Material data sheet

EOS Titanium Ti64ELI

EOS Titanium Ti64ELI is a titanium alloy powder intended for processing on EOS DMLS™ machines. This document provides information and data for parts built using:

- EOS Titanium Ti64ELI powder (EOS art.-no. 9011-0017 and 9011-0040)
- EOS DMLS™ machine: EOSINT M 290 400 W
- HSS blade (2200-4073)
  - Argon atmosphere
  - IPCM extra sieving module with 63 µm mesh (9044-0032) recommended
- EOSYSTEM:
  - EOSPRINT v 1.5 or newer
  - HCS v 2.4.14 or newer
- EOS Parameter set: Ti64ELI_Performance_M291 1.10

Description

EOS Titanium Ti64ELI has a chemical composition and corresponding to ASTM F136 and ASTM F3001.

Ti64ELI is well-known light alloy, characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight and biocompatibility. This material is ideal for many high-performance applications.

Parts built with EOS Titanium Ti64ELI powder can be machined, shot-peened and polished in as-built and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy.

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Material data sheet

Technical Data

Powder properties

The chemical composition of the powder (wt-%):

Material composition

Element	Min	Max
Al	5.50	6.50
V	3.50	4.50
O	-	0.13
N	-	0.05
C	-	0.08
H	-	0.015
Fe	-	0.25
Y	-	0.005
Other elements, each	-	0.10
Other elements, total	-	0.40
Ti	Bal.	

Max. particle size	
> 63µm	max. 0.3 wt%

General process data

Layer thickness	30 µm
Volume rate [1]	5 mm^3/s (18 cm^3/h) 1.1 in^3/h

[1] The volume rate is a measure of build speed during laser exposure of the skin area per laser scanner. 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.

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Physical and chemical properties of parts

Part density [2]	Approx. 4.41 g/cm³ Approx. 0.159 lb/in³
Min. wall thickness [3]	Approx. 0.3 - 0.4 mm Approx. 0.012 - 0.016 inch
Surface roughness after shot peening [4]	Ra 5 - 9 µm; Rz 20-50 µm Ra 0.20 – 0.35 x 10^{-3} inch Rz 0.79– 1.96 x 10^{-3} inch

[2] Weighing in air and water according to ISO 3369.

[3] Mechanical stability is dependent on geometry (wall height etc.) and application.

[4] Measurement according to ISO 4287. 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.

Hardness

Hardness as build [5]	Approx. 320 HV5

[5] Hardness measurement according to standard EN ISO 6507-1 with load 5kg (HV5)

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Material data sheet

Tensile data at room temperature [6, 7]

	Heat treated [8]	
	Horizontal	**Vertical**
Ultimate tensile strength, Rm	1055 MPa	1075 MPa
Yield strength, Rp0.2	945 MPa	965 MPa
Elongation at break, A	13 %	14 %
Reduction of area, Z	> 25 %	> 25 %

[6] Tensile testing according to ISO 6892-1 A14, proportional test pieces. Horizontal: diameter of the neck area 5 mm (0.2 inch), original gauge length 20 mm (0.79 inch). Vertical: diameter of the neck area 4 mm (0.16 inch), original gauge length 16 mm (0.63 inch).

[7] The numbers are average values determined from samples with horizontal and vertical orientation respectively Values are subject to variations depending on process conditions.

[8] Heat treatment procedure: Specimens were heat treated at 800 °C for 2 hours in argon inert atmosphere.

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Material data sheet

Abstract

Min.	Minimum
Max.	Maximum
Approx.	Approximately
Wt.	Weight

The quoted values refer to the use of this material with above specified type of EOS DMLS system, EOSYSTEM software version, parameter set and operation in compliance with parameter sheet and operating instructions. Part properties are measured with specified measurement methods using defined test geometries and procedures. Further details of the test procedures used by EOS are available on request. Any deviation from these standard settings may affect the measured properties.

The data correspond to EOS knowledge and experience at the time of publication and they are subject to change without notice as part of EOS' continuous development and improvement processes.

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Material data sheet - FlexLine

EOS Titanium Ti64 ELI

EOS Titanium Ti64ELI is a titanium alloy powder intended for processing on EOS DMLS™ machines.This document provides information and data for parts built using EOS Titanium Ti64ELI powder (EOS art.-no. 9011-0040) on the following system setup:

- EOS DMLS™ system: EOS M400 SF
  - HSS recoating blade
  - Argon atmosphere
  - IPCM M extra sieving module with 63µm mesh recommended
- EOSPRINT v.1.5/HCS v.2.4 or newer
- EOS Parameter set Ti64ELI_030_FlexM400_100

Description

Parts built in EOS Titanium Ti64ELI have a chemical composition corresponding to ASTM F136 and ASTM F3001.

Ti64ELI is well-known light alloy, characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight and biocompatibility. This material is ideal for many high-performance applications.

Parts built with EOS Titanium Ti64ELI powder can be machined, shot-peened and polished in as-built and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy.

Quality Assurance

The quality of the EOS Titanium Ti64 powder lots is ensured by the Quality Assurance procedures. The procedures include sampling (ASTM B215), PSD analysis (ISO 13320), chemical analyses (ASTM E2371, ASTM E1409, ASTM E1941, ASTM E1447), and mechanical testing (ISO 6892-1).

The results of the quality assurance tests are given in the lot specific Mill Test Certificates (MTC) according to EN 10204 type 3.1.

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Technical Data

Powder properties

Material composition [wt.%]	Element	Min	Max
	Al	5.50	6.50
	V	3.50	4.50
	O	-	0.13
	N	-	0.05
	C	-	0.08
	H	-	0.012
	Fe	-	0.25
	Y	-	0.005
	Other elements, each	-	0.10
	Other elements, total	-	0.40
	Ti		bal.

Particle size	
d50 [1]	39 ± 3 µm

[1] Particle size distribution analysis according to ISO 13320

General process data

Layer thickness	30 µm
Volume rate [2]	5 mm^3/s (18 cm^3/h)

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[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 properties of parts

Part density [3]	4.4 g/cm3
Surface roughness after shot peening [4]	Approx. R_a 5-10 µm; R_z 15-30 µm
Hardness as built [5]	typ. 340 HV5

[3] Weighing in air and water according to ISO 3369.

[4] 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.

[5] Hardness measurement according to standard EN ISO 6507-1 with load 5kgf (HV5)

Tensile data at room temeprature [6,7]

	As built	Heat treated [8]
Ultimate tensile strength	typ. 1270 MPa	typ. 1040 MPa
Yield strength, Rp0.2%	typ. 1100 MPa	typ. 930 MPa
Elongation at break A	typ. 8,7 %	typ. 14,0 %

[6] The numbers are average values and are determined from samples with horizontal and vertical orientation.

[7] Tensile testing according to ISO 6892-1 A14, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), original gauge length 20 mm (0,79 inch).

[8] Heat treatment procedure: 2 hours at 800°C in Argon atmosphere.

Abbreviations

min. minimum

max. maximum

wt. weight

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The quoted values refer to the use of this material with above specified EOS DMLS system, EOSYSTEM software version, parameter set and operation in compliance with parameter sheet and operating instructions. All measured values are average numbers. Part properties are measured with specified measurement methods using defined test geometries and procedures and. Further details of the test procedures used by EOS are available on request. Any deviation from these standard settings may affect the measured properties.

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Material data sheet

EOS Titanium Ti64

EOS Titanium Ti64 is a titanium alloy powder which has been optimized especially for processing on EOSINT M systems.

This document provides information and data for parts built using EOS Titanium Ti64 powder (EOS art.-no. 9011-0014) on the following system specifications:

- EOSINT M 280 with PSW 3.6 and Original EOS Parameter Set Ti64_Speed 1.0
- EOS M 290 400W with EOSPRINT 1.0 and Original EOS Parameter Set Ti64_Performance 1.0 und Ti64_Speed 1.0

Description

Parts built in EOS Titanium Ti64 have a chemical composition corresponding to ISO 5832-3, ASTM F1472 and ASTM B348.

This well-known light alloy is characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight and biocompatibility.

This material is ideal for many high-performance engineering applications, for example in aerospace and motor racing, and also for the production of biomedical implants (note: subject to fulfilment of statutory validation requirements where appropriate).

Due to the layerwise building method, the parts have a certain anisotropy, which can be reduced or removed by appropriate heat treatment - see Technical Data for examples.

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Material data sheet

Technical data

General process and geometric data

Typical achievable part accuracy [1], [8]	± 50 µm
Min. wall thickness [2], [8]	approx. 0.3 – 0.4 mm approx. 0.012 – 0.016 inch
Surface roughness, as built [3], [8]	
Ti64 Performance (30 µm)	R_a 9 - 12 µm, R_z 40 - 80 µm R_a 0.36 – 0.47 x 10^{-3} inch, R_z 1.6 – 3.2 x 10^{-3} inch
Ti64 Speed (60 µm)	R_a 6 - 10 µm, R_z 35 - 40 µm R_a 0.23 – 0.39 x 10^{-3} inch, R_z 1.37 –1.57 x 10^{-3} inch
Volume rate [4]	
Ti64 Performance (30 µm)	5 mm^3/s (18 cm^3/h) 0.82 in^3/h
Ti64 Speed (60 µm)	9 mm^3/s (32.4 cm^3/h) 1.98 in^3/h

[1] Based on users' experience of dimensional accuracy for typical geometries. Part accuracy is subject to appropriate data preparation and post-processing, in accordance with EOS training.

[2] Mechanical stability is dependent on geometry (wall height etc.) and application

[3] Due to the layerwise building, the surface structure depends strongly on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect. The values also depend on the measurement method used. The values quoted here given an indication of what can be expected for horizontal (up-facing) or vertical surfaces.

[4] Volume rate is a measure of build speed during laser exposure. The total build speed depends on the average volume rate, the recoating time (related to the number of layers) and other factors such as DMLS-Start settings.

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Material data sheet

Physical and chemical properties of parts

Material composition	Ti (balance) Al (5.5 – 6.75 wt.-%) V (3.5 – 4.5 wt.-%) O (< 2000 ppm) N (< 500 ppm) C (< 800 ppm) H (< 150 ppm) Fe (< 3000 ppm)
Relative density	approx. 100 %
Density	4.41 g/cm³ 0.159 lb/in³

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Mechanical properties of parts [8]

	As built	Heat treated [6]
Tensile strength [5]		
- in horizontal direction (XY)	typ. 1290 ± 50 MPa typ. 187 ± 7 ksi	min. 930 MPa (134.8 ksi) typ. 1100 ± 40 MPa (160 ± 6 ksi)
- in vertical direction (Z)	typ. 1240 ± 50 MPa typ. 187 ± 7 ksi	min. 930 MPa (134.8 ksi) typ. 1100 ± 40 MPa (160 ± 6 ksi)
Yield strength ($R_{p0.2}$) [5]		
- in horizontal direction (XY)	typ. 1140 ± 50 MPa typ. 165 ± 7 ksi	min. 860 MPa (124.7 ksi) typ. 1000 ± 50 MPa (145 ± 7 ksi)
- in vertical direction (Z)	typ. 1120 ± 80 MPa typ. 162 ± 12 ksi	min. 860 MPa (124.7 ksi) typ. 1000 ± 60 MPa (145 ± 9 ksi)
Elongation at break [5]		
- in horizontal direction (XY)	typ. (7 ± 3) %	min. 10 % typ. (13.5 ± 2 %)
- in vertical direction (Z)	typ. (10 ± 3) %	min. 10 % typ. (14.5 ± 2 %)
Modulus of elasticity [5]		
- in horizontal direction (XY)	typ. 110 ± 15 GPa typ. 16 ± 2 Msi	typ. 110 ± 15 GPa typ. 16 ± 2 Msi
- in vertical direction (Z)	typ. 110 ± 15 GPa typ. 16 ± 2 Msi	typ. 110 ± 15 GPa typ. 16 ± 2 Msi
Hardness [7]	typ. 320 ± 12 HV5	

[5] 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).

[6] Specimens were treated at 800 °C (1470 °F) for 4 hours in argon inert atmosphere. Mechanical properties are expressed as minimum values to indicate that mechanical properties exceed the minimum requirements of material specification standards. ASTM F1472-08. By fulfilling these minimum values, also the specifications of standards ASTM B348-09 and ISO 5832-3:2000 are meet.

[7] Vickers hardness measurement (HV) according to EN ISO 6507-1 on polished surface. Note that measured hardness can vary significantly depending on how the specimen has been prepared.

[8] Hint: these properties were determined for Ti64_Performance 1.0 on an EOSINT M 280-400W and EOSINT M 290-400W. Test parts from Ti64_Speed 1.0 were determined on machine types EOSINT M 280-400W and correspond with data from an EOS M 290-400W.

Material data sheet

Thermal properties of parts

Maximum long-term operating temperature	approx. 350 °C approx. 660 °F

Abbreviations

typ.	typical
min.	minimum
wt.	weight
approx.	approximately

Notes

The data are valid for the combinations of powder material, machine and parameter sets referred to on page 1, when used in accordance with the relevant Operating Instructions (including Installation Requirements and Maintenance) and Parameter Sheet. Part properties are measured using defined test procedures. Further details of the test procedures used by EOS are available on request.

The data correspond to our knowledge and experience at the time of publication. They do not on their own provide a sufficient basis for designing parts. Neither do they provide any agreement or guarantee about the specific properties of a part or the suitability of a part for a specific application. The producer or the purchaser of a part is responsible for checking the properties and the suitability of a part for a particular application. This also applies regarding any rights of protection as well as laws and regulations. The data are subject to change without notice as part of EOS' continuous development and improvement processes.

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GE Additive

remanium star® CL

CoCrW-alloy (powder) acc. to EN ISO 9693 / DIN EN ISO 22674, Type 5

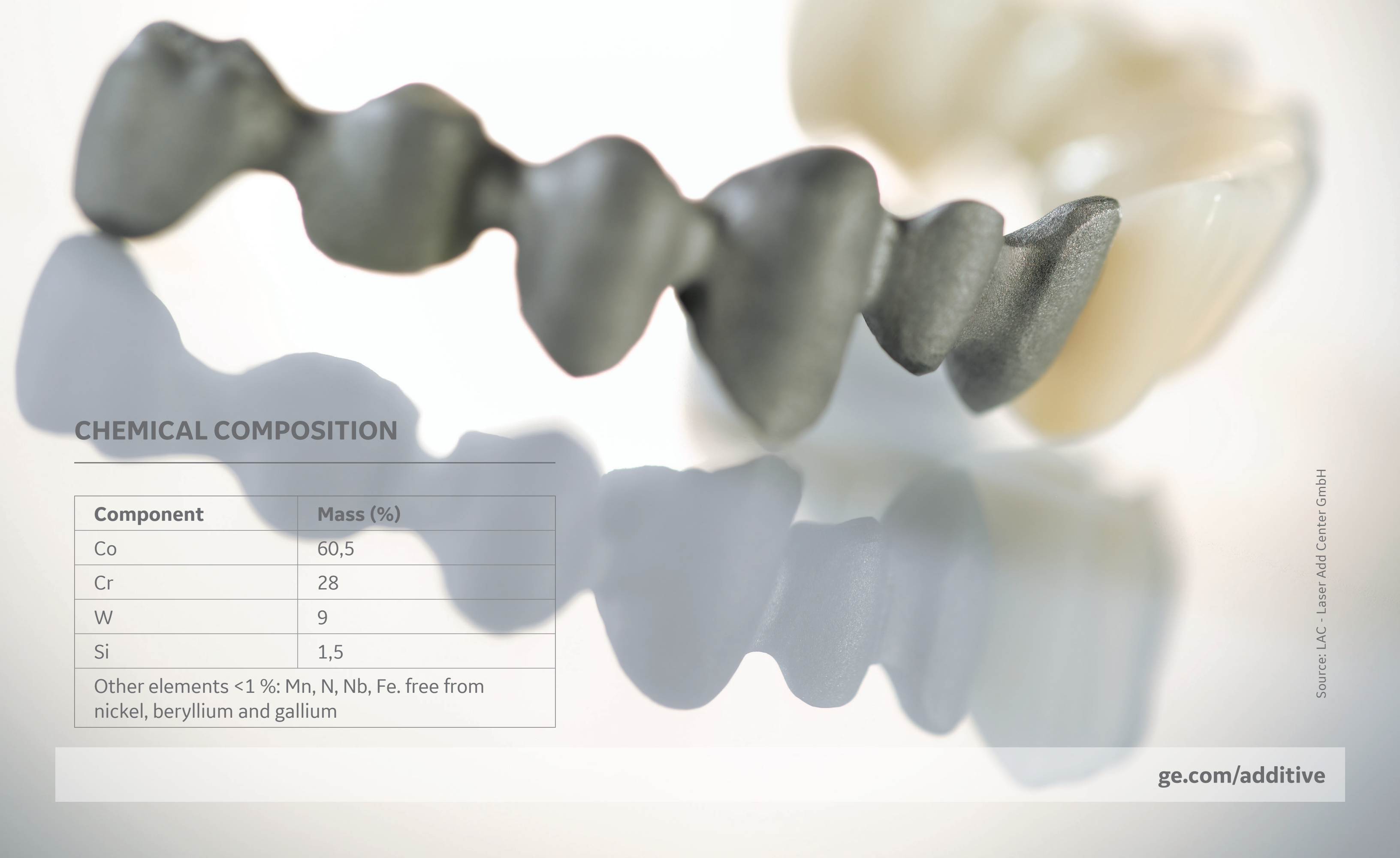
CE 0483

With an appropriate approval* remanium star can be used for production of metallic restaurations by means of the metal laser melting process.

27
Co
58,933

RANGE OF APPLICATION

With an appropriate approval* remanium star CL can be used for production of crowns and bridges, frames for metal ceramic veneering, cast partials, primary – and secondary parts for combined restorations.



Source: LAC - Laser Add Center GmbH

CHEMICAL COMPOSITION

Component	Mass (%)
Co	60,5
Cr	28
W	9
Si	1,5
Other elements <1 %: Mn, N, Nb, Fe. free from nickel, beryllium and gallium	

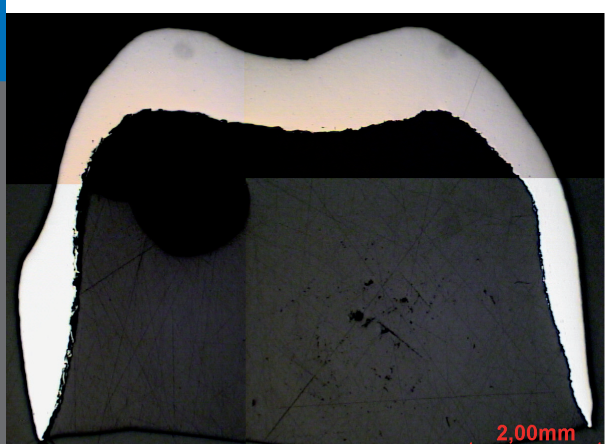
TECHNICAL DATA IN LINE WITH DIN EN ISO 9693 / DIN EN ISO 22674 AFTER RECOMMENDED HEAT TREATMENT

	90° (horizontal)	**45° (polar angle)**	**0° (upright)**
Yield Strength $R_{p0,2}$	792 ± 24 N/mm^2	822 ± 14 N/mm^2	835 ± 44 N/mm^2
Tensile Strenght R_m	1136 ± 24 N/mm^2	1200 ± 14 N/mm^2	1156 ± 9 N/mm^2
Elongation at fracture A_5	8 ± 3 %	8 ± 3 %	11 ± 1 %
Young's Modulus	230.000 N/mm^2	230.000 N/mm^2	230.000 N/mm^2
Melting range Δ	1320 – 1420°C	1320 – 1420°C	1320 – 1420°C
Density ρ	8,6 g/cm^3	8,6 g/cm^3	8,6 g/cm^3
Coefficient of thermal Expansion TEC (25-500°C)	14,1 x $10^{-6}K^{-1}$	14,1 x $10^{-6}K^{-1}$	14,1 x $10^{-6}K^{-1}$
Colour	white	white	white
Metal-ceramic bond strength acc. to EN ISO 9693, 3-Pt.-bending test (min. 25 N/mm^2 acc. to EN ISO 9693)	40 N/mm^2 (Carmen CCS, Dentaurum)	40 N/mm^2 (Carmen CCS, Dentaurum)	40 N/mm^2 (Carmen CCS, Dentaurum)
Type	5	5	5
Biocompatibility, L 929-Proliferation acc. to EN ISO 10993-5, -12, ISO 9363-1, LM SOP 4-06-01	No deliberation of cell toxic active substances	No deliberation of cell toxic active substances	No deliberation of cell toxic active substances
Corrosion resistance, static immersion test acc. to EN ISO 10271 (max. 200 $µg/cm^2$ x 7d acc. to EN ISO 22674)	Ion release 3,5 $µg/cm^2$ x 7d	Ion release 3,5 $µg/cm^2$ x 7d	Ion release 3,5 $µg/cm^2$ x 7d

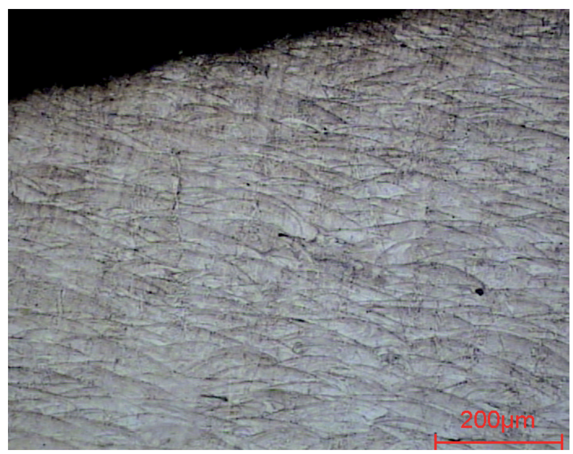
remanium star CL

MICROSECTION

3-unit bridge (16 x)



3-unit bridge etched (100 x)



HEAT TREATMENT

Perform heat treatment under an argon atmosphere. Heat up to 1150°C. Maintain temperature for 1 hour. Allow the components to cool down to 300°C in the oven.

MICROSTRUCTURE

Components made from the cobalt-chromium alloy remanium star display a homogeneous, pore-free structure after they are constructed by means of the metal laser melting process DMLM.

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CoCr-0404 powder for additive manufacturing

Process specification

Powder description	Cobalt-chromium alloy powder
Layer thickness	30 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

CoCr-0404 alloy comprises cobalt alloyed with chromium of mass fraction up to 30% and molybdenum up to 7%, along with other minor elements. The alloy has a high melting point making it stable at high temperatures, along with its high level of corrosion resistance.

The alloy's excellent biocompatibility, strength and wear resistance have also led to it being used widely in the orthopaedics and dental industries. For medical and dental applications Renishaw supply CoCr DG1, for more information refer to document H-5745-9080.

Material properties

- High strength and hardness
- Excellent biocompatibility
- High corrosion resistance
- High temperature resistance

Applications

- Medical and dental (Refer to document H-5745-9080)
- Gas and wind turbines
- Engine components

Generic data - wrought material

Density	8.3 g/cm^3
Thermal conductivity	13 W/mK
Melting range	1260 °C to 1482 °C
Coefficient of thermal expansion (see note 1)	12 10^{-6} K^{-1}

Note 1 In the range of 0 °C to 100 °C.

Note 2 Solution treated conditions: 1. Heat to 650 °C ±10 °C, hold for 15 min; 2. Heat to 1000 °C ±10 °C hold for 5 min; 3. Heat to 1050 °C ±10 °C hold for 2 hr; 4. Fast cool to < 60 °C ±10 °C using 2 bar argon quench.

Note 3 Tested at ambient temperature by Nadcap and UKAS accredited independent laboratory. Test ASTM E8. Machined prior to testing.

Note 4 Tested to ASTM E384-11, after polishing.

Note 5 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

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Composition of powder

Element	Mass (%)
Cobalt	Balance
Chromium	27.00 to 30.00
Molybdenum	5.00 to 7.00
Manganese	< 1.00
Silicon	< 1.00
Iron	< 0.75
Nickel	< 0.50
Nitrogen	< 0.25
Tungsten	< 0.20
Aluminium	< 0.10
Oxygen	< 0.10
Titanium	< 0.10
Carbon	< 0.05
Phosphorus	< 0.02
Boron	< 0.01
Sulphur	< 0.01

Mechanical properties of additively manufactured parts

	Solution treated (See note 2)
Tensile strength (UTS) (See note 3)	
Horizontal direction (XY)	1104 MPa ±17 MPa
Vertical direction (Z)	1097 MPa ±16 MPa
Yield strength (see note 3)	
Horizontal direction (XY)	714 MPa ±12 MPa
Vertical direction (Z)	683 MPa ±11 MPa
Elongation at break (see note 3)	
Horizontal direction (XY)	16% ±2%
Vertical direction (Z)	21% ±1%
Modulus of elasticity (see note 3)	
Horizontal direction (XY)	220 GPa ±37 GPa
Vertical direction (Z)	221 GPa ±25 GPa
Hardness (Vickers) (see note 4)	
Horizontal direction (XY)	412 HV0.5 ±16 HV0.5
Vertical direction (Z)	400 HV0.5 ±9 HV0.5
Surface roughness (R_a) (See note 5)	
Horizontal direction (XY)	4 µm to 8 µm
Vertical direction (Z)	8 µm to 12 µm

Issued: 05.2018

H-5800-0706-03-A

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In718-0405 powder for additive manufacturing

Process specification

Powder description	Nickel alloy powder
Layer thickness	30 µm and 60 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

In718-0405 alloy comprises nickel mass fraction up to 55% alloyed with iron up to 21% and chromium up to 21%, along with other minor elements. Properties include high strength, excellent corrosion resistance and a working temperature range between -250 °C and 650 °C (-418 °F to 1200 °F). It is also age-hardenable.

In718-0405 has a wide range of applications within industry and is particularly suitable for applications where good tensile, creep, and rupture strength is required. Similar to In625-0402 which is suitable for applications where corrosion and oxidation resistance at high temperatures is required. Its excellent welding characteristics and resistance to cracking makes it an ideal material for additive manufacturing.

Material properties

- Retains strength up to 650 °C
- High creep resistance
- High corrosion resistance
- Solidification properties suit additive manufacture

Applications

- Aerospace and defence
- Gas turbine blades
- Exhaust manifolds
- Rocket motors
- Heat exchangers
- Nuclear

Generic data - wrought material

Density	8.19 g/cm^3
Thermal conductivity	6 W/mK to 12 W/mK
Melting range	1260 °C to 1336 °C
Coefficient of thermal expansion (see note 1)	12 µm/mK to 16 µm/mK

Note 1 In the range of 25 °C to 760 °C.

Note 2 Heat treated conditions: 1. Solution treated at 980 °C ± 10 °C for 1 hr 2. Aged at 720 °C ± 10 °C for 8 hr, and further aged at 620 °C ± 10 °C for 8 hr.

Note 3 Hot Isostatically pressed.

Note 4 Tested at ambient temperature to ASTM E8. Machined before testing. Values based on a sample size of 6.

Note 5 Tested to ASTM E384-11, after polishing.

Note 6 Tested to JIS B 0601-2001 (ISO 97), after bead blasting.

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Composition of powder

Element	Mass (%)
Nickel	50.00 to 55.00
Chromium	17.00 to 21.00
Iron	Balance
Niobium and Tantalum	4.75 to 5.5
Molybdenum	2.80 to 3.30
Titanium	0.65 to 1.15
Cobalt	≤ 1.00
Aluminium	0.20 to 0.80
Manganese	≤ 0.35
Silicon	≤ 0.35
Copper	≤ 0.30
Carbon	0.02 to 0.05
Nitrogen	≤ 0.03
Oxygen	≤ 0.03
Phosphorus	≤ 0.015
Sulphur	≤ 0.015
Calcium	≤ 0.01
Magnesium	≤ 0.01
Selenium	≤ 0.005
Boron	≤ 0.005

*ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter specification powder. Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Mechanical properties of additively manufactured components using 30 µm layers

	As built		**Solution treated and aged** (See note 2)		**HIP treated** (See note 3)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Ultimate tensile strength (UTS) (See note 4)						
Horizontal direction (XY)	1040 MPa	7 MPa	1467 MPa	6 MPa	1379 MPa	3 MPa
Vertical direction (Z)	971 MPa	3 MPa	1391 MPa	9 MPa	1346 MPa	5 MPa
Yield strength (see note 4)						
Horizontal direction (XY)	758 MPa	4 MPa	1259 MPa	5 MPa	1088 MPa	26 MPa
Vertical direction (Z)	636 MPa	19 MPa	1202 MPa	15 MPa	1052 MPa	4 MPa
Elongation at break (see note 4)						
Horizontal direction (XY)	30%	1%	17%	1%	25%	1 %
Vertical direction (Z)	36%	1%	17%	1%	24%	1%
Modulus of elasticity (see note 4)						
Horizontal direction (XY)	186 GPa	5 GPa	195 GPa	13 GPa	207 GPa	4 GPa
Vertical direction (Z)	158 GPa	18 GPa	186 GPa	15 GPa	201 GPa	3 GPa
Hardness (Vickers) (see note 5)						
Horizontal direction (XY)	277 HV0.5	9 HV0.5	418 HV0.5	9 HV0.5	456 HV0.5	11 HV0.5
Vertical direction (Z)	302 HV0.5	8 HV0.5	488 HV0.5	11 HV0.5	463 HV0.5	7 HV0.5
Surface roughness (R_a) (See note 6)						
Horizontal direction (XY)	1.28 µm to 1.36 µm					
Vertical direction (Z)	1.72 µm to 1.96 µm					

Density of additively manufactured In718 is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

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Mechanical properties of additively manufactured components using 60 µm layers

	As built		**Solution treated and aged** (See note 2)		**HIP treated** (See note 3)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Ultimate tensile strength (UTS) (See note 4)						
Horizontal direction (XY)	1057 MPa	11 MPa	1504 MPa	3 MPa	1289 MPa	4 MPa
Vertical direction (Z)	943 MPa	38 MPa	1439 MPa	11 MPa	1228 MPa	24 MPa
Yield strength (see note 4)						
Horizontal direction (XY)	753 MPa	8 MPa	1306 MPa	10 MPa	958 MPa	8 MPa
Vertical direction (Z)	639 MPa	13 MPa	1231 MPa	10 MPa	929 MPa	10 MPa
Elongation at break (see note 4)						
Horizontal direction (XY)	25%	3%	16%	2%	23%	2 %
Vertical direction (Z)	19%	8%	16%	2%	17%	4%
Modulus of elasticity (see note 4)						
Horizontal direction (XY)	203 GPa	10 GPa	202 GPa	4 GPa	219 GPa	6 GPa
Vertical direction (Z)	191 GPa	9 GPa	198 GPa	11 GPa	214 GPa	7 GPa
Hardness (Vickers) (see note 5)						
Horizontal direction (XY)	275 HV0.5	14 HV0.5	465 HV0.5	28 HV0.5	408 HV0.5	11 HV0.5
Vertical direction (Z)	295 HV0.5	11 HV0.5	467 HV0.5	20 HV0.5	418 HV0.5	16 HV0.5
Surface roughness (R_a) (See note 6)						
Horizontal direction (XY)	1.14 µm to 1.70 µm					
Vertical direction (Z)	2.36 µm to 3.0 µm					

Density of additively manufactured In718 is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

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H-5800-1052-03-B

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AlSi10Mg-0403 powder for additive manufacturing

Process specification

Powder description	Aluminium alloy powder
Layer thickness	25 µm
Laser power	400 W
Additive manufacturing system	AM250

Material description

AlSi10Mg-0403 alloy comprises aluminium alloyed with silicon of mass fraction up to 10%, small quantities of magnesium and iron, along with other minor elements. The presence of silicon makes the alloy both harder and stronger than pure aluminium due to the formation of Mg_2Si precipitate.

Due to the natural formation of an oxide layer on the surface of the aluminium alloy, the material has high corrosion resistance which can be further improved by chemically anodising.

Material properties

- Low density (good for light weight components)
- High specific strength (strength to mass ratio)
- High thermal conductivity
- Very high electrical conductivity
- Responds well to post process finishing

Applications

- Automotive
- Aerospace and defence
- Electronics cooling
- Consumer goods

Generic data - wrought material

Density	2.68 g/cm³
Thermal conductivity	130 W/mK to 190 W/mK
Melting range	570 °C to 590 °C
Coefficient of thermal expansion (see note 1)	20 µm/mK to 21 µm/mK

Note 1 In the range of 20 °C to 100 °C.

Note 2 Stress relieved at 300 °C ±10 °C for 2 hr, air cooled.

Note 3 Tested at ambient temperature by Nadcap and UKAS accredited independent laboratory. Test ASTM E8. Machined before testing.

Note 4 Tested to ASTM E384-11, after polishing.

Note 5 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

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Composition of powder

Element	Mass (%)
Aluminium	Balance
Silicon	9.00 to 11.00
Magnesium	0.25 to 0.45
Iron	< 0.25
Nitrogen	< 0.20
Oxygen	< 0.20
Titanium	< 0.15
Zinc	< 0.10
Manganese	< 0.10
Nickel	< 0.05
Copper	< 0.05
Lead	< 0.02
Tin	< 0.02

Mechanical properties of additively manufactured components

	As Built	**Stress relieved** (see note 2)
Tensile strength (UTS) (See note 3)		
Horizontal direction (XY)	442 MPa ±6 MPa	334 MPa ±1 MPa
Vertical direction (Z)	417 MPa ±27 MPa	339 MPa ±6 MPa
Yield strength (see note 3)		
Horizontal direction (XY)	264 MPa ±2 MPa	211 MPa ±2 MPa
Vertical direction (Z)	206 MPa ±6 MPa	174 MPa ±4 MPa
Elongation at break (see note 3)		
Horizontal direction (XY)	9% ±1%	9% ± 2%
Vertical direction (Z)	6% ±2%	4% ±1%
Modulus of elasticity (see note 3)		
Horizontal direction (XY)	71 GPa ±5 GPa	71 GPa ±2 GPa
Vertical direction (Z)	68 GPa ±2 GPa	66 GPa ±3 GPa
Hardness (Vickers) (see note 4)		
Horizontal direction (XY)	119 HV0.5 ±5 HV0.5	103 HV0.5 ±5 HV0.5
Vertical direction (Z)	123 HV0.5 ±2 HV0.5	98 HV0.5 ±5 HV0.5
Surface roughness (R_a) (See note 5)		
Horizontal direction (XY)	5 µm to 9 µm	
Vertical direction (Z)	7 µm to 9 µm	

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AlSi10Mg-0403 powder for additive manufacturing

Process specification

Powder description	Aluminium alloy powder
Layer thickness	25 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

AlSi10Mg-0403 alloy comprises aluminium alloyed with silicon of mass fraction up to 10%, small quantities of magnesium and iron, along with other minor elements. The presence of silicon makes the alloy both harder and stronger than pure aluminium due to the formation of Mg_2Si precipitate.

Due to the natural formation of an oxide layer on the surface of the aluminium alloy, the material has high corrosion resistance which can be further improved by chemically anodising.

Material properties

- Low density (good for light weight components)
- High specific strength (strength to mass ratio)
- High thermal conductivity
- Very high electrical conductivity
- Responds well to post process finishing

Applications

- Automotive
- Aerospace and defence
- Electronics cooling
- Consumer goods

Generic data - wrought material

Density	2.68 g/cm³
Thermal conductivity	130 W/mK to 190 W/mK
Melting range	570 °C to 590 °C
Coefficient of thermal expansion (see note 1)	20 $10^{-6}K^{-1}$ to 21 $10^{-6}K^{-1}$

Note 1 In the range of 0 °C to 100 °C.

Note 2 Stress relieved at 300 °C ±10 °C for 2 hrs, air cooled.

Note 3 Tested at ambient temperature by Nadcap and UKAS accredited independent laboratory. Test ASTM E8. Machined prior to testing.

Note 4 Tested to ASTM E384-11, after polishing.

Note 5 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

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Composition of powder

Element	Mass (%)
Aluminium	Balance
Silicon	9.00 to 11.00
Magnesium	0.25 to 0.45
Iron	< 0.25
Nitrogen	< 0.20
Oxygen	< 0.20
Titanium	< 0.15
Zinc	< 0.10
Manganese	< 0.10
Nickel	< 0.05
Copper	< 0.05
Lead	< 0.02
Tin	< 0.02

Mechanical properties of additively manufactured components

	As Built	**Stress relieved** (See note 2)
Ultimate tensile strength (UTS) (See note 3)		
Horizontal direction (XY)	400 MPa ±13 MPa	361 MPa ±4 MPa
Vertical direction (Z)	366 MPa ±30 MPa	394 MPa ±4 MPa
Yield strength (see note 3)		
Horizontal direction (XY)	266 MPa ±2 MPa	236 MPa ±3 MPa
Vertical direction (Z)	220 MPa ±11 MPa	215 MPa ±6 MPa
Elongation at break (see note 3)		
Horizontal direction (XY)	4% ±1%	5% ±1%
Vertical (Z)	3% ±1%	5% ±2%
Modulus of elasticity (see note 3)		
Horizontal direction (XY)	64 GPa ±16 GPa	78 GPa ±6 GPa
Vertical direction (Z)	69 GPa ±9 GPa	85 GPa ±7 GPa
Hardness (Vickers) (see note 4)		
Horizontal direction (XY)	83 HV0.5 ±2 HV0.5	116 HV0.5 ±3 HV0.5
Vertical direction (Z)	113 HV0.5 ±3 HV0.5	112 HV0.5 ±2 HV0.5
Surface roughness (R_a) (See note 5)		
Horizontal direction (XY)	5 µm to 7 µm	
Vertical direction (Z)	7 µm to 9 µm	

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Ti6Al4V ELI-0406 powder for additive manufacturing

Process specification

Powder description	Titanium alloy powder
Layer thickness	30 µm and 60 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

Ti6Al4V ELI-0406 alloy comprises titanium mass fraction up to 90% alloyed with aluminium up to 6.75% and vanadium up to 4.5%, along with other minor elements. Ti6Al4V grade 23 is otherwise referred to as Extra Low Interstitial (ELI) with regards to the interstitial impurities oxygen, carbon, and nitrogen. It is a higher purity version of the most commonly used titanium alloy Ti6Al4V grade 5. The reduced interstitial elements in grade 23 lead to an increase in both ductility and fracture toughness.

Ti6Al4V ELI-0406 has excellent specific strength (strength to weight ratio) which makes it an ideal choice where weight saving load structures are required. It has good corrosion resistance, it is also biocompatible, so can be used for a range of surgical and dental applications. For medical and dental applications Renishaw supplies Ti DG1 powder, for more infomation refer to document H-5983-9026.

Material properties

- High specific strength
- High corrosion resistance
- Excellent biocompatibility
- Good osseointegration
- Low thermal expansion
- Low thermal conductivity

Applications

- Medical and dental (Refer to document H-5983-9026)
- Aerospace and defence
- Motor sport
- Jewellery and art
- Maritime applications
- High-end sports equipment

Generic data - wrought material

Density	4.42 g/cm^3
Thermal conductivity	6 W/mK to 8 W/mK
Melting range	1635 °C to 1665 °C
Coefficient of thermal expansion (see note 1)	8×10^{-6} K^{-1} to 9×10^{-6} K^{-1}

Note 1 In the range of 0 °C to 100 °C.

Note 2 Annealed at 850 °C ±10 °C for 2 hr.

Note 3 Tested at ambient temperature to ASTM E8. Machined before testing. Values based on a sample size of 6.

Note 4 Tested to ASTM E384-11, after polishing.

Note 5 Tested to JIS B 0601-2001 (ISO 97), after bead blasting.

Note 6 HIP (hot isostatic pressing).

Composition of powder

Element	Mass (%)
Titanium	Balance
Aluminium	5.50 to 6.50
Vanadium	3.50 to 4.50
Iron	≤ 0.25
Oxygen	≤ 0.13
Carbon	≤ 0.08
Nitrogen	≤ 0.05
Hydrogen	≤ 0.012
Yttrium	≤ 0.005
Residuals	≤ 0.10 each, ≤ 0.40 total

*ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter specification powder. Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Mechanical properties of additively manufactured components processed in 30 µm layers

	Heat treated (See note 2)		**HIP treated** (see note 6)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Ultimate tensile strength (UTS) (See note 3)				
Horizontal direction (XY)	1089 MPa	7 MPa	1033 MPa	4 MPa
Vertical direction (Z)	1085 MPa	12 MPa	1034 MPa	7 MPa
Yield strength (see note 3)				
Horizontal direction (XY)	1007 MPa	5 MPa	947 MPa	4 MPa
Vertical direction (Z)	985 MPa	23 MPa	923 MPa	21 MPa
Elongation at break (See note 3)				
Horizontal direction (XY)	16%	1%	16%	1%
Vertical direction (Z)	14%	1%	17%	1%
Modulus of elasticity (see note 3)				
Horizontal direction (XY)	129 GPa	7 GPa	127 GPa	3 GPa
Vertical direction (Z)	126 GPa	15 GPa	125 GPa	4 GPa
Hardness (Vickers) (see note 4)				
Horizontal direction (XY)	368 HV0.5	10 HV0.5	352 HV0.5	9 HV0.5
Vertical direction (Z)	372 HV0.5	7 HV0.5	360 HV0.5	7 HV0.5
Surface roughness (R_a) (See note 5)				
Horizontal direction (XY)	4 µm to 6 µm			
Vertical direction (Z)	4 µm to 7 µm			

Density of additively manufactured Ti6Al4V is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

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Mechanical properties of additively manufactured components processed in 60 µm layers

	Heat treated (see note 2)		**HIP treated** (see note 6)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Ultimate tensile strength (UTS) (see note 3)				
Horizontal direction (XY)	1091 MPa	6 MPa	1052 MPa	3 MPa
Vertical direction (Z)	1084 MPa	8 MPa	1058 MPa	9 MPa
Yield strength (see note 3)				
Horizontal direction (XY)	1020 MPa	25 MPa	957 MPa	2 MPa
Vertical direction (Z)	987 MPa	22 MPa	973 MPa	24 MPa
Elongation at break (see note 3)				
Horizontal direction (XY)	16%	1%	16%	1%
Vertical direction (Z)	17%	1%	18%	1%
Modulus of elasticity (see note 3)				
Horizontal direction (XY)	132 GPa	9 GPa	127 GPa	3 GPa
Vertical direction (Z)	128 GPa	7 GPa	131 GPa	6 GPa
Hardness (Vickers) (see note 4)				
Horizontal direction (XY)	363 HV0.5	11 HV0.5	361 HV0.5	7 HV0.5
Vertical direction (Z)	363 HV0.5	13 HV0.5	360 HV0.5	10 HV0.5
Surface roughness (R_a) (see note 5)				
Horizontal direction (XY)	3 µm to 4 µm			
Vertical direction (Z)	5 µm to 7 µm			

Density of additively manufactured Ti6Al4V is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

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H-5800-1086-04-C

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In625-0402 powder for additive manufacturing

Process specification

Powder description	Nickel alloy powder
Layer thickness	30 µm and 60 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

In625-0402 alloy comprises nickel alloyed with chromium of mass fraction up to 23% and molybdenum up to 10%, along with other minor elements. The addition of niobium, acting with molybdenum, gives the alloy high strength and toughness in the annealed condition.

In625-0402 has a wide range of applications within industry and is particularly suitable for seawater applications and applications where corrosion and oxidation resistance at high temperatures is required. Similar to In718-0405 which is suitable for applications where good tensile, creep, and rupture strength is required.

Material properties

- High creep resistance
- Very high corrosion and oxidation resistance at high temperatures
- High fatigue strength in seawater
- Excellent welding characteristics
- Nonmagnetic

Applications

- Automotive
- Aerospace and defence
- Chemical process industry
- Marine engineering
- Oil and gas industry
- Nuclear
- Seawater heat exchangers

Generic data - wrought material

Density	8.44 g/cm^3
Thermal conductivity	9.2 W/mK to 10.7 W/mK
Melting range	1290 °C to 1350 °C
Coefficient of thermal expansion (see note 1)	12.8 $10^{-6}K^{-1}$

Note 1 In the range of 20 °C to 200 °C.

Note 2 Annealed at 1048 °C for 1 hr followed by furnace cool.

Note 3 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on a sample size of 6.

Note 4 Tested to ASTM E384-11, after polishing.

Note 5 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

Composition of powder

Element	Mass (%)
Nickel	Balance
Chromium	20.00 to 23.00
Molybdenum	8.00 to 10.00
Iron	≤ 5.00
Niobium	3.15 to 4.15
Cobalt	≤ 1.00
Copper	≤ 0.50
Manganese	≤ 0.50
Silicon	≤ 0.50
Aluminium	≤ 0.40
Titanium	≤ 0.40
Carbon	≤ 0.10
Tantalum	≤ 0.05
Nitrogen	≤ 0.02
Oxygen	≤ 0.02
Phosphorus	≤ 0.015
Sulphur	≤ 0.015

*ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter specification powder. Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Mechanical properties of additively manufactured components built using 30 µm layer thickness

	As built		**Heat treated** (see note 2)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Ultimate Tensile strength (UTS) (See note 3)				
Horizontal direction (XY)	1055 MPa	3 MPa	1020 MPa	1 MPa
Vertical direction (Z)	964 MPa	2 MPa	955 MPa	2 MPa
Yield strength (see note 3)				
Horizontal direction (XY)	767 MPa	9 MPa	633 MPa	1 MPa
Vertical direction (Z)	676 MPa	7 MPa	598 MPa	2 MPa
Elongation at break (see note 3)				
Horizontal direction (XY)	34%	1%	39%	1%
Vertical direction (Z)	42%	1%	43%	1%
Modulus of elasticity (see note 3)				
Horizontal direction (XY)	205 GPa	10 GPa	206 GPa	3 GPa
Vertical direction (Z)	186 GPa	11 GPa	200 GPa	2 GPa
Hardness (Vickers) (See note 4)				
Horizontal direction (XY)	331 HV0.5	8 HV0.5	251 HV0.5	13 HV0.5
Vertical direction (Z)	332 HV0.5	8 HV0.5	254 HV0.5	16 HV0.5
Surface roughness (R_a) (See note 5)				
Horizontal direction (XY)	2 µm to 3 µm			
Vertical direction (Z)	6 µm to 7 µm			

Density of additively manufactured In625 is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

Mechanical properties of additively manufactured components built using 60 µm layer thickness

	As built		Heat treated (see note 2)	
Ultimate Tensile strength (UTS) (See note 3)	**Mean**	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Horizontal direction (XY)	922 MPa	9 MPa	1005 MPa	6 MPa
Vertical direction (Z)	770 MPa	56 MPa	985 MPa	10 MPa
Yield strength (see note 3)				
Horizontal direction (XY)	667 MPa	11 MPa	600 MPa	4 MPa
Vertical direction (Z)	536 MPa	34 MPa	583 MPa	2 MPa
Elongation at break (see note 3)				
Horizontal direction (XY)	18%	2%	31%	2 %
Vertical direction (Z)	11%	4%	32%	4 %
Modulus of elasticity (see note 3)				
Horizontal direction (XY)	175 GPa	16 GPa	208 GPa	4 GPa
Vertical direction (Z)	176 GPa	9 GPa	209 GPa	6 GPa
Hardness (Vickers) (See note 4)				
Horizontal direction (XY)	302 HV0.5	13 HV0.5	279 HV0.5	7 HV0.5
Vertical direction (Z)	308 HV0.5	6 HV0.5	290 HV0.5	8 HV0.5
Surface roughness (R_a) (See note 5)				
Horizontal direction (XY)	1.5 µm to 2 µm			
Vertical direction (Z)	6 µm to 7 µm			

Density of additively manufactured In625 is typically 99.8%, measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

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H-5800-1105-02-B

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SS 316L-0407 powder for additive manufacturing

Process specification

Powder description	Stainless steel powder
Layer thickness	50 µm
Laser power	200 W
Additive manufacturing system	AM250

Material description

316L-0407 alloy is an austenitic stainless steel which comprises iron alloyed with chromium of mass fraction up to 18%, nickel up to 14% and molybdenum up to 3%, along with other minor elements. The alloy is an extra-low carbon variation on the standard 316L alloy.

Due to its low carbon content, 316L-0407 is resistant to sensitisation (carbide precipitation at grain boundaries) and displays good welding characteristics. It also has low stress to rupture and tensile strength at high temperatures.

Material properties

- High hardness and toughness
- High corrosion resistance
- High machine-ability
- Can be highly polished

Applications

- Plastic injection and pressure die-casting moulds, extrusion dies
- Surgical tools
- Cutlery and kitchenware
- Maritime components
- Spindles and screws
- General engineering

Generic data - wrought material

Density	7.99 g/cm³
Thermal conductivity	16.2 W/mK
Melting range	1 371 °C to 1 399 °C
Coefficient of thermal expansion (see note 1)	16 10^{-6} K^{-1}

Note 1 In the range of 0 °C to 100 °C.

Note 2 Tested at ambient temperature by Nadcap and UKAS accredited independent laboratory. Test ASTM E8. Machined prior to testing.

Note 3 Tested to ASTM E384-11, after polishing.

Note 4 Tested to JIS B 0601-2001 (ISO 97), after bead blasting.

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Composition of powder

Element	Mass (%)
Iron	Balance
Chromium	16.00 to 18.00
Nickel	10.00 to 14.00
Molybdenum	2.00 to 3.00
Manganese	≤ 2.00
Silicon	≤ 1.00
Nitrogen	≤ 0.10
Oxygen	≤ 0.10
Phosphorus	≤ 0.045
Carbon	≤ 0.03
Sulphur	≤ 0.03

Mechanical properties of additively manufactured components

	As Built
Upper tensile strength (UTS) *(See note 2)*	
Horizontal direction (XY)	676 MPa ±2 MPa
Vertical direction (Z)	624 MPa ±17 MPa
Yield strength *(see note 2)*	
Horizontal direction (XY)	547 MPa ±3 MPa
Vertical direction (Z)	494 MPa ±14 MPa
Elongation at break *(see note 2)*	
Horizontal direction (XY)	43% ±2%
Vertical direction (Z)	35% ±8%
Modulus of elasticity *(see note 2)*	
Horizontal direction (XY)	197 GPa ±4 GPa
Vertical direction (Z)	190 GPa ±10 GPa
Hardness (Vickers) *(see note 3)*	
Horizontal direction (XY)	198 HV0.5 ±8 HV0.5
Vertical direction (Z)	208 HV0.5 ±6 HV0.5
Surface roughness (R_a) *(see note 4)*	
Horizontal direction (XY)	4 µm to 6 µm
Vertical direction (Z)	4 µm to 6 µm

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H-5800-3001-03-A

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Maraging steel M300 powder for additive manufacturing

Process specification

Powder description	Maraging steel
Layer thickness	40 µm
Laser power	400 W
Additive manufacturing system	AM 400

Material description

Maraging steels form a class of iron alloys. This group of materials has a martensitic crystal structure and is strengthened via aging at approximately 500 °C (900 °F), hence the name 'maraging'. These ultra-low carbon alloys have very high strength and hardness properties derived from precipitation of intermetallic compounds rather than carbon content.

Nickel is the main alloying element, with cobalt, molybdenum, and titanium as secondary intermetallic alloying metals.

Maraging steel M300 is also commonly referred to as 1.2709.

Material properties

- High strength
- High hardness
- High fatigue strength
- Good machinability

Applications

- Tooling inserts
- Mould and die
- High strength components

Generic data - wrought material

Density	8.1 g/cm³
Thermal conductivity (see note 1)	14.2 W/mK at 20 °C, 21.0 W/mK at 600 °C, 28.6 W/mK at 1300 °C
Melting point	1413 °C
Coefficient of thermal expansion	10.3 10^{-6} K^{-1}

Note 1 Age hardened at 490 °C ±10 °C for 6 hrs.

Note 2 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on a sample size of 6.

Note 3 Tested to ASTM E384-11, after polishing.

Note 4 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

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Composition of powder*

Element	Mass / max. %
Iron	Balance
Nickel	17.00 to 19.00
Cobalt	7.00 to 10.00
Molybdenum	4.50 to 5.20
Titanium	0.30-1.20
Silicon	≤ 0.10
Manganese	≤ 0.15
Carbon	≤ 0.03
Phosphorous	≤ 0.01
Sulphur	≤ 0.01

*ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter specification powder. Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Mechanical properties of additively manufactured parts

	As built		**Age hardened** (See note 1)	
	Mean	**Standard deviation (±1σ)**	**Mean**	**Standard deviation (±1σ)**
Tensile strength (UTS) (See note 2)				
Horizontal direction (XY)	1147 MPa	3 MPa	1917 MPa	8 MPa
Vertical direction (Z)	1035 MPa	10 MPa	1952 MPa	23 MPa
Yield strength (see note 2)				
Horizontal direction (XY)	976 MPa	17 MPa	1873 MPa	26 MPa
Vertical direction (Z)	794 MPa	22 MPa	1898 MPa	29 MPa
Elongation at break (see note 2)				
Horizontal direction (XY)	15%	1%	6%	2%
Vertical direction (Z)	10%	2%	3%	1%
Modulus of elasticity (see note 2)				
Horizontal direction (XY)	185 GPa	9 GPa	218 GPa	22 GPa
Vertical direction (Z)	189 GPa	6 GPa	199 GPa	8 GPa
Hardness (Vickers) (see note 3)				
Horizontal direction (XY)	350 HV0.5	15 HV0.5	574 HV0.5	7 HV0.5
Vertical direction (Z)	357 HV0.5	12 HV0.5	561 HV0.5	13 HV0.5
Surface roughness (R_a) (See note 4)				
Horizontal direction (XY)	3.5 µm to 4 µm			
Vertical direction (Z)	7.5 µm to 10.5 µm			

Density of additively manufactured maraging steel M300 is typically 99.8%, measured optically on a 10 mm x 10 mm x 10 mm sample at 75× magnification.

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Issued: 07.2017

H-5800-3695-01-A

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Maraging steel M300 powder for additive manufacturing

Process specification

Powder description	Maraging steel
Layer thickness	40 µm
Laser power	200 W
Additive manufacturing system	AM250 and AM 400

Material description

Maraging steels form a class of iron alloys. This group of materials has a martensitic crystal structure and is strengthened via aging at approximately 500 °C (900 °F), hence the name 'maraging'. These ultra-low carbon alloys have very high strength and hardness properties derived from precipitation of intermetallic compounds rather than carbon content.

Nickel is the main alloying element, with cobalt, molybdenum, and titanium as secondary intermetallic alloying metals.

Maraging steel M300 is also commonly referred to as 1.2709.

Material properties

- High strength
- High hardness
- High fatigue strength
- Good machinability

Applications

- Tooling inserts
- Mould and die
- High strength components

Generic data - wrought material

Density	8.1 g/cm^3
Thermal conductivity	14.2 W/mK at 20 °C, 21.0 W/mK at 600 °C, 28.6 W/mK at 1300 °C
Melting point	1413 °C
Coefficient of thermal expansion	10.3 10^{-6} K^{-1}

Note 1 Age hardening conditions: 1. Heat up to 500 °C ±10 °C over the course of 60 minutes to 90 minutes, hold temperature for 6 hours; 2. Furnace cool to 300 °C; 3. Air cool.

Note 2 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on a sample size of 6.

Note 3 Tested to ASTM E384-11, after polishing.

Note 4 Tested to JIS B 0601-2001 (ISO 97). As built after bead blasting.

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Composition of powder

Element	Mass / max. %
Iron	Balance
Nickel	17.00 to 19.00
Cobalt	7.00 to 10.00
Molybdenum	4.50 to 5.20
Titanium	0.30-1.20
Silicon	≤ 0.10
Manganese	≤ 0.15
Carbon	≤ 0.03
Phosphorous	≤ 0.01
Sulphur	≤ 0.01

*ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter specification powder. Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Mechanical properties of additively manufactured parts

	As built	Standard deviation (±1σ)	Age hardened (See note 1)	Standard deviation (±1σ)
Tensile strength (UTS) (See note 2)				
Horizontal direction (XY)	1141 MPa	7 MPa	1806 MPa	6 MPa
Vertical direction (Z)	1122 MPa	14 MPa	1794 MPa	9 MPa
Yield strength (see note 2)				
Horizontal direction (XY)	1016 MPa	8 MPa	1753 MPa	20 MPa
Vertical direction (Z)	999 MPa	20 MPa	1730 MPa	20 MPa
Elongation at break (see note 2)				
Horizontal direction (XY)	7.3%	1%	5.5%	1%
Vertical direction (Z)	7.5%	1%	7%	1%
Modulus of elasticity (see note 2)				
Horizontal direction (XY)	160 GPa	5 GPa	170 GPa	8 GPa
Vertical direction (Z)	162 GPa	10 GPa	175 GPa	11 GPa
Hardness (Vickers) (see note 3)				
Horizontal direction (XY)	363 HV0.5	5 HV0.5	542 HV0.5	7 HV0.5
Vertical direction (Z)	355 HV0.5	7 HV0.5	543 HV0.5	8 HV0.5
Surface roughness (R_a) (See note 4)				
Horizontal direction (XY)	3.5 µm to 5 µm			
Vertical direction (Z)	4 µm to 6 µm			

Density of additively manufactured maraging steel M300 is typically 99.8%, measured optically on a 10 mm x 10 mm x 10 mm sample at 75× magnification.

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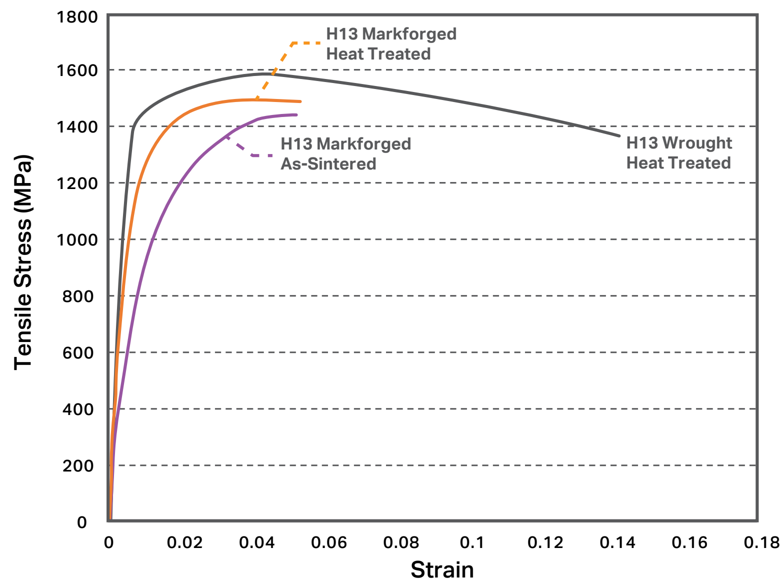
Issued: 09.2017

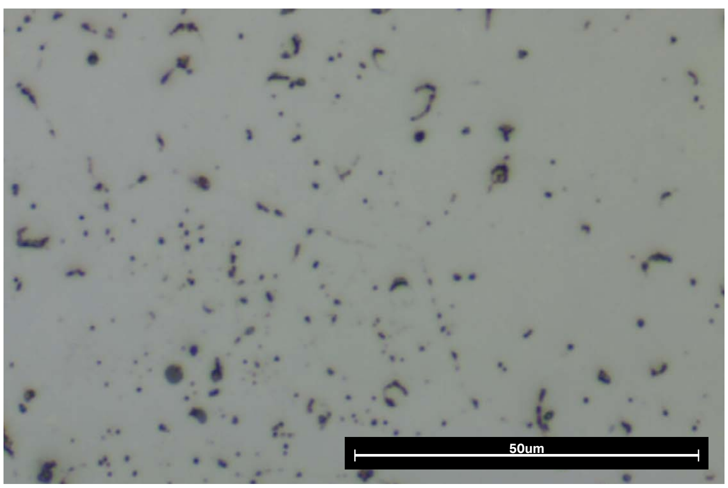
H-5800-3429-03-A

MATERIAL DATASHEET

H13 Tool Steel

Composition	Amount
Chromium	4.7-5.5%
Molybdenum	1.3-1.7%
Silicon	0.8-1.2%
Vanadium	0.8-1.2%
Carbon	0.3-0.45%
Manganese	0.2-0.5%
Phosphorous	0.03% max
Sulfur	0.03% max
Iron	bal





Markforged H13 As-Sintered

H13 Tool Steel printed on the Metal X, washed in the Wash-1, and sintered in the Sinter-1. As Sintered Microstructure is pictured to the left.

Markforged H13 Heat Treated

H13 Tool Steel printed with the Metal X system, air quenched at 1010C, and double tempered at 600C

Wrought H13 Heat Treated

Wrought H13 tool steel standard from *ASM Specialty Handbook* - air quenched at 1010C and double tempered at 600C.

Typical Mechanical Properties	Standard	Markforged As-Sintered	Markforged Heat Treated	Wrought Heat Treated*
Ultimate Tensile Strength	ASTM E8	1420 MPa	1500 MPa	1580 MPa
0.2% Yield Strength	ASTM E8	800 MPa	1250 MPa	1360 MPa
Elongation at Break	ASTM E8	5%	5%	14%
Hardness	ASTM E18	40 HRC	45 HRC	46 HRC
Relative Density	ASTM B923	94.5%	94.5%	100%

These data represent typical values for Markforged H13 Tool Steel as-sintered and after heat treatment. Values were tested in house, and both material composition and "As-Sintered" data were confirmed by outside testing. These representative data were tested, measured, or calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied.
*Wrought Heat Treated data included in table only. Data from *ASM Specialty Handbook: Tool Materials* page 140

VELO 3D

HASTELLOY® C22

Material & Process Capability

HASTELLOY® C22 is one of the most versatile alloys available today with resistance to both uniform and localized corrosion and a variety of mixed industrial chemicals. It is used in severely corrosive environments with high chloride and high temperature conditions, such as flue-gas scrubbers, nuclear fuel re-processing, sour gas handling, and pesticide production. It provides superior protection from pitting, crevice attack, and stress corrosion cracking.

The VELO3D intelligent additive printing solution uniquely enables companies to build the parts they need without compromising design or quality—resulting in complex parts higher in performance than traditional casting techniques or other additive methods.

General Process

This datasheet specifies the expected mechanical properties and characteristics of this alloy when manufactured on a VELO3D Sapphire® System. All data is based on parts built using VELO3D standard 50 μm layer thickness parameters, using Praxair TruForm C22, a VELO3D-approved powder.

Mechanical Properties at Room Temperature

Accuracy, Small Parts	±0.050 (±0.002)	(in)
Accuracy, Large Parts	±0.2	percent
Minimum Wall Thickness; up to 500:1 aspect ratio	0.200 (0.008)	(in)
Typical Volume Rate[1]	60	cc per hr
Density	8.69 (0.313)	g/cc (lbs/in^3)
Relative Density	99.9+	percent
Surface Finish, Sa[2]	6 (240)	μm (μin)
Electrical Conductivity (ASTM E1004-17)	1.4	%IACS
Thermal Conductivity (ASTM E1225-13)	8.9 @ 23C; 15.2 @ 400C	W/mK
Hardness	87.5	HRB

Corrosion[3]

- ASTM G28A: Corrosion rate noted after 24 hrs is 29 mpy
- ASTM G36: No cracking in 48 hrs
- ASTM G48B : No pitting, crevice corrosion or weight loss noted in 48 hrs
- ASTM G150: No pitting or crevice corrosion noted up to 85 C

	As Printed				After Hot Isostatic Pressing [5]				
	Without Stress Relief		With Stress Relief[6]		Without Stress Relief		With Stress Relief[6]		
Property[4]	Min	Average	Min	Average	Min	Average	Min	Average	
Modulus of Elasticity	141	176	158	163	173	206	156	160	GPa
Ultimate Tensile Strength	780 (113)	784 (114)	840 (122)	845 (123)	720 (104)	722 (105)	705 (102)	710 (103)	MPa (KSI)
Yield (0.2% Offset)	520 (75.4)	537 (78)	490 (71.1)	493 (71.5)	380 (55.1)	386 (56.0)	420 (60.9)	423 (61.3)	MPa (KSI)
Elongation At Break	34.5	38.3	39.5	41.6	31	43.3	55.5	56.5	percent

1. Geometry-dependent. 2. Depends on orientation and process selected. 3. Results were also obtained for commercially available rolled material and found to be comparable. 4. Mechanical & test samples printed in vertical orientation, machined to ASTM E8 (specimen #3). 5. HIP at 100 MPa, 1120 C ± 15 C, hold for 240 min ± 60 min and cool under inert atmosphere to below 425 C. 6. Stress relief at 1038 C ± 14 C for 45 min and air cool. Mechanical properties were also checked in the following states and verified to be within ASTM B575 specification: Vertical orientation, net shape (not machined) / Horizontal orientation / Horizontal orientation utilizing both lasers (stitch line at gauge region of tensile bar).

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DS-AlumF357.EN2021-05-06.v0-1a.U.USL 0905-10330_x 2021-05-06

HASTELLOY-X

Material & Process Capability

HASTELLOY® X alloy (UNS N06002) is a nickel-chromium-iron-molybdenum alloy widely used in high-temperature and corrosive atmosphere applications. The alloy is commonly used in gas turbine engines. Its corrosion resistance also makes it an excellent candidate for applications in petrochemical and energy generation applications, such as transition ducts, combustor cans, afterburners, and spray bars.

The VELO^{3D} intelligent additive printing solution uniquely enables companies to build the parts they need without compromising design or quality—resulting in complex, higher performance parts than traditional casting techniques or other additive methods.

General Process

This data sheet specifies the expected mechanical properties and characteristics of this alloy when manufactured on a VELO^{3D} Sapphire® system. All data is based on parts built using VELO^{3D} standard 50 µm layer thickness parameters, using Praxair TruForm HXLC, a VELO^{3D} -approved HASTELLOY® X powder. HASTELLOY® is a registered trademark of Haynes International, Inc.

Accuracy, Small Parts	±0.050 (±0.002)	(in)
Accuracy, Large Parts	±0.2	percent
Minimum Wall Thickness; up to 500:1 aspect ratio	0.200 (0.008)	(in)
Typical Volume Rate[1]	60	cc per hr
Density	8.22 (0.297)	g/cc (lbs/in^3)
Relative Density	99.9+	percent
Surface Finish, Sa[2]	6 (240)	µm (µin)

Mechanical Properties at Room Temperature

	As Printed		After Heat Treatment[4]		After Hot Isostatic Pressing[5]		
Property[3]	Mean -3σ/ Min	Average	Mean -3σ/ Min	Average	Mean -3σ/ Min	Average	
Modulus of Elasticity	131 (19)	179 (25.9)	132 (19.1)	227 (32.9)	148 (21.5)	204 (29.5)	GPa (MSI)
Ultimate Tensile Strength	665 (96.4)	674 (97.7)	625 (90.7)	644 (93.5)	643 (93.2)	658 (95.4)	MPa (KSI)
Yield (0.2% Offset)	461 (66.8)	487 (70.6)	320 (46.5)	336 (48.8)	303 (44.0)	323 (46.9)	MPa (KSI)
Elongation At Break	40.0	45.6	52.6	57.8	51	57.7	percent

1. Geometry-dependent. 2. Depends on orientation and process selected. 3. Mechanical & test samples printed in vertical orientation.
4. Solution annealed at 1177°C for 2 hours followed by rapid air cool. 5. HIP at 1177°C & 14.5 KSI for 3-5 hrs, followed by cooling at 150-200°C/min, processed at Quintus Technologies.

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DS-AlumF357.EN2021-05-06.v0-1a.U.USL 0905-10330_x 2021-05-06

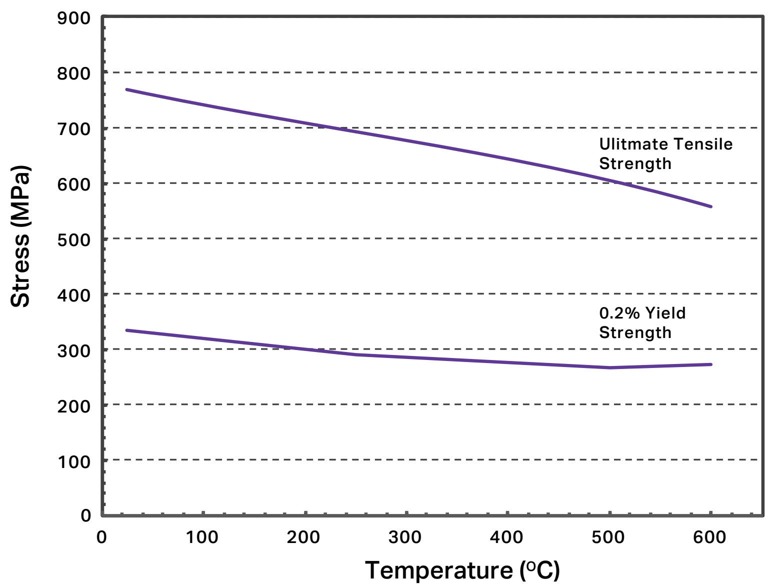
MATERIAL DATASHEET

Inconel 625

Other Designations: UNS N06625, ISO NW6625, DIN 17744

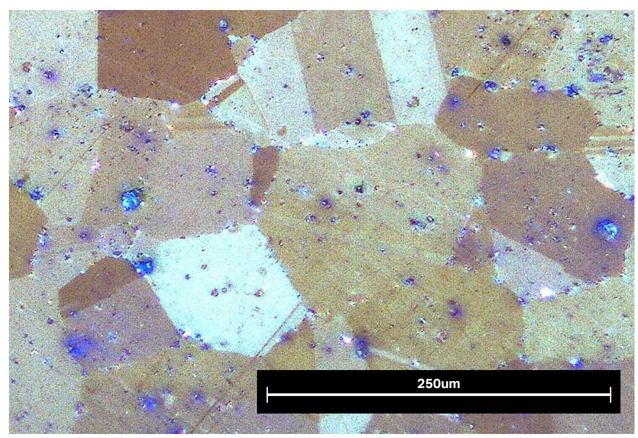
Inconel 625 is a nickel-chromium based superalloy that is highly resistant to corrosion and high temperatures. It's easy to print; allowing you to make functional prototypes and end-use parts for harsh environments. Markforged Inconel 625 meets chemical requirements of ASTM B443.

Composition	Amount
Chromium	20-23%
Molybdenum	8-10%
Iron	5% max
Niobium	3.15-4.15%
Cobalt	1% max
Manganese	0.5% max
Silicon	0.5% max
Aluminum	0.4% max
Titanium	0.4% max
Carbon	0.1% max
Phosphorus	0.015% max
Sulfur	0.015% max
Nickel	bal



Markforged Inconel 625 As-Sintered

Inconel 625 printed on the Metal X, washed in the Wash-1, and sintered in the Sinter-1. As-Sintered microstructure captured at 100x is pictured to the right.



Typical Mechanical Properties	Standard	Markforged As-Sintered	Wrought AMS 5599[1]
Ultimate Tensile Strength	ASTM E8	765 MPa	827 MPa
0.2% Yield Strength	ASTM E8	334 MPa	414 MPa
Elongation at Break	ASTM E8	42%	30%
Hardness	ASTM E18	7 HRC	0-19 HRC
Relative Density[2]	ASTM B923	96.5%	100%

1. Wrought AMS 5599 data represent minimum values, except for Hardness.
2. Relative density for Inconel 625 assumes a reference density of 8.44 g/cm³.
3. ASTM E21 elevated temperature testing was conducted by 3rd party NADCAP lab. Samples were printed in XY and gauge length was machined to size.

These data represent typical values for Markforged Inconel 625 as-sintered. Markforged samples were printed as fully dense parts with 100% infill. Hardness and density data were tested in house, and all other data were tested and confirmed by outside sources. These representative data were tested, measured, or calculated using standard methods and are subject to change without notice. Markforged makes no warranties of any kind, express or implied.

Inconel 718

SPECIFICATIONS

EU	NiCr19Fe19Nb5Mo
USA	N07718

MATERIAL DESCRIPTION

- Nickel-based alloy, hardening γ/γ ' with good resistance to oxidation and having high mechanical properties up to 650°C.

COMPOSITION

weight %

Ni	Balance
Cr	17
Fe	12
Nb	2
Mo	1,5
Ti	0,03
Al	0,5

APPLICATIONS

MATERIAL SHEET

Typical mechanical properties

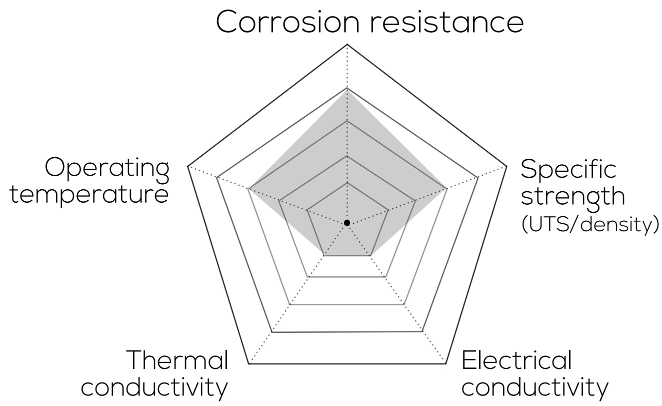
The data provided in this document represent typical but not guaranteed values.

	Stress-relieved	Heat treated*
Ultimate Tensile Strength UTS, MPa	1380	1450
Yield Strength YS, MPa	1200	1300
Elongation at break E 5D, %	16	16

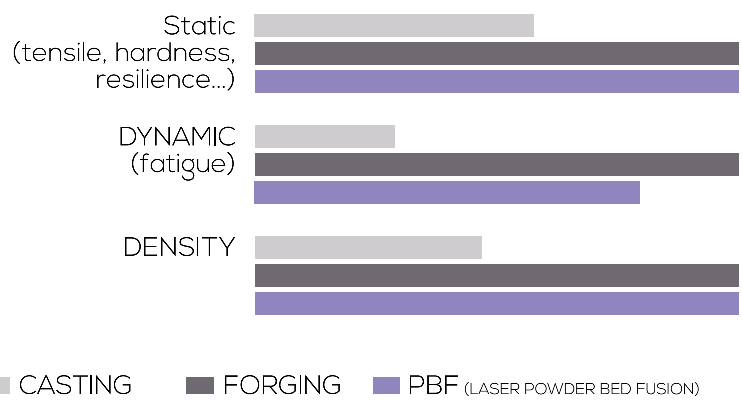
* Heat treatment: 1095°C/2h + 720°C/8h + 620°C/8h.

The mechanical characteristics along the Z axis are lowered by about 100 MPa after manufacturing.
The anisotropy is significantly reduced, if not eliminated, after heat treatment.

Physical properties:



Qualitative comparison according to processes



Technical data

PARTICULES SIZE :
Available in different granulometries.

SUPPLIERS :
AddUp will provide support with your choice of powder supplier.

Inconel 718

MATERIAL SHEET

Applications, in detail

AUTOMOTIVE
Exhaust manifold

To reach high performances, engines need to improve its maximal operating temperature as well as geometric and mechanical characteristics.

Inconel 718 helps designers to reach those goals.

AERONAUTIC
Disc

Ni-based alloy Inconel 718 is a commonly used grade for high temperature applications.

Typically, its operating range is between 650°C to 700°C where its high yield strength combined with a good creep vs. fatigue resistance ratio allows for an extremely versatile alloy suitable for a variety of applications.

POWER GENERATION
Fastener, heat exchanger

Parts with complex shapes (i.e. heat exchangers) require a good degree of weldability.

Moreover, to improve the overall dimensional requirements of these parts at elevated temperatures, high mechanical characteristics are required. In these cases, Inconel 718 is a great candidate for these applications.

AddUp
GLOBAL ADDITIVE SOLUTIONS

Inconel IN718

Material & Process Capability

Inconel® IN718 is a precipitation-hardenable nickel-based superalloy known for its superb tensile strength when subjected to extreme pressure and heat. It has a rupture strength at temperatures of up to 1290 °F (980 °C), which makes it ideal for high temperature applications such as gas turbine and power/process industry parts. The material is often used for critical applications in the aerospace, defense, and petrochemical industries.

The VELO3D intelligent additive printing solution uniquely enables companies to build the parts they need without compromising design or quality—resulting in complex parts higher in performance than traditional casting techniques or other additive methods.

General Process

This data sheet specifies the expected mechanical properties and characteristics of this alloy when manufactured on a VELO3D Sapphire® system. All data is based on parts built using VELO3D standard 50 µm layer thickness parameters, using Praxair Tru-Form 718-35, a VELO3D- approved powder. Parts built from IN718 on a Sapphire system can be heat treated like those manufactured by other methods.

Accuracy, Small Parts	±0.050 (±0.002)	(in)
Accuracy, Large Parts	±0.2	percent
Minimum Wall Thickness; up to 500:1 aspect ratio	0.200 (0.008)	(in)
Typical Volume Rate[1]	60	cc per hr
Density	8.19 (0.296)	g/cc (lbs/in^3)
Relative Density	99.9+	percent
Surface Finish, Sa[2]	6 (240)	µm (µin)

Mechanical Properties at Room Temperature

	As Printed		After Heat Treatment & HIP[6]		
Property[3]	Mean -3σ/ Min	Average	Mean -3σ/ Min	Average	
Modulus of Elasticity	103 (14.9)	110 (15.9)	166 (24.1)	199 (28.9)	GPa (MSI)
Ultimate Tensile Strength	912 (132)	953 (138)	1286 (187)	1320 (191)	MPa (KSI)
Yield (0.2% Offset)	512 (74.3)	603 (87.4)	1022 (148)	1063 (154)	MPa (KSI)
Elongation At Break	24.1	30.9	15.3	20.7	percent
Hardness, HRC			42.3	43.3	

1. Geometry-dependent. 2. Depends on orientation and process selected. 3. Mechanical & test samples printed in vertical orientation. 4. Heat treatment per ASTM F3055, Hot Isostatic Pressing per ASTM F3055, solution & age per AMS 5662.

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LENS® MATERIAL STARTER RECIPES

LENS Material Starter Recipes are time saving tools helping customers speed the development of new additive manufacturing applications. Developed by Optomec LENS application engineers and material scientists, each recipe provides detailed instructions covering powder feedstock characteristics, machine set-up, processing parameters and expected results for a variety of commercially available powders. Each recipe is also geometry specific providing time savings guidelines to produce quality results for thin wall, small volume and large volume structures. Optical and SEM images showing the microstructure and morphology of samples printed using each recipe are provided. Tensile tests conducted by an independent lab are also provided for small and large volume structures according to ASTM Standard E8.

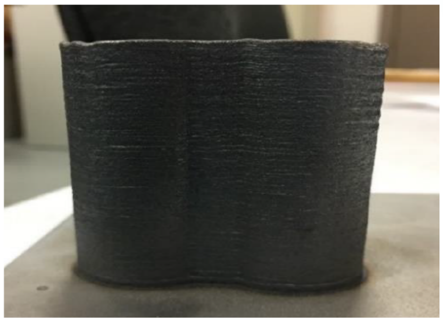

Figure 1: Single Wall Dumbbell Structure Fabricated from Stainless Steel 420LC

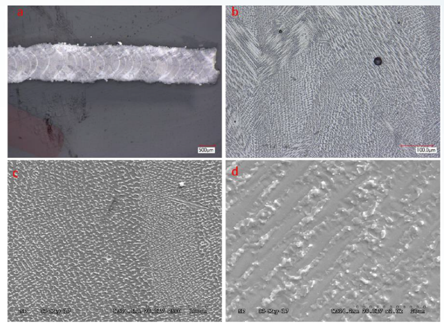

Figure 2: Optical and SEM images showing the micostructure and morphology of LENS deposited SS 420 LC

Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Reduction of Area (%)	Elongation (%)
ksi	MPa	ksi	MPa		
172.10 ± 12.99	1186.58 ± 89.56	157.16 ± 2.85	1083.58 ± 19.65	4.36 ± 0.49	0.53 ± 0.25

Table 1: Tensile Properties of LENS processed SS 420LC in open environment.

Commercially available annealed stainless steel 420 typically has ultimate tensile strength of 95 ksi or 655 MPa whereas commercially available stainless steel 420 tempered at 593°C/1100°F typically has ultimate tensile strength of 150 ksi or 1035 MPa.

KEY FEATURES

- Developed by Optomec Experts – save weeks of trial and error
- Proven – use with confidence
- Commercially Available Powders – easy to repeat results
- Geometry Specific – speed application development
- Independently Tested –assure quality results

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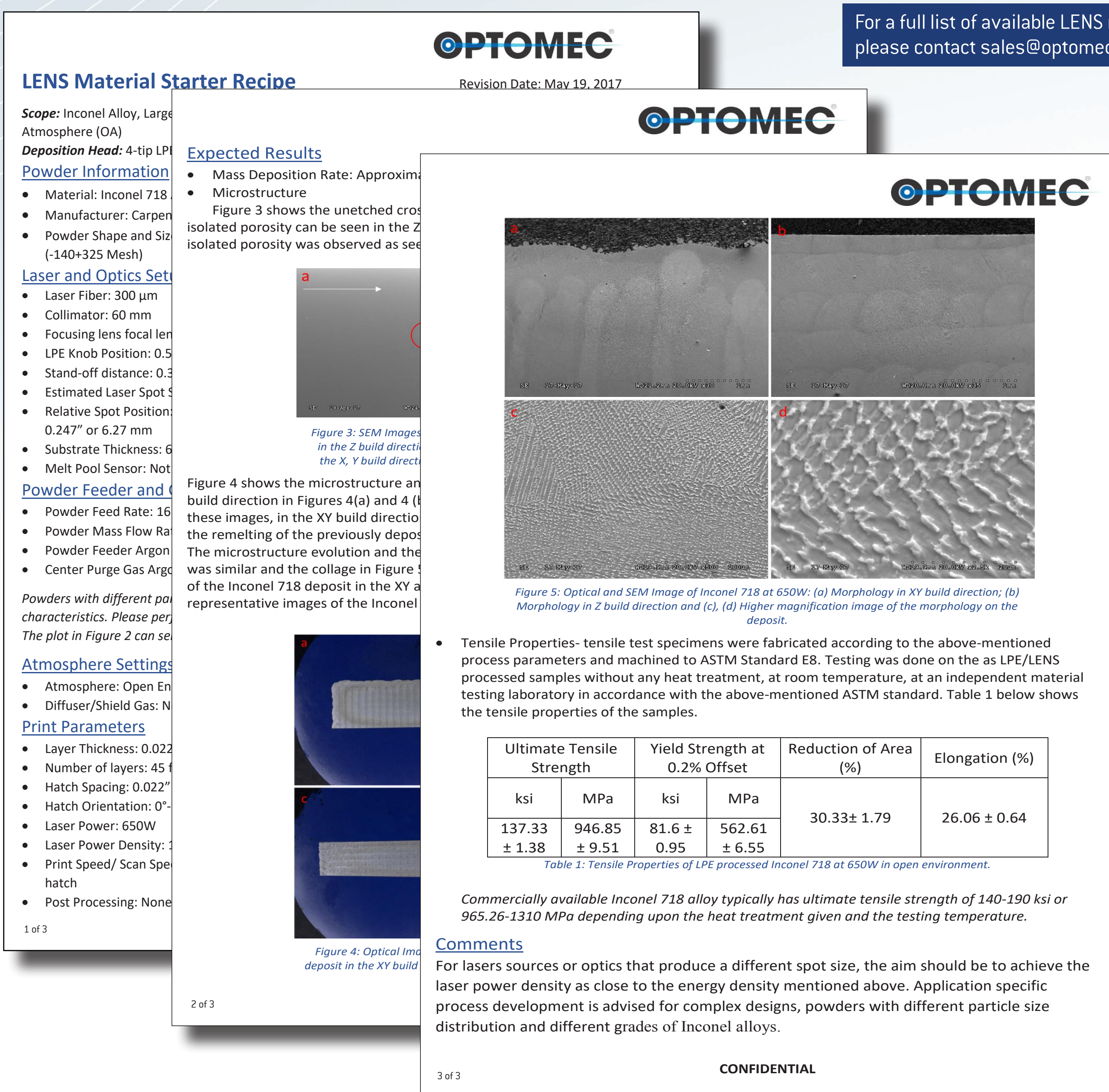
EXAMPLE LENS® STARTER RECIPES

For a full list of available LENS recipes, please contact sales@optomec.com


OPTOMEC

LENS Material Starter Recipe

Revision Date: May 19, 2017

Scope: Inconel Alloy, Large
Atmosphere (OA)
Deposition Head: 4-tip LPE

Powder Information
- Material: Inconel 718
- Manufacturer: Carpen
- Powder Shape and Siz (-140+325 Mesh)

Laser and Optics Setu
- Laser Fiber: 300 µm
- Collimator: 60 mm
- Focusing lens focal len
- LPE Knob Position: 0.5
- Stand-off distance: 0.3
- Estimated Laser Spot S
- Relative Spot Position: 0.247" or 6.27 mm
- Substrate Thickness: 6
- Melt Pool Sensor: Not

Powder Feeder and C
- Powder Feed Rate: 16
- Powder Mass Flow Ra
- Powder Feeder Argon
- Center Purge Gas Argo

Powders with different pa characteristics. Please per The plot in Figure 2 can se

Atmosphere Settings
- Atmosphere: Open En
- Diffuser/Shield Gas: N

Print Parameters
- Layer Thickness: 0.022
- Number of layers: 45 f
- Hatch Spacing: 0.022"
- Hatch Orientation: 0°-
- Laser Power: 650W
- Laser Power Density: 1
- Print Speed/ Scan Spe hatch
- Post Processing: None

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Expected Results
- Mass Deposition Rate: Approxima
- Microstructure

Figure 3 shows the unetched cros isolated porosity can be seen in the Z isolated porosity was observed as see

Figure 3: SEM Images in the Z build directi the X, Y build directi

Figure 4 shows the microstructure an build direction in Figures 4(a) and 4 (b these images, in the XY build directio the remelting of the previously depos The microstructure evolution and the was similar and the collage in Figure 5 of the Inconel 718 deposit in the XY a representative images of the Inconel

Figure 4: Optical Ima deposit in the XY build

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Figure 5: Optical and SEM Image of Inconel 718 at 650W: (a) Morphology in XY build direction; (b) Morphology in Z build direction and (c), (d) Higher magnification image of the morphology on the deposit.

- Tensile Properties- tensile test specimens were fabricated according to the above-mentioned process parameters and machined to ASTM Standard E8. Testing was done on the as LPE/LENS processed samples without any heat treatment, at room temperature, at an independent material testing laboratory in accordance with the above-mentioned ASTM standard. Table 1 below shows the tensile properties of the samples.

Ultimate Tensile Strength		Yield Strength at 0.2% Offset		Reduction of Area (%)	Elongation (%)
ksi	MPa	ksi	MPa	30.33± 1.79	26.06 ± 0.64
137.33 ± 1.38	946.85 ± 9.51	81.6 ± 0.95	562.61 ± 6.55		

Table 1: Tensile Properties of LPE processed Inconel 718 at 650W in open environment.

Commercially available Inconel 718 alloy typically has ultimate tensile strength of 140-190 ksi or 965.26-1310 MPa depending upon the heat treatment given and the testing temperature.

Comments

For lasers sources or optics that produce a different spot size, the aim should be to achieve the laser power density as close to the energy density mentioned above. Application specific process development is advised for complex designs, powders with different particle size distribution and different grades of Inconel alloys.

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ABOUT OPTOMEC

Optomec® is a privately-held, rapidly growing supplier of Additive Manufacturing systems. Optomec's patented Aerosol Jet Systems for printed electronics and LENS 3D Printers for metal components are used by industry to reduce product cost and improve performance. Together, these unique printing solutions work with the broadest spectrum of functional materials, ranging from electronic inks to structural metals and even biological matter. Optomec has more than 300 marquee customers around the world, targeting production applications in the Electronics, Energy, Life Sciences and Aerospace industries. For more information about Optomec, visit http://www.optomec.com.

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