size[2]	10 – 45 µm	Particle shape[3]	Spherical
Mass density[4]	8.2 g/cm³	Thermal conductivity[5]	11.2 W/(m·K)

Material Data Sheet

Ni-Alloy IN718 / 2.4668 [1]

Layer thickness 30 µm [6]			As-built		Heat-treated [14]	
Build-up rate [8]	$[cm^3/h]$		$16.85\ cm^3/h$			
Component density [9]	[%]		>99.5 %			

Tensile test [10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1098	10	1507	15
			V	1027	10	1412	86
Offset yield strength	$R_{p0,2}$	[MPa]	H	764	14	1281	32
			V	684	6	1225	68
Elongation at break	A	[%]	H	27	5	9	5
			V	29	5	11	5
Reduction of area	Z	[%]	H	39	3	17	2
			V	40	5	25	6
Young's modulus	E	[GPa]	H	183	24	230	33
			V	168	10	186	15

Hardness test [11]		M	SD	M	SD
Vickers hardness	HV10	303	7	470	4

Tenacity test [12]				M	SD	M	SD
Impact energy	KV	[J]	H	70	5	23	2
			V	80	8	28	3

Roughness measurement [13]			As-built	
			M	SD
Roughness average	Ra	[µm]	6	2
Mean roughness depth	Rz	[µm]	47	5

Material Data Sheet

Ni-Alloy IN718 / 2.4668 [1]

Layer thickness 60 µm [7]		As-built	Heat-treated [14]
Build-up rate [8]	[cm^3/h]	25.92 cm^3/h	
Component density [9]	[%]	>99.5 %	

Tensile test [10]				M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1037	20	1467	22
			V	942	15	1369	20
Offset yield strength	$R_{p0,2}$	[MPa]	H	665	29	1248	24
			V	606	8	1206	12
Elongation at break	A	[%]	H	38	5	13	5
			V	31	5	15	5
Reduction of area	Z	[%]	H	35	3	18	4
			V	36	6	22	4
Young's modulus	E	[GPa]	H	172	48	182	10
			V	154	13	194	7

Hardness test [11]		M	SD	M	SD
Vickers hardness	HV10	292	6	458	9

Tenacity test [12]				M	SD	M	SD
Impact energy	KV	[J]	H	74	3	22	2
			V	80	12	25	2

Roughness measurement [13]			As-built	
			M	SD
Roughness average	Ra	[µm]	8	2
Mean roughness depth	Rz	[µm]	50	8

Ni-Alloy IN718 / 2.4668 [1]

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[1] Material according to DIN 17744:2002, ASTM B637.

[2] With respect to powder material.

[3] According to DIN EN ISO 3252:2001.

[4] Material density varies within the range of possible chemical composition variations.

[5] Literature value for conventionally manufactured material at 20 °C.

[6] Material data file: IN 718_SLM_MBP3.0_30_CE2_400W_Stripes_V2.0

[7] Material data file: IN 718_SLM_MBP3.0_60_CE2_400W_Stripes_V2.0

[8] Optical density determination at test specimens by light microscopy.

[9] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[10] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0° and 90°; heat treatment: none; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature; test laboratory: EWIS GmbH. Test samples were turned before tensile test.

[11] Hardness testing according to DIN EN ISO 6507-1:2018.

[12] Tenacity testing according to DIN EN ISO 148-1:2017-05.

[13] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[14] Specimens were heated up to 980 °C in a furnace, held for 1 h, followed by air-cooling. Then anew heating up to 720 °C, hold for 8h, then cool down to 620 °C in furnace with 50 °C/h. Hold at 620 °C for 8 h, then air-cooling.

SLM Solutions Group AG | Estlandring 4 | 23560 Lübeck | Germany
+49 451 4060 - 3000 | info@slm-solutions.com | slm-solutions.com

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Material Data Sheet

Ti-Alloy TA15[1]

General

TA15 is a near-alpha titanium-alloy with additives of aluminum, zirconium, and others. Very good mechanical properties, also at high temperatures, a good weldability as well as a high specific strength complete the outstanding pro le of this material. Due to its combination of a high loadability in multiaxial stress state and a high corrosion resistance, TA15 is primarily used within the aerospace industry and engines. Examples of application include heavily loaded components such as frames and other structural parts of airframes.

Material Structure

SLM®-processed components made of TA15 show a homogenous, nearly non-porous structure, with mechanical values in the range of material specifications. TA15's microstructure in the as-build condition consists of fine basket-weaves with α-laths. Through subsequent processing such as heat-treatment or hot isostatic pressing (HIP), the components' properties can be adapted to meet specific requirements.

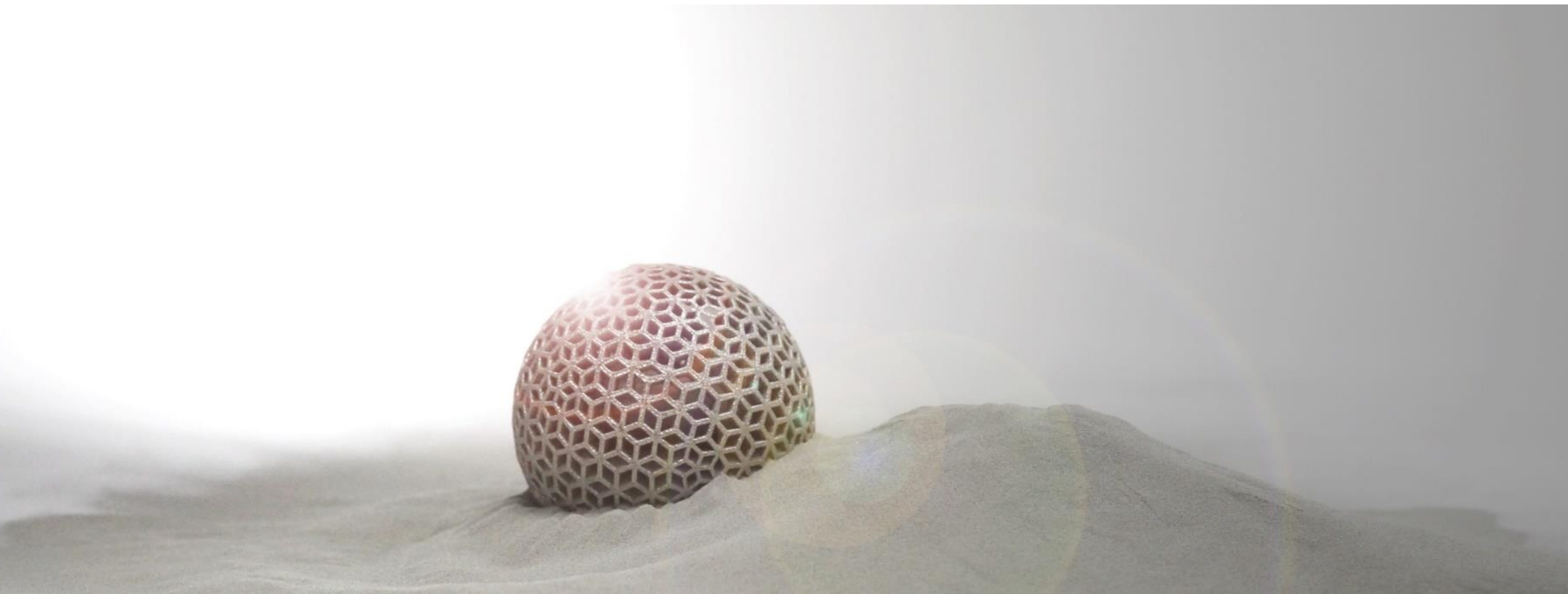
Chemical composition [Mass fraction in %][6]

Ti	Al	Zr	Mo	V	Si	C	Fe	O	N	H	Others
Balance	5.5 – 7.1	1.5 – 2.5	0.5 – 2.0	0.8 – 2.5	0.15	0.08	0.25	0.15	0.05	0.015	0.10

Total others
0.30

Powder properties

Particle size[6]	20 – 63 µm	Particle shape[7]	Spherical
Mass density[2]	~ 4.5 g/cm³	Thermal conductivity[6]	/



Ti-Alloy TA15[1]

Layer thickness 30 µm [3]		As-built
Build-up rate [4]	[cm³/h]	28.51 cm³/h
Component density[5]	[%]	> 99.5 %

Tensile test[8]				M	SD
Tensile strength	R_m	[MPa]	H	1358	34
			V	1404	8
Offset yield strength	$R_{p0,2}$	[MPa]	H	1186	27
			V	1260	16
Elongation at break	A	[%]	H	4	1
			V	6	1
Reduction of area	Z	[%]	H	6	1
			V	13	2
Young's modulus	E	[GPa]	H	110	7
			V	110	1

Hardness test[9]		M	SD
Vickers hardness	HV10	385	4

Roughness measurement[10]			As-built		Corundum blasted		Glass-bead blasted	
			M	SD	M	SD	M	SD
Roughness average	Ra	[µm]	17	4	13	3	11	2
Mean roughness depth	Rz	[µm]	102	19	88	18	69	14

Ti-Alloy TA15[1]

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[1] Material according to GB/T 3620-2007.

[2] Rough value. Material density varies within the range of possible chemical composition variations.

[3] Material data file: TA15_SLM_MBP3.0_60_CE2_400W_Stripes_V1.2

[4] Optical density determination by light microscopy.

[5] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[6] With respect to powder material.

[7] According to DIN EN ISO 3252:2001.

[8] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – B6x30); orientation: 0°, 90°; heat treatment: none; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature. Test samples were turned before tensile test.

[9] Hardness testing according to DIN EN ISO 6507-1:2018.

[10] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

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Material Data Sheet

Ti Grade 2 / ASTM F67 / 3.7035[1]

General

Ti Grade 2 is a commercially pure titanium grade with excellent biocompatibility and good mechanical properties. The achievable yield strength compares to that of austenitic stainless steels. Interstitially solved elements in small quantities increase the corrosion resistance. Ti Grade 2 is widely used in many different applications that require strength, ductility, and low density, potentially surrounded by corrosive media. Ti Grade 2 can be used in continuous operation at temperatures up to 425 °C; operation at up to 540 °C is possible for a short time. Typical applications for Ti Grade 2 are orthopedic implants in medical engineering or heat exchangers in energy technology. Further possible applications can also be found in aircraft and electrochemistry.

Material Structure

SLM®-processed components made of Ti Grade 2 show a homogenous, nearly non-porous structure, with mechanical properties in the range of material specifications. In the SLM® process with Ti Grade 2, an α-structure corresponding to annealed state is formed. An additional heat treatment is, therefore, not necessary.

Chemical composition [Mass fraction in %][6]

Ti	C	Fe	H	N	O	Other each	Other total	S	Cr	Cu	Mo
Balance	0.08	0.30	0.015	0.03	0.25	0.10	0.40	/	/	/	/

Powder properties

Particle size[6]	20 – 63 µm	Particle shape[7]	Spherical
Mass density[2]	4.5 g/cm³	Thermal conductivity	22 W/(m·K)

Ti Grade 2 / ASTM F67 / 3.7035[1]

30 µm / 400 W[3]		As-built
Build-up rate [5]	[cm³/h]	18.14 cm³/h
Component density[4]	[%]	> 99.5 %

Tensile test[8]				M	SD
Tensile strength	R_m	[MPa]	H	701	4
			V	703	5
Offset yield strength	$R_{p0,2}$	[MPa]	H	593	12
			V	577	5
Elongation at break	A	[%]	H	24	1
			V	25	2
Reduction of area	Z	[%]	H	65	3
			V	68	2
Young's modulus	E	[GPa]	H	115	8
			V	111	3

Hardness test[9]		M	SD
Vickers hardness	HV10	225	6

Roughness measurement[10]			As-built	
			M	SD
Roughness average	Ra	[µm]	13	2
Mean roughness depth	Rz	[µm]	80	6

Ti Grade 2 / ASTM F67 / 3.7035[1]

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[1] Material according to DIN 17850, ASTM F67.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: Ti Grade 2_SLM_MBP3.0_30_CE2_400W_Stripes_V1.0

[4] Optical density determination at test specimens by light microscopy.

[5] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[6] With respect to powder material.

[7] According to DIN EN ISO 3252:2001.

[8] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0° and 90°; heat treatment: none; testing machine: Zwick 1484; load range: 200 kN; testing speed: 0,008 1/s; testing temperature: room temperature; test laboratory: EWIS GmbH. Test samples were turned before tensile test.

[9] Hardness testing according to DIN EN ISO 6507-1:2018.

[10] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

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Material Data Sheet

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

General

Ti6Al4V is the most frequently used titanium alloy worldwide and, due to its density of 4.43 g/cm³ [2], ranks among the lightweight alloys. High strength at low density and also excellent corrosion resistance allow a broad range of applications of titanium parts. Titanium and its alloys have been used successfully in the automotive and aerospace industry since the 1950s. Furthermore, titanium stands out through thermal expansion coefficient. Due to titanium's biocompatibility, it can also be used in medical technology. Thus, implants for dentistry or individual hip implants can be manufactured of Ti6Al4V ELI Grade 23 (extra low interstitials, small amount of interstitial iron and oxygen atoms).

Material Structure

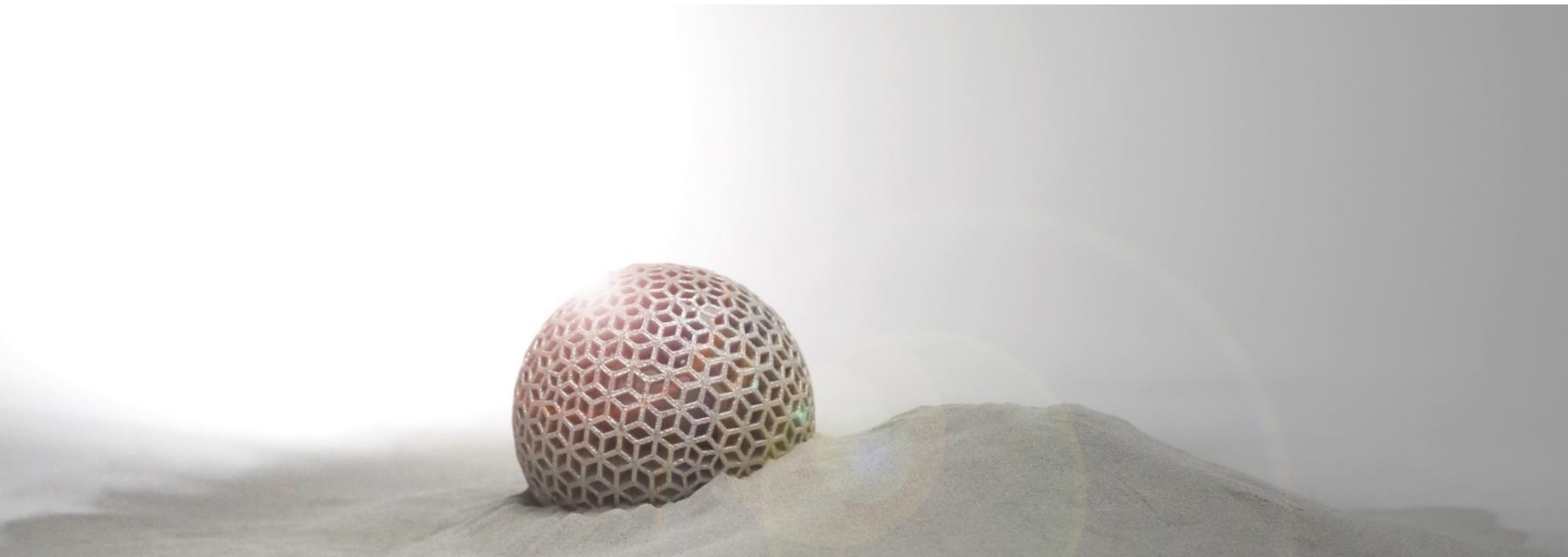
SLM®-processed components made of Ti6Al4V show a homogenous, nearly non-porous structure, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat-treatments (e.g. stress-relief annealing, recrystallization annealing, precipitation hardening) or hot isostatic pressing (HIP), the components' properties can be adapted to meet specific requirements. For Ti6Al4V-components produced with SLM®, a heat treatment at 940 °C for 4 h under inert argon atmosphere is recommended. Alternatively, HIP can be performed at 920 °C and 1000 bar for 2 h.

Chemical composition [Mass fraction in %][9]

Ti	Al	V	C	O	N	Fe	H	Other each	Other each	Cu	Mn
Balance	5.50 – 6.50	3.50 – 4.50	0.08	0.13	0.03	0.25	0.0125	0.10	0.40	/	/

Powder properties

Particle size[9]	20 – 63 µm	Particle shape[10]	Spherical
Mass density[5]	4.43 g/cm³	Thermal conductivity	7.1 W/(m·K)



Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

30 µm / 400 W[3]				As-built		Heat-treated [15]		HIP[16]	
Build-up rate [8]	[cm³/h]			18.14 cm³/h					
Component density[7]	[%]			> 99.5 %					

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1281	7	956	5	962	2
			V	1289	17	960	4	1002	7
Offset yield strength	$R_{p0,2}$	[MPa]	H	1076	30	851	12	821	21
			V	1170	26	887	12	935	12
Elongation at break	A	[%]	H	8	1	13	1	14	1
			V	9	1	14	1	14	1
Reduction of area	Z	[%]	H	19	3	47	3	42	3
			V	29	7	50	2	41	4
Young's modulus	E	[GPa]	H	113	1	120	5	124	11
			V	117	2	126	1	124	6

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	362	11	307	4	316	10

Tenacity test[13]			M	SD	M	SD	M	SD
Impact energy	KV	[J]	11	1	29	3	23	3

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	6	1
Mean roughness depth	Rz	[µm]	76	6	39	3

Material Data Sheet

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

60 µm / 400 W[4]				As-built		Heat-treated [15]		HIP[16]	
Build-up rate [8]	[cm³/h]			28.51 cm³/h					
Component density[7]	[%]			> 99.5 %					

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1351	17	987	4	1021	3
			V	1330	12	991	3	1027	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1189	49	894	5	885	11
			V	1196	26	905	11	953	7
Elongation at break	A	[%]	H	7	1	12	1	15	1
			V	9	1	15	1	15	1
Reduction of area	Z	[%]	H	13	2	45	5	39	2
			V	26	3	49	1	38	9
Young's modulus	E	[GPa]	H	113	7	112	5	127	6
			V	120	4	130	8	125	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Tenacity test[13]			M	SD	M	SD	M	SD
Impact energy	KV	[J]	14	1	27	2	21	2

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	6	1
Mean roughness depth	Rz	[µm]	71	6	36	3

Material Data Sheet

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

60 µm / 700 W[5]				As-built		Heat-treated [15]		HIP[16]	
Build-up rate [8]	[cm³/h]			38.88 cm³/h					
Component density[7]	[%]			> 99.5 %					

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1251	11	963	6	1104	5
			V	1260	12	964	4	998	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1098	68	870	3	860	15
			V	1129	23	883	8	926	6
Elongation at break	A	[%]	H	8	1	16	1	15	2
			V	8	2	14	1	15	1
Reduction of area	Z	[%]	H	17	3	50	1	34	3
			V	22	11	46	3	38	2
Young's modulus	E	[GPa]	H	108	8	113	5	121	17
			V	115	4	124	3	125	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	11	1	5	1
Mean roughness depth	Rz	[µm]	70	6	34	4

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

90 µm / 700 W[6]				As-built		Heat-treated [15]		HIP[16]	

Build-up rate [8]	[cm³/h]	53.46 cm³/h
Component density[7]	[%]	> 99.5 %

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1271	11	966	7	981	2
			V	1215	30	952	20	999	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1108	31	872	7	857	22
			V	1108	23	868	16	924	2
Elongation at break	A	[%]	H	7	1	15	1	15	1
			V	10	2	14	1	15	1
Reduction of area	Z	[%]	H	16	5	47	1	37	4
			V	24	9	50	2	39	3
Young's modulus	E	[GPa]	H	111	8	114	4	128	15
			V	117	4	123	2	124	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	7	1
Mean roughness depth	Rz	[µm]	70	4	43	8

Material Data Sheet

SLM SOLUTIONS

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

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[1] Ti6Al4V ELI (Grade 23) according to DIN 17851:1990, ASTM B348, F136.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: Ti6Al4V_SLM_MBP3.0_30_CE2_400W_Stripes_V1.4

[4] Material data file: Ti6Al4V_SLM_MBP3.0_60_CE2_400W_Stripes_V1.2

[5] Material data file: Ti6Al4V_SLM_MBP3.0_60_CE2_700W_Stripes_V1.0

[6] Material data file: Ti6Al4V_SLM_MBP3.0_90_CE2_700W_Stripes_V1.0.

[7] Optical density determination by light microscopy.

[8] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[9] With respect to powder material.

[10] According to DIN EN ISO 3252:2001.

[11] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0°, 90°.

[12] Hardness testing according to DIN EN ISO 6507-1:2018.

[13] Charpy pendulum impact test according to DIN EN ISO 148-1:2017-05.

[14] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[15] Specimens were heated up in vacuum atmosphere at a rate of < 450 °C/h up to 910 °C, then with < 300 °C/h up to 940 °C. Subsequent holding at 940 ± 10 °C for 4 h -0/+30 min. Cooling down in vacuum at a rate of 40 ± 10 °C/h to 760 ± 15 °C, then in argon with 560 ± 100 °C/h to ≤ 480 °C, followed by gas fan quenching at any rate to ≤ 50 °C.

[16] Specimens were HIPed with 920 ± 10 °C and 1000 bar for 2 h.

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MELTIO

Material Datasheet

Inconel - 718

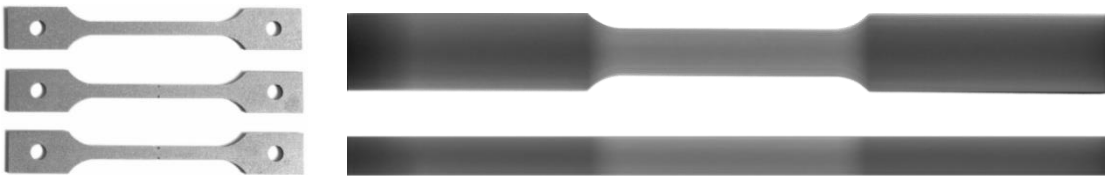
Description Inconel 718 is a high-strength, corrosion-resistant nickel chromium material used at -423° to 1300°F. Poor thermal conductivity, high toughness, and strong work hardening tendency adversely affect its machinability, creating a very good business case for additive manufacturing.

Applications It is used in aerospace industries for its excellent physical, mechanical, and chemical properties.

Composition AMS 5832 Wire classification 1.2mm diameter <0.08% C, <0.35% Mn, <0.35% Si, <0.015% S, <0.015% P, 12-21% Cr, 50-55% Ni, 0.65-1.15% Ti, 2.8-3.3% Mo, 4.75-5.5% Nb, 0.2-0.8% Al, <1% Co, <0.006% B, <0.3% Cu, Balance Fe.

Computed Tomography

Scans cover external and internal surfaces, with micrometre-level resolutions. Full 3D density maps of the samples inspected consistently report 99.998% density, with no trace of voids, porosity, contamination or cracking.



Images represent the tested specimens and the imaging from the computed tomography data for YZ and XY section planes at 60µm resolution.

Mechanical Properties

Results show Meltio's WP-LMD 3D printed specimens to perform at the same level as conventional manufacturing methods, with low deviations and near isotropic properties between horizontal (XY) and vertical (XZ) print orientations.

	Wrought Properties	Cast Properties	Meltio XY Properties	Meltio XZ Properties
Tensile Strength (MPa)	1241	802	1308 ± 10	1235 ± 11
Yield Strength (MPa)	1034	758	1128 ± 20	1040 ± 12
Elongation (%)	10	5	6.6 ± 2.1	8.5 ± 0.7

Data represents typical reference values from Wrought (AMS 5662) and Cast (AMS 5383) material classification compared to Meltio horizontal (XY) and vertical (Z) specimens extracted from 3D printed walls and tensile tested according to ASTM E8.

MELTIO

Material Datasheet

Inconel - 718

Notes

Properties reported in this material datasheet are average of a typical batch. The test coupons were extracted from multiple 3D printed walls, cut in horizontal (XY) and vertical (Z) directions for coupon extraction. The walls were 3D printed on a Meltio M450 and the testing was performed according to ASTM E8.

Disclaimer

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Version	2.2
Date	April 5, 2021

Material Datasheet

Stainless Steel – SS 316L

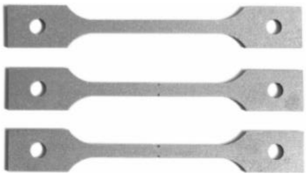
Description SS 316L is an austenitic steel with excellent durability, good biocompatibility, and adequate elevated temperature properties. The alloy has low carbon content which makes it particularly recommended when there is risk of intergranular corrosion. Thus, parts built in stainless steel have good corrosion resistance.

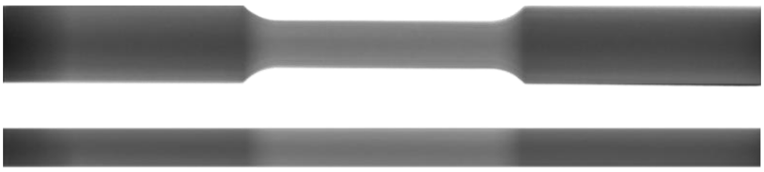
Applications This alloy has very good corrosion resistance in acid and chlorinated environments and it is widely used in the chemical and food industries, as well as in shipbuilding and various types or architectural structures.

Composition ISO 14343-A wire electrode classification with 1.2mm diameter. 0.01% C, 1.8% Mn, 0.9% Si, 12.2% Ni, 18.4% Cr, 2.6% Mo, 0.12% Cu, 7% Ferrite.

Computed Tomography

Scans cover external and internal surfaces, with micrometre-level resolutions. Full 3D density maps of the samples inspected consistently report 99.998% density, with no trace of voids, porosity, contamination or cracking.





Images represent the tested specimens and the imaging from the computed tomography data for YZ and XY section planes at 60μm resolution.

Mechanical Properties

Results show Meltio's WP-LMD 3D printed specimens to perform at the same level as conventional manufacturing methods, with low deviations and near isotropic properties between horizontal (XY) and vertical (XZ) print orientations.

	Wrought Properties	Cast Properties	Meltio XY Properties	Meltio XZ Properties
Tensile Strength (MPa)	515	550	635 ± 13	650 ± 7
Yield Strength (MPa)	208	260	390 ± 30	380 ± 17
Elongation (%)	40	35	52 ± 3	46 ± 4

Data represents typical reference values from Wrought (ASTM A403) and Cast (ASTM A351) classification compared to Meltio horizontal (XY) and vertical (XZ) specimens extracted from 3D printed walls and tensile tested according to ASTM A370 / ASME SA-370

Material Datasheet

Stainless Steel – SS 316L

Notes

Properties reported in this material datasheet are average of a typical batch. The test coupons were extracted from multiple 3D printed walls, cut in horizontal (XY) and vertical (Z) directions for coupon extraction. The walls were 3D printed on a Meltio M450 and the testing experiments were done according to ASTM E8 standard.

Disclaimer

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Material Datasheet

Titanium Alloy – Ti-6Al-4V

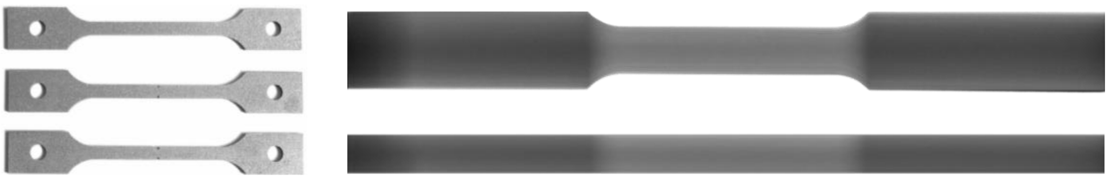
Description Ti-6Al-4V alloy, also known as Ti64, is an α + β titanium alloy with high strength, low density, high fracture toughness, excellent corrosion resistance and superior biocompatibility. Ti64 is recognized as the most popular titanium alloy.

Applications Typically used for direct manufacturing of parts and prototypes for aerospace, marine, motorsport, chemical, biomedical and gas industries.

Composition ASTM B863 Wire electrode classification with 1.2mm diameter. 6.03% Al, 3.95% V, 0.01% Sn, 0.131% Fe, 0.012% C, 0.043% N, <0.001% H, 0.096% O.

Computed Tomography

Scans cover external and internal surfaces, with micrometre-level resolutions. Full 3D density maps of the samples inspected consistently report 99.998% density, with no trace of voids, porosity, contamination or cracking.



Images represent the tested specimens and the imaging from the computed tomography data for YZ and XY section planes at 60µm resolution.

Mechanical Properties

Results show Meltio's WP-LMD 3D printed specimens to perform at the same level as conventional manufacturing methods, with low deviation across tested coupons.

	Wrought Properties	Cast Properties	Meltio XY Properties
Tensile Strength (MPa)	930	860	950 ± 5
Yield Strength (MPa)	860	758	882 ± 5
Elongation (%)	>10%	>8%	12 ± 0.5

Data represents typical reference values from Wrought (ASTM F1472) and Cast (ASTMF1108) material classification compared to Meltio horizontal (XY) and vertical (Z) specimens extracted from 3D printed walls and tensile tested according to ASTM E8.

Material Datasheet

Titanium Alloy – Ti-6Al-4V

Notes

Properties reported in this material datasheet are average of a typical batch. The test coupons were extracted from multiple 3D printed walls. The walls were 3D printed on a Meltio M450 and the testing experiments were done according to ASTM E8 standard.

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