OPTOMEC®

Production Grade 3D Printers... with a Material Difference

LENS® MATERIALS FAQs

LENS systems process common engineering materials such as stainless steels, tool steels, titanium alloys, and cobalt alloys. LENS technology can also process other materials including Zirconium, Tantalum, Tungsten, Aluminum, Bronze, refractory metals and some ceramics. These materials are available in powder form from a variety of commercial suppliers.

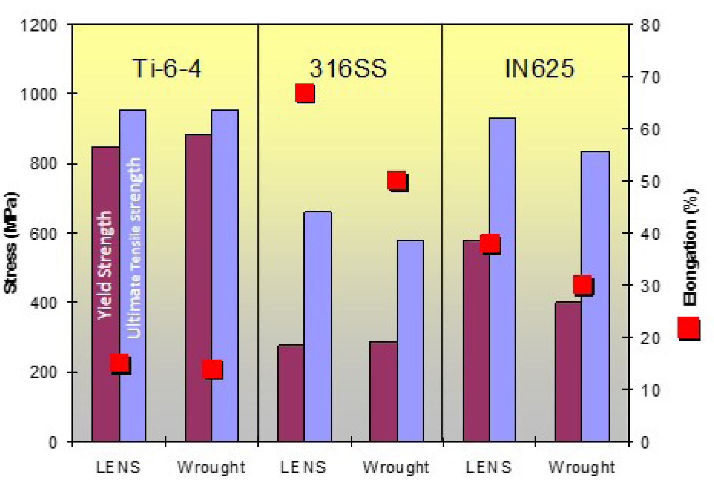
Printing Features of LENS Systems:

- Layer Thickness: 250 to 750 microns
- Melt Pool Diameter: 2,000 microns Typical
- Minimum Wall Thickness: 300 microns
- Deposition Rate Based on Laser Power: 2 kW = 0.5kg/hr.
- Surface Roughness: On the sides, 12- 25 microns Ra

Schematic cross-section through a part. This schematic shows five layers. The sides will show a layered appearance, with a generally smooth top.

Printed Metal Properties

In general, the LENS process produces fully-dense material that has mechanical properties at least equal or better than cast material, and in some cases very similar to forged material.



Powder Characteristics:

- Size: Powder particle size is -100/+325 mesh, equivalent to a powder diameter of 44 to 150 microns.
- **Shape:** Powder sufficiently spherical to flow.
- **Chemistry:** The LENS process does not alter powder chemistry.
- **Cleanliness:** Inert-Gas-Atomized or Plasma-Rotating-Electrode powders are normally of acceptable quality.

MATERIALS FOR OPEN ATMOSPHERE

ALLOY CLASS	ALLOY
Stainless Steel	13-8
	17-4
	304
	316
	410
	420
	15-5PH
	AM 355
	309
	416
	420

ALLOY CLASS	ALLOY
Nickel	IN625
	IN718
	IN690
Copper	Pure Copper
	Bronze
	Cu-Ni
	GRCOP-84
Tool Steel	H13
	S7
	A-2
Cobalt	Stellite 6, 21
Carbide	Ni-WC
	Co-WC

MATERIALS FOR CONTROLLED ATMOSPHERE

ALLOY CLASS	ALLOY
Titanium	CP-Ti
	Ti 6-4
	Ti 6-2-4-2
	Ti-6-2-4-6
	Ti-48-2-2
	Ti-22Al-23Nb
Ceramics	Alumina
Aluminum	4047

ALLOY CLASS	ALLOY
Nickel	Waspalloy
	Hastelloy X
	MarM 247
	Rene 41
	Rene 142
Refactories	W, Mo, Nb
Composites	TiC
	CrC

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.

OPTOMEC®
Production Grade 3D Printers... with a Material Difference

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M300

Steel M300 is a maraging tool steel which can be used for manufacturing tool components with conformal cooling for series injection-molding as well as diecasting and functional components.

Data in this document represents material built with 40 µm layer thickness and in a Nitrogen atmosphere on an M2 /M2 Multilaser machine. Values listed are typical.

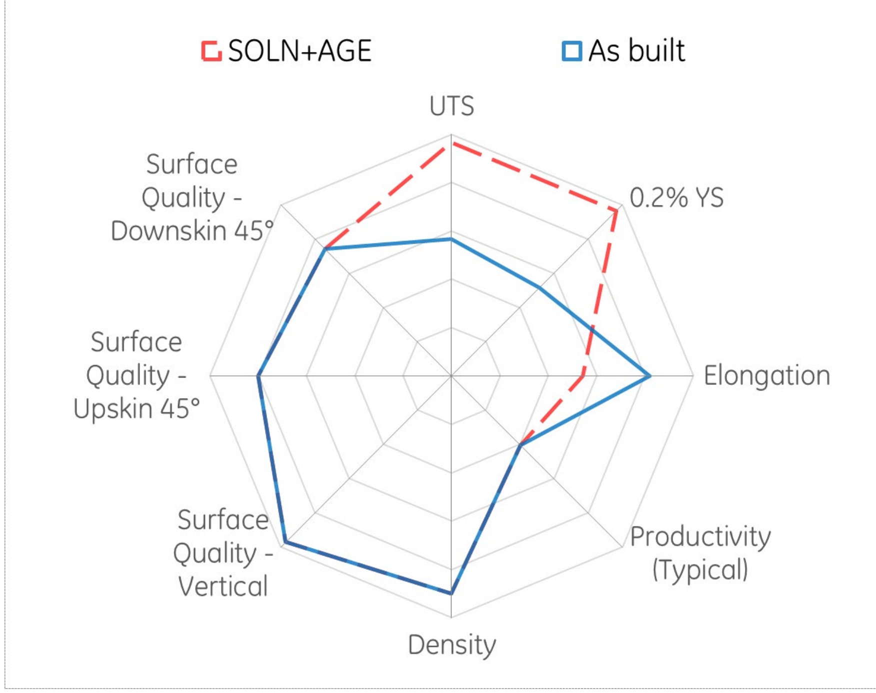
26
Fe

POWDER CHEMISTRY

Element	Indicative value (wt%)
C	0-0.03
Si	0-0.10
Mn†	0-0.15
P	0-0.01
S	0-0.01
Cr	0-0.25
Mo	4.50-5.20
Ni†	17.0-19.0
Ti†	0.80-1.20
Co†	8.50-10.0
Fe	Balance

†M300 (powder) chemical composition et al. according to ASTM A646/A646M with exception of Mn, Ni, Co, Ti content

SPIDER PLOT



MACHINE CONFIGURATION

- M2 / M2 Multilaser
- Nitrogen Gas
- Rubber blade
- Layer thickness 40µm

- Build rate dual laser w/ coating *[cm/h³]: 12.1
- Max. Build rate per Laser** [cm/h³]: 15.0

*Measured by using Factory Acceptance Test layout
**Calculated (layer thickness x scan velocity x hatch distance)

THERMAL STATES

1. AS BUILT
2. AGE: Age hardening at 540°C for 6 hour

PHYSICAL DATA AT ROOM TEMPERATURE

	Surface Roughness - Overhang (µm) 45°	60°	75°
Upskin	12	10	9
Downksin	14	11	8

	Surface Roughness (µm)
H	18
V	6

	Porosity (% Density)		Hardness (HV10)		Poisson's Ratio	
Thermal State	H	V	H	V	H	V
As-Built	99.9	99.9	370	--	--	--
SOLN+AGE	99.9	99.9	600	--	--	--

TENSILE DATA

Tensile testing done in accordance with ASTM E8 and ASTM E21

Temperature: RT

	Modulus of Elasticity (GPa)		0.2% YS (MPa)		UTS (MPa)		Elongation (%)		Reduction of Area (%)	
Thermal State	H	V	H	V	H	V	H	V	H	V
As-Built	158	148	865	1095	1120	1140	13.5	14.5	--	--
SOLN+AGE	190	176	1860	1800	1970	1895	5.7	5.8	--	--

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

* All of the figures contained herein are approximate only. The figures provided are dependent on a number of factors, including but not limited to, process and machine parameters, and the approval is brand specific and/or application specific. The information provided on this material data sheet is illustrative only and cannot be relied on as binding.

AddUp GLOBAL ADDITIVE SOLUTIONS

Maraging 300

SPECIFICATIONS

EU	X3NiCoMoTi18-9-5
WN	1.2709
	18Ni300

MATERIAL DESCRIPTION

- Steel with excellent mechanical properties and good creep resistance. It is commonly used for structural parts or tools.

COMPOSITION

weight %

Fe	Balance
Ni	18
Co	9
Mo	5
Ti	0,6
C	0,02

APPLICATIONS

MATERIAL SHEET

Typical mechanical properties

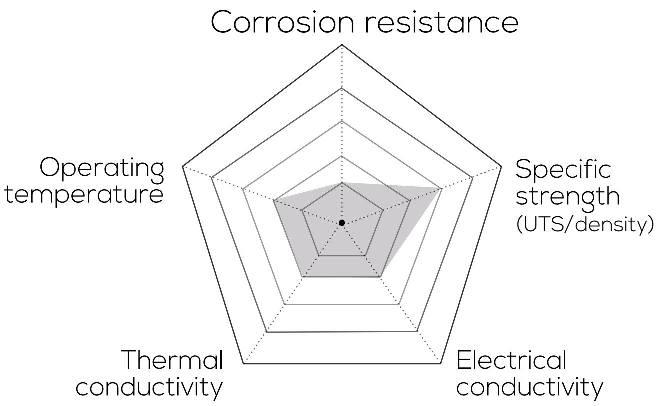
The data provided in this document represent typical but not guaranteed values.

	Stress-relieved	Heat treated*
Ultimate Tensile Strength UTS, MPa	1550	1800
Yield Strength YS, MPa	1400	1750
Elongation at break E 5D, %	12	6

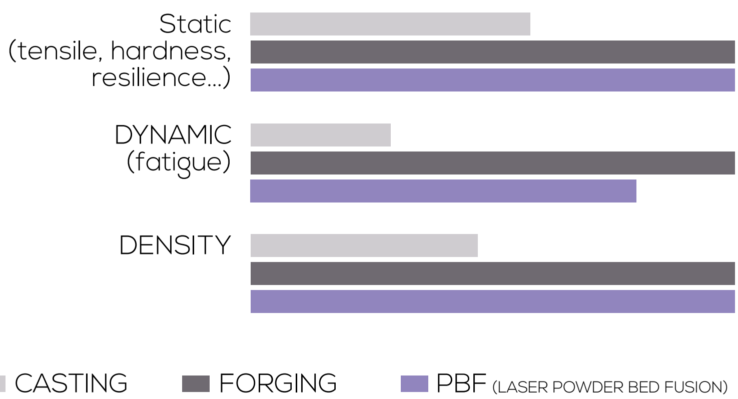
* Heat treatment : 825°C/1h + 480°C/2h.

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.

Maraging 300

MATERIAL SHEET

Applications, in detail

INDUSTRY
Die casting mold

Maraging Steel can be used in die-casting applications due to its great combination of impact resistance and dimensional stability at elevated temperatures.

Additive Manufacturing allows us to further improve on the design of these parts. For example, unique features such as complex, cooling channels can be integrated into these products.

AERONAUTIC
Driveshaft

Maraging Steel has both good creep strength and mechanical properties which is an important requirement for driveshaft and rotor shaft components.

These properties make this alloy suitable for other aeronautic applications as well.

AddUp
GLOBAL ADDITIVE SOLUTIONS

Metal
Solutions

TRL 7
Premium

EOS Aluminium AlF357
Material Data Sheet

EOS Aluminium AlF357
Light Weight & Corrosion Resistance

EOS Aluminium AlF357 is an ideal material for applications requiring a combination of low weight and mechanical / thermal load endurance. It is a beryllium free derivative of the A357 (AlSi7Mg0.6) alloy. Parts built of EOS Aluminium AlF357 can be machined, shot-peened and polished in the as-built or heat treated state. For this product, a T6-like heat treatment may be utilized to enhance the overall mechanical properties.

Main Characteristics:

- → Light-weight
- → Corrosion resistance
- → High dynamic load bearing capacity

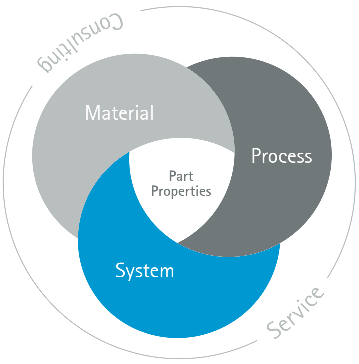
Typical Applications:

- → Aerospace industry applications
- → Defense and automotive industries
- → Structural components requiring high strength

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.



Powder Properties

Chemical composition of the EOS Aluminium AlF357 powder is in compliance with SAE AMS 4289 standard.

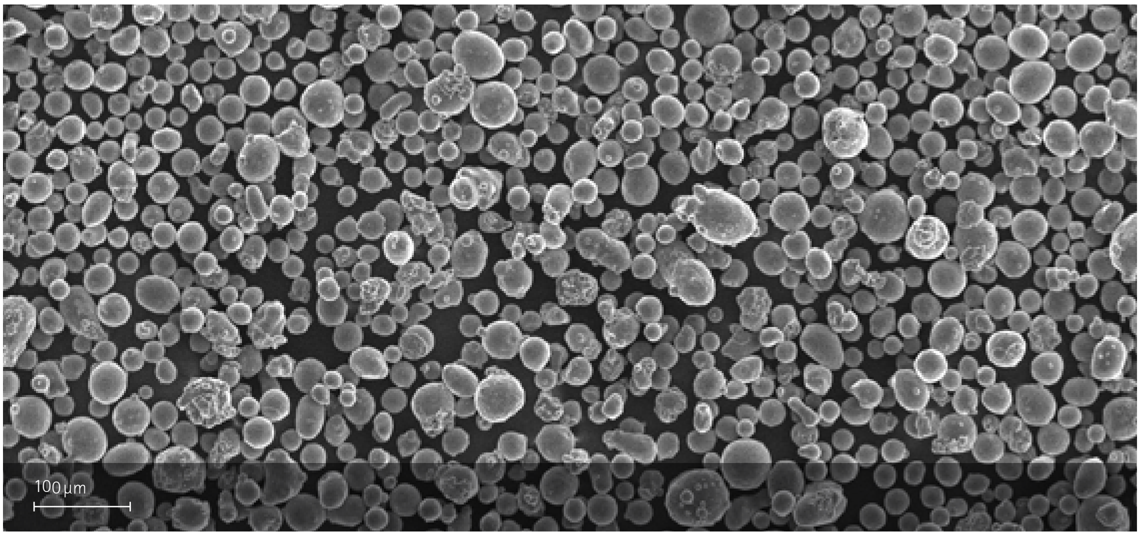
Powder chemical composition (wt.-%)

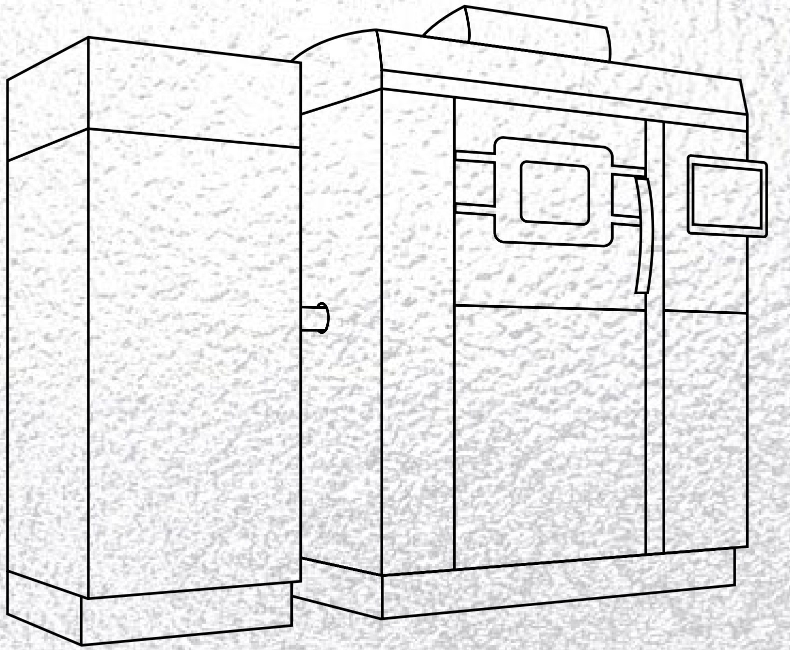
Element	**Min.**	**Max.**
Al	Balance	
Si	6.5	7.5
Fe	-	0.10
Cu	-	0.20
Mn	-	0.10
Mg	0.40	0.7
Zn	-	0.10
Ti	0.04	0.20
Be	-	0.002
Other elements, each	-	0.05
Other elements, total	-	0.15

Powder particle size

Generic particle size distribution	20 – 90 µm

SEM image of EOS Aluminium AlF357 powder.





EOS Aluminium AlF357
for EOS M 290

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

EOS Aluminium AlF357 for EOS M 290

Process Information

System set-up	EOS M 290
EOS ParameterSet	M 290 AlF357 030 V1
EOSPAR name	AlF357_030_M291_100
Software requirements	EOSPRINT 2.5 or newer EOSYSTEM 2.10 or newer
Powder part no.	9011-0049
Recoater blade	EOS HSS blade
Inert gas	Nitrogen
Sieve	106 µm

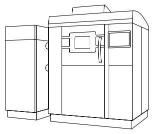
Additional information	
Layer thickness	30 µm
Volume rate	5.8 mm³/s

Heat Treatment

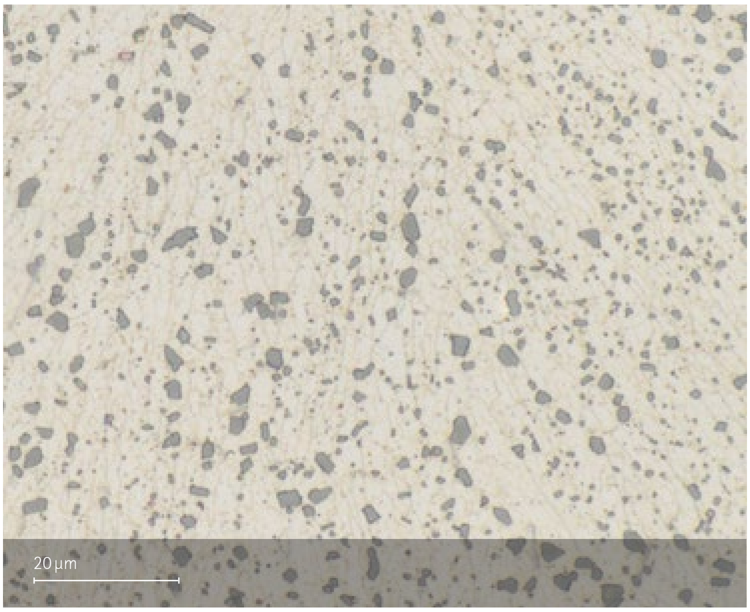
Laser melting process comprises extremely fast melting and re-solidification. Due to the layerwise manufacturing method, the parts exhibit anisotropic properties depending on the building direction. Suitable heat treatments can be used to meet the needs of various applications, e.g. to reduce the anisotropy. Conventionally cast components of this type of aluminum alloy are often heat treated using a T6 cycle consisting of solution annealing, quenching and age hardening. A T6-like heat treatment has been specifically developed to increase the ductility and yield strength, and to reduce the anisotropy of the built parts, consisting of the following cycles:

Solution Annealing:
30 minutes at 540 °C (±6 °C) measured from the part, followed by instant quenching in water at room temperature.

Aging:
6 hours at 165 °C (±6 °C) measured from the part, followed by air cooling. This step is carried out with a maximum delay of 40 hours after the solution annealing.
The mechanical properties for the heat treated condition have been attained through the described heat treatment procedure.



Physical Part Properties



Heat treated microstructure. Etched according to internal procedure using Groesbeck reagent.

Microstructure of the produced parts (as manufactured state)

Defects	Result	Number of samples
Average defect percentage	0.03 %	20
Density ISO 3369	**Result**	**Number of samples**
Average density	2.67 g/cm^3	1

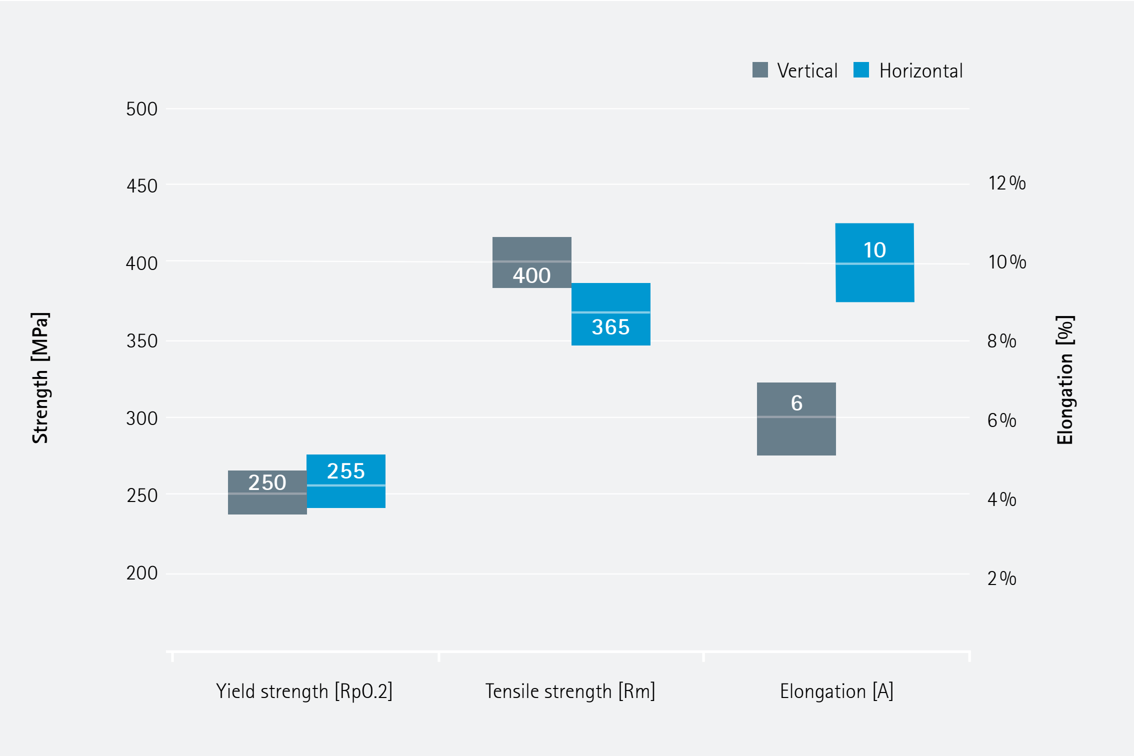
The areal defect percentage was determined from cross-cuts of the built parts using an optical microscope fitted with a camera and analysis software. The analysis was carried out for sample area of 15 x 15 mm. The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images. The density of the built specimen was measured according to ISO3369.

EOS Aluminium AlF357 for EOS M 290

Mechanical Properties

Mechanical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	250	400	6	84
Horizontal	255	365	10	72

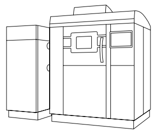


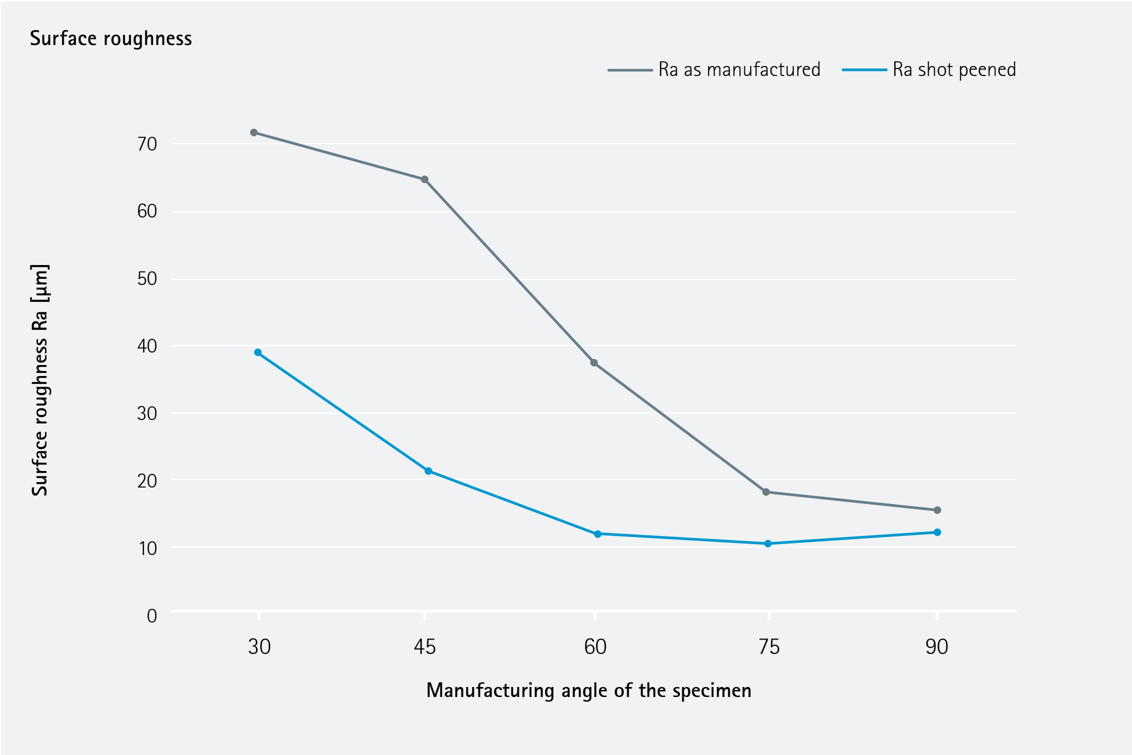
The testing was done according to EN 2002-001 2005 on round specimen machined according to standard Annex C. Results of both horizontal and vertical building direction are presented.

Typical Mechanical properties (heat treated state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	265	330	11.5	56
Horizontal	270	340	11.5	28

Additional Data



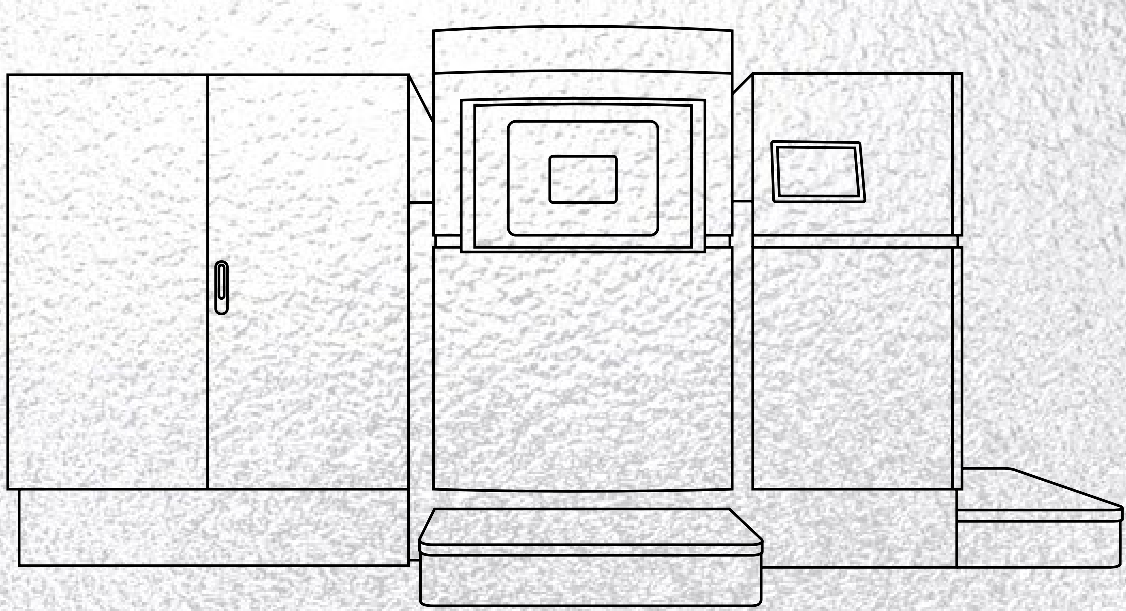


The surface quality was characterized by optical profiling from down-facing surfaces according to internal procedure. The 90 degree angle corresponds to vertical surface.

AlF357 thermal and electrical conductivity

Typical values for F357	Thermal conductivity as built W/m·K	Thermal conductivity T6 W/m·K	Electrical conductivity as built % IACS	Electrical conductivity T6 % IACS
Horizontal	140	150	28-36	35-40
Vertical	140	150		

Thermal conductivity measured according to ISO 22007-2, Hot Disk slab method (xy-plane) and Hot Disk 1D-method (Z-direction). Electrical conductivity measured according to ASTM E1004 Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy Current) Method.



EOS Aluminium AlF357
for EOS M 400

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

EOS Aluminium AlF357 for EOS M 400

Process Information

System set-up	EOS M 400
EOS ParameterSet	M 400 AlF357 060 V1
EOSPAR name	AlF357_060_FlexM400_100
Software requirements	EOSPRINT 1.6 or newer EOSYSTEM 2.6 or newer
Powder part no.	9011-0049
Recoater blade	EOS HSS blade
Inert gas	Nitrogen
Sieve	106 µm

Additional information	
Layer thickness	60 µm
Volume rate	17 mm^3/s

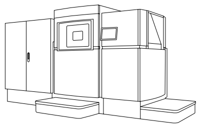
Heat Treatment

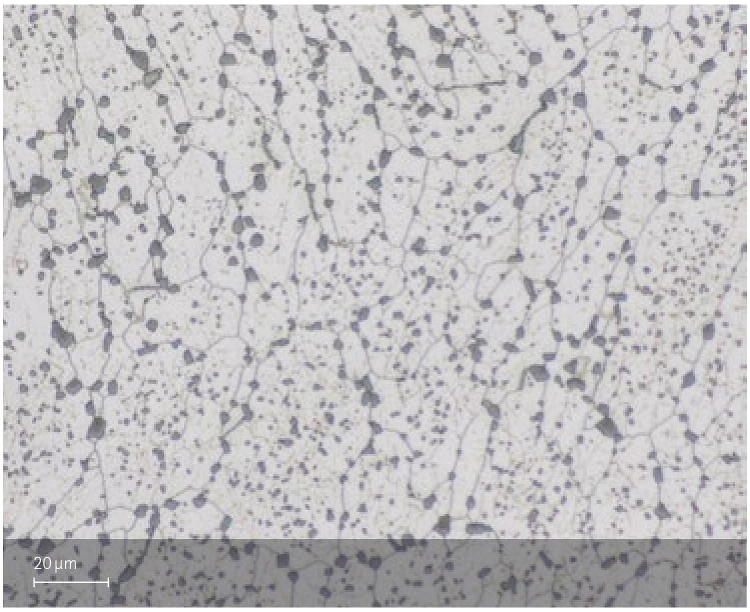
Laser melting process comprises extremely fast melting and re-solidification. Due to the layerwise manufacturing method, the parts exhibit anisotropic properties depending on the building direction. Suitable heat treatments can be used to meet the needs of various applications, e.g. to reduce the anisotropy. Conventionally cast components of this type of aluminum alloy are often heat treated using a T6 cycle consisting of solution annealing, quenching and age hardening. A T6-like heat treatment has been specifically developed to increase the ductility and yield strength, and to reduce the anisotropy of the built parts, consisting of the following cycles:

Solution Annealing:
30 minutes at 540 °C (±6 °C) measured from the part, followed by instant quenching in water at room temperature.

Aging:
6 hours at 165 °C (±6 °C) measured from the part, followed by air cooling. This step is carried out with a maximum delay of 40 hours after the solution annealing.
The mechanical properties for the heat treated condition have been attained through the described heat treatment procedure.

Physical Part Properties





Heat treated microstructure. Etched according to internal procedure using Groesbeck reagent.

Microstructure of the produced parts (as manufactured state)

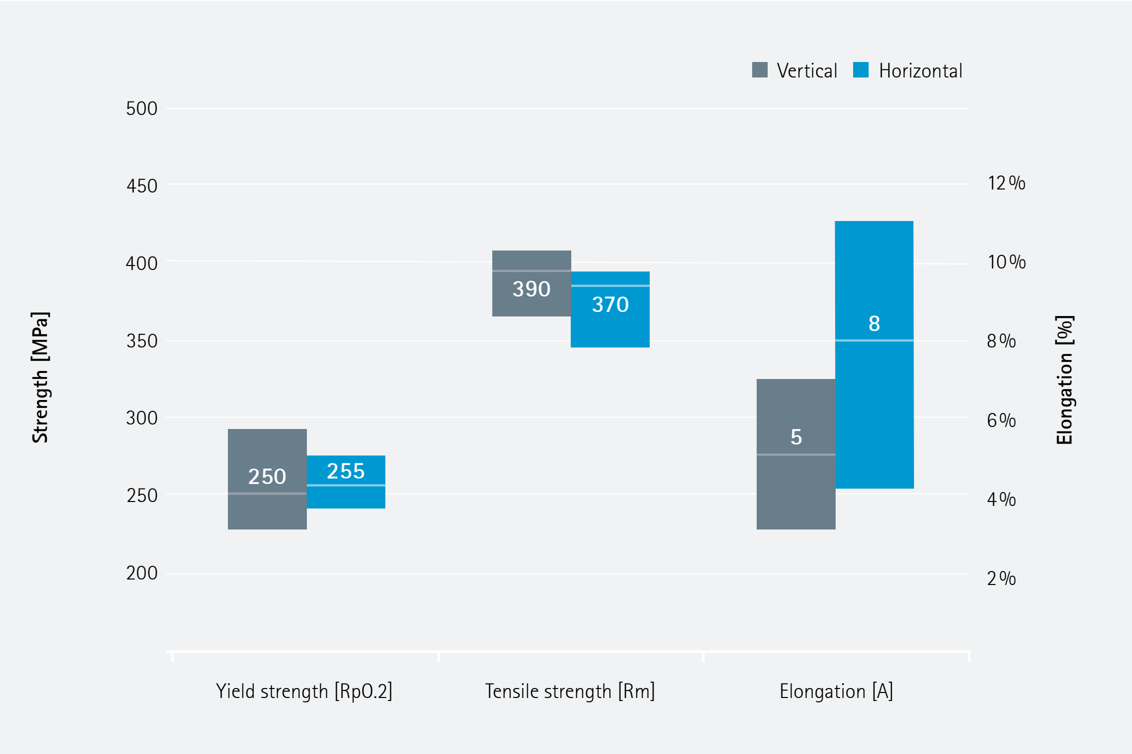
Defects	Result	Number of samples
Average defect percentage	0.16 %	30
Density ISO 3369	**Result**	**Number of samples**
Average density	2.67 g/cm^3	10

The areal defect percentage was determined from cross-cuts of the built parts using an optical microscope fitted with a camera and analysis software. The analysis was carried out for sample area of 15 x 15 mm. The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images. The density of the built specimen was measured according to ISO3369.

EOS Aluminium AlF357 for EOS M 400
Mechanical Properties

Mechanical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	250	390	5	111
Horizontal	255	370	8	84



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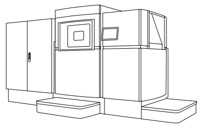
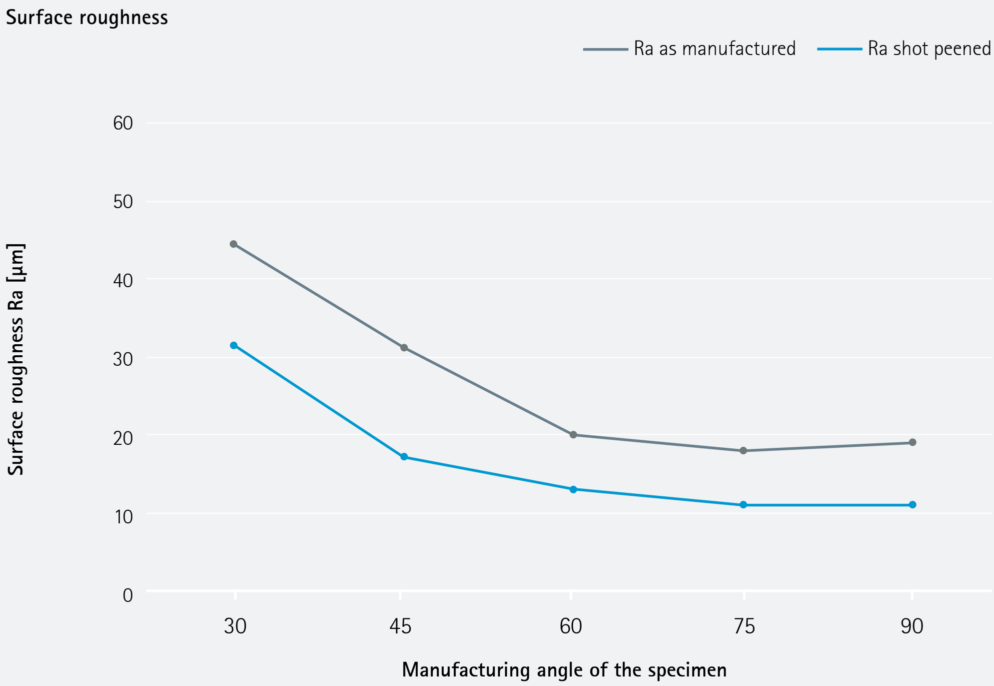
Mechanical properties (heat treated state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	265	330	11.5	56
Horizontal	270	340	11.5	28



Additional Data



The surface quality was characterized by optical profiling from down-facing surfaces according to internal procedure. The 90 degree angle corresponds to vertical surface.

AlF357 thermal and electrical conductivity

Typical values for F357	Thermal conductivity as built W/m·K	Thermal conductivity T6 W/m·K	Electrical conductivity as built % IACS	Electrical conductivity T6 % IACS
Horizontal	140	150	28-36	35-40
Vertical	140	150		

Thermal conductivity measured according to ISO 22007-2, Hot Disk slab method (xy-plane) and Hot Disk 1D-method (Z-direction). Electrical conductivity measured according to ASTM E1004 Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy Current) Method.

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Status 02/2020 (V2.0, CR689, 2019-07)

Cover: This image shows a possible application.

The quoted values refer to the use of this material with above specified type of EOS DMLS system, EOSYSTEM and EOSPRINT 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. EOS does not warrant any properties or fitness for a specific purpose, unless explicitly agreed upon. This also applies regarding any rights of protection as well as laws and regulations.

Metal
Solutions

EOS Aluminium AlSi10Mg
Material Data Sheet

EOS Aluminium AlSi10Mg
Good Strength & Dynamic Load Bearing Capacity

EOS Aluminium AlSi10Mg is a widely used alloy that combines light weight and good mechanical properties. Different heat treatments can be applied to modify properties for example to increase ductility and conductivity. The material has good thermal and electrical conductivity especially after heat treatment. In addition, gas tight parts can be manufactured with EOS Aluminium AlSi10Mg.

Main Characteristics:

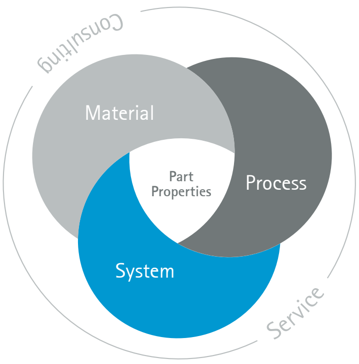
- → Good strength, hardness and dynamic properties
- → High corrosion resistance
- → Good thermal and electrical conductivity
- → Properties can be modified with heat treatments

Typical Applications:

- → General engineering components and parts subject to high loads
- → Lightweight designs
- → Aerospace and automotive components
- → Substitution of cast AlSi10Mg parts

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process. The data resulting from each combination is assigned a Technology Readiness Level (TRL) which makes the expected performance and production capability of the solution transparent.



EOS incorporates these TRLs into the following two categories:

- → Premium products (TRL 7-9): offer highly validated data, proven capability and reproducible part properties.
- → Core products (TRL 3 and 5): enable early customer access to newest technology still under development and are therefore less mature with less data.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

The chemical composition of the EOS Aluminium AlSi10Mg powder is in compliance with the DIN EN 1706 (EN AC–43000) standard.

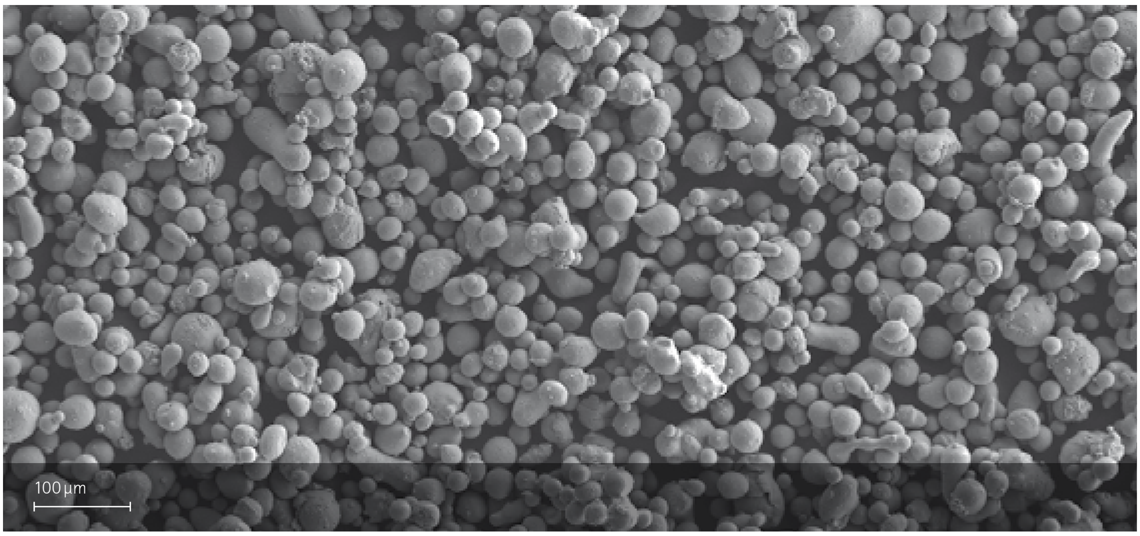
Powder chemical composition (wt.-%)

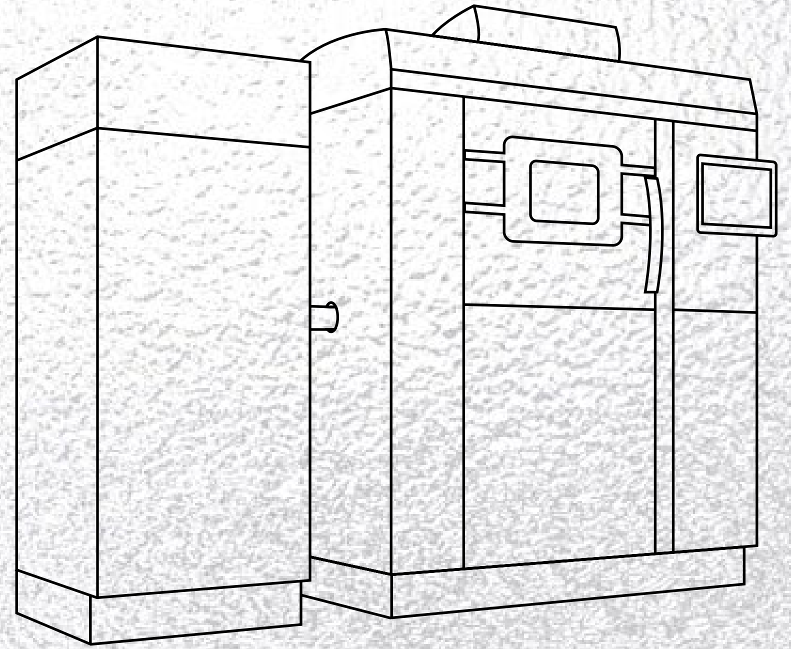
Element	Min.	Max.
Al	Balance	
Si	9.0	11.0
Fe	-	0.55
Cu	-	0.05
Mn	-	0.45
Mg	0.25	0.45
Ni	-	0.05
Zn	-	0.10
Pb	-	0.05
Sn	-	0.05
Ti	-	0.15

Powder particle size

Generic particle size distribution	25 - 70 µm

SEM image of EOS Aluminium AlSi10Mg powder.





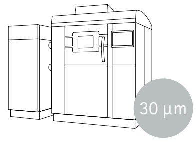
EOS Aluminium AlSi10Mg
for EOS M 290 | 30 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

CR774

EOS Aluminium AlSi10Mg for EOS M 290 | 30 µm

Process Information



High performance process with smooth and shiny surfaces. Process is developed to have high density with smooth vertical surfaces. T6 heat treatment enables excellent elongation with moderate strength and reduced anisotropy.

Main Characteristics:

- → Good mechanical properties and low amount of defects.
- → Shiny and smooth surfaces on vertical areas.
- → Mechanical properties can be modified with heat treatment.

System set-up	EOS M 290
EOS MaterialSet	AlSi10Mg_FlexM291 2.01
Software requirements	EOSPRINT 1.6 or newer EOSYSTEM 2.4 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS blade
Build platform temperature	35 °C
Nozzle	EOS standard nozzle
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	30 µm
Volume rate	5.1 mm³/s
Minimum wall thickness	0.4 mm

Increasing build platform temperature can improve buildability but build platform temperatures >100 °C together with high energy input from laser may lead to aging / overaging of parts and thus a change in mechanical properties. This risk is relevant in builds with long duration and when heat conductivity from parts is reduced due to light support structures.

Heat Treatment

EOS T6 Heat Treatment:

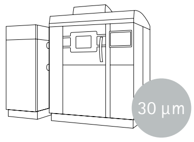
EOS has developed an AM optimized heat treatment procedure that is 40 % shorter than conventional T6 heat treatment procedures.
Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.
Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties.
For complex and massive parts uniform heating and cooling needs to be arranged.
EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).
An increase in porosity due to heat treatment is possible.
A more detailed description of heat treatment is available upon request.

Solution Annealing:

30 minutes in 530 °C followed by immediate quenching to water.

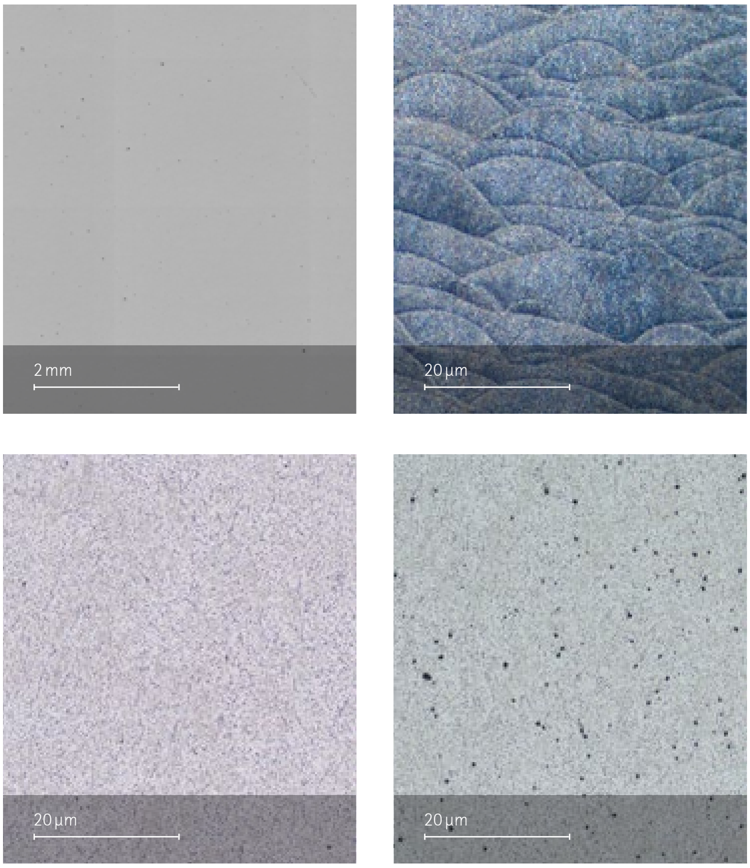
Aging:

Artificial aging of 6 hours in 165 °C followed by cooling in air.



Physical Part Properties

The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.

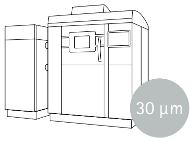


Microstructure images in the top row are as manufactured and as manufactured plus etched. Those in the bottom row are heat treated and heat treated plus etched.
Etched according to internal procedure using Groesbeck reagent.

Microstructure of the produced parts

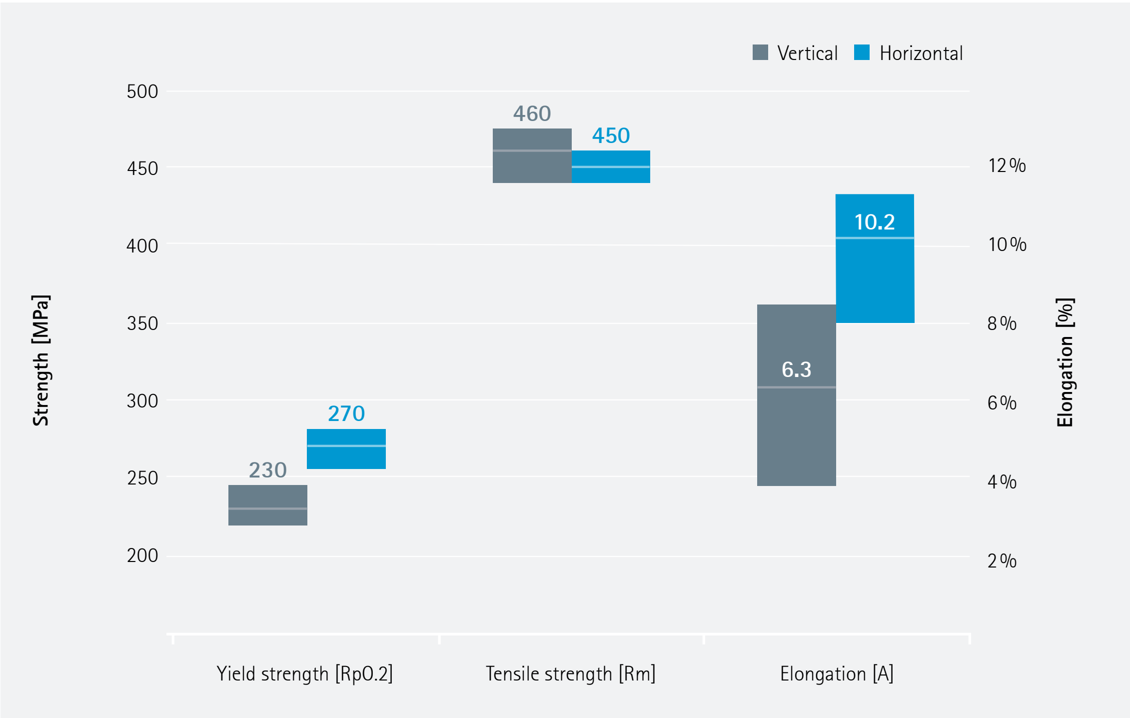
Defects	Result	Number of samples
Average defect percentage as manufactured	0.04 %	45
Average defect percentage after EOS T6 HT	0.1 - 0.2 %	-
Density ISO 3369	**Result**	**Number of samples**
Average density	≥ 2.67 g/cm³	34

Mechanical Properties



Mechanical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	230	460	6.3	261
Horizontal	270	450	10.2	108



The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

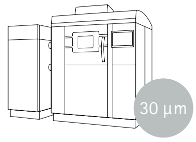
Typical mechanical properties (heat treated state, EOS T6)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	250	310	11	42
Horizontal	260	320	11	36

In case higher build platform temperature is used it is strongly advised to perform EOS T6 heat treatment in order to obtain mechanical properties similar to those stated in the MDS.

In case stress relieving of parts is needed prior to removal from build platform, EOS recommends SR HT: 90 minutes @ 270 °C.
Typical properties obtained after SR: YS 200 MPa; TS 310 MPa; elongation 9 %.

EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relieve heat treatment).



Additional Data

Thermal conductivity

Thermal conductivity (ISO 22007-2:2015)

Typical values	as manufactured [W/m·K]	EOS T6 [W/m·K]	stress-relieved [W/m·K]
Vertical	100	165	160
Horizontal	110	155	165

Electrical conductivity

Electrical conductivity (ASTM E1004)

Typical values	as manufactured [% IACS]	EOS T6 [% IACS]	stress-relieved [% IACS]
Horizontal	25	44	44

Fatigue strength

Typical lower limit of fatigue strength

[MPa] as manufactured	110

Method:
HCF, ASTM E466-15, 20 million cycles, fully reversed

High cycle fatigue testing performed on machined vertical and horizontal samples. No heat treatment.

Aluminum alloys do not have fatigue limit. Actual fatigue values depend on sample geometry and specially surface finish.

Coefficient of thermal expansion

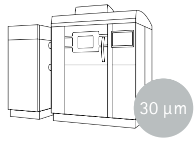
Coefficient of thermal expansion

Standard			ASTM E228
Temperature	25-100 °C	25-200 °C	25-300 °C
CTE	$20*10^{-6}$/K	$22*10^{-6}$/K	$27*10^{-6}$/K

Gas tightness

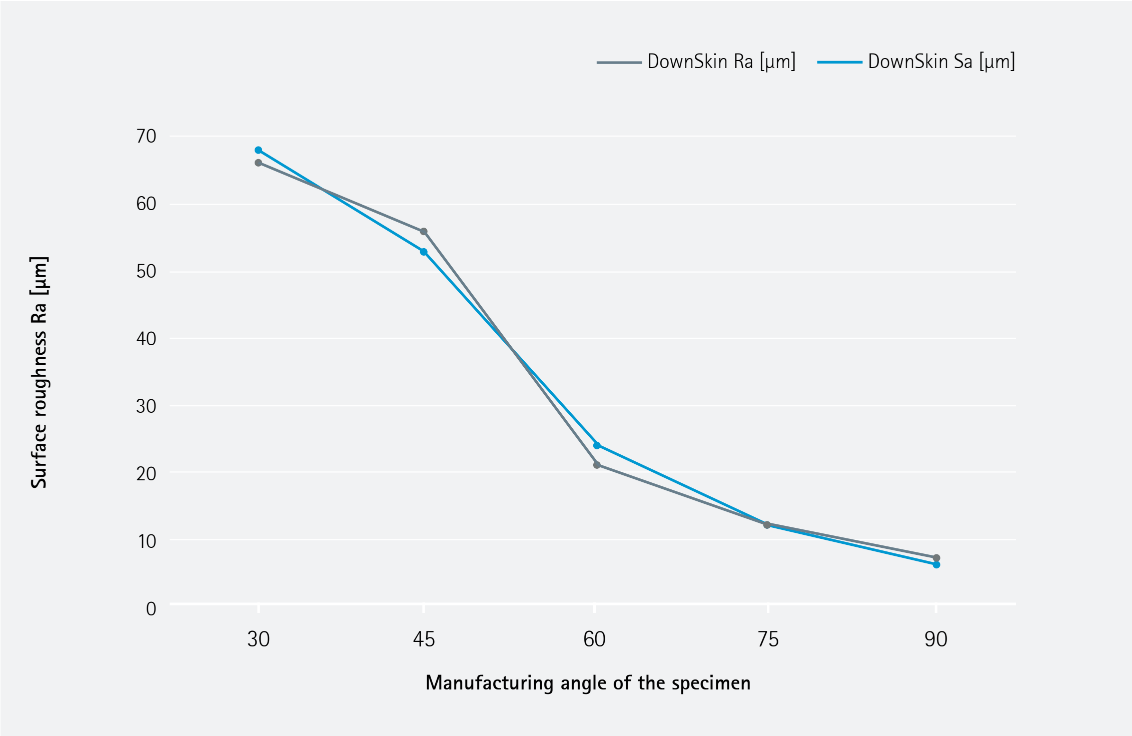
Typical lower limit of fatigue strength

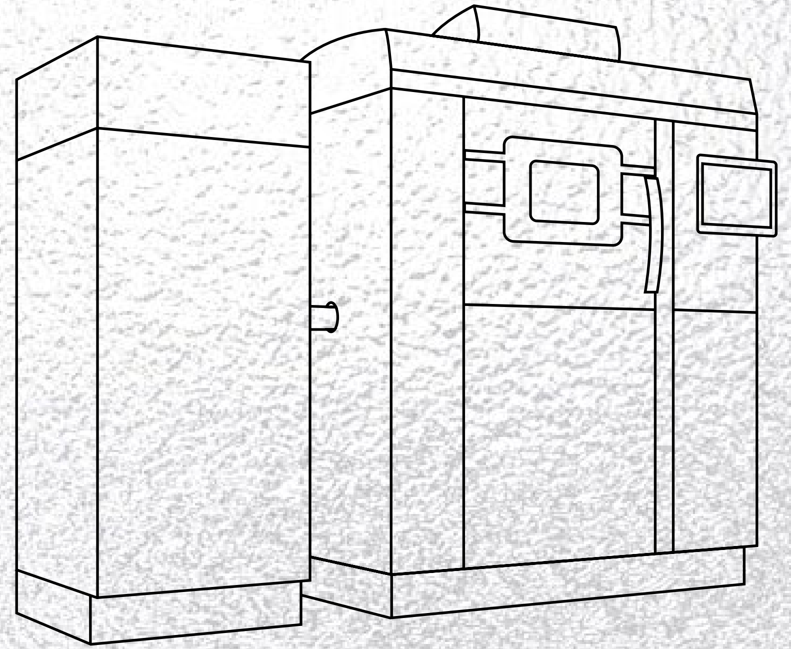
Standard	EN 13185:2001
Typical leak level	10^{-6} mbar l/s



Additional Data

Surface roughness as manufactured



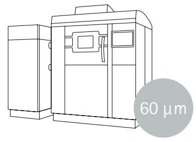


EOS Aluminium AlSi10Mg
for EOS M 290 | 60 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

CR774

EOS Aluminium AlSi10Mg for EOS M 290 | 60 µm
Process Information



Higher productivity process can be used where mechanical requirements are less demanding but where cost-efficiency is needed. The 60 µm EOS M 290 process has high resolution of fine features and buildabilty of thin walls.

Heat treatment can be used to affect mechanical properties.

Main Characteristics:

- → Increased productivity of aluminum parts with EOS M 290
- → Good mechanical properties
- → Good buildability of challenging geometries

System set-up	EOS M 290
EOS MaterialSet	AlSi10Mg_060_CoreM291 1.00
Software requirements	EOSPRINT 2.6 or newer EOSYSTEM 2.6 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS blade
Build platform temperature	100 °C
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	90 µm

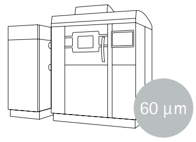
Additional information	
Layer thickness	60 µm
Volume rate	10.5 mm³/s

Heat Treatment

EOS T6 Heat Treatment:
EOS has developed an AM optimized heat treatment procedure that is 40 % shorter than conventional T6 heat treatment procedures.
Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.
Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties. For complex and massive parts uniform heating and cooling needs to be arranged.
EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).
An increase in porosity due to heat treatment is possible.
A more detailed description of heat treatment is available upon request.

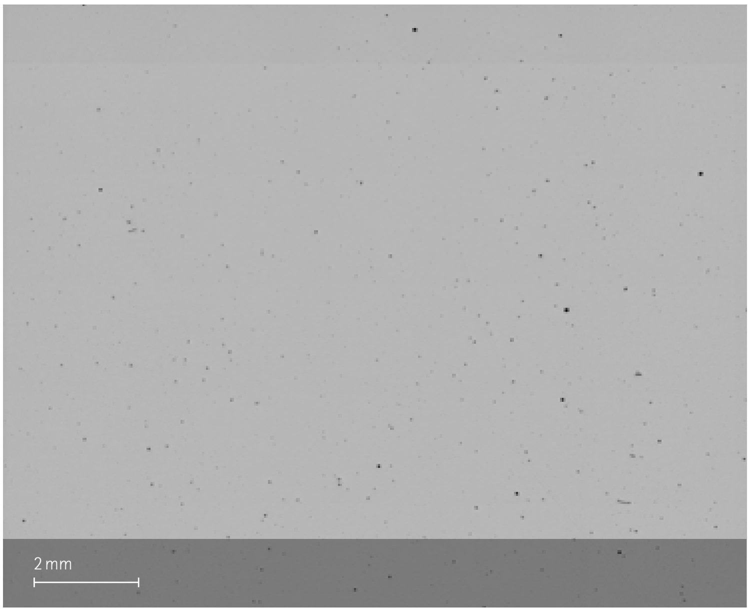
Solution Annealing:
30 minutes in 530 °C followed by immediate quenching to water.

Aging:
Artificial aging of 6 hours in 165 °C followed by cooling in air.



Physical Part Properties

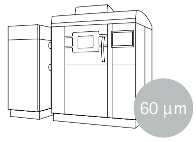
The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.



Microstructure as manufactured.

Microstructure of the produced parts (as manufactured state)

Defects	**Result**
Average defect percentage	0.2 %
Density ISO 3369	**Result**
Average density	≥ 2.66 g/cm³



Mechanical Properties

Typical properties (as manufactured state)

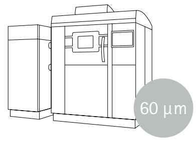
	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	240	440	4
Horizontal	250	440	7

The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

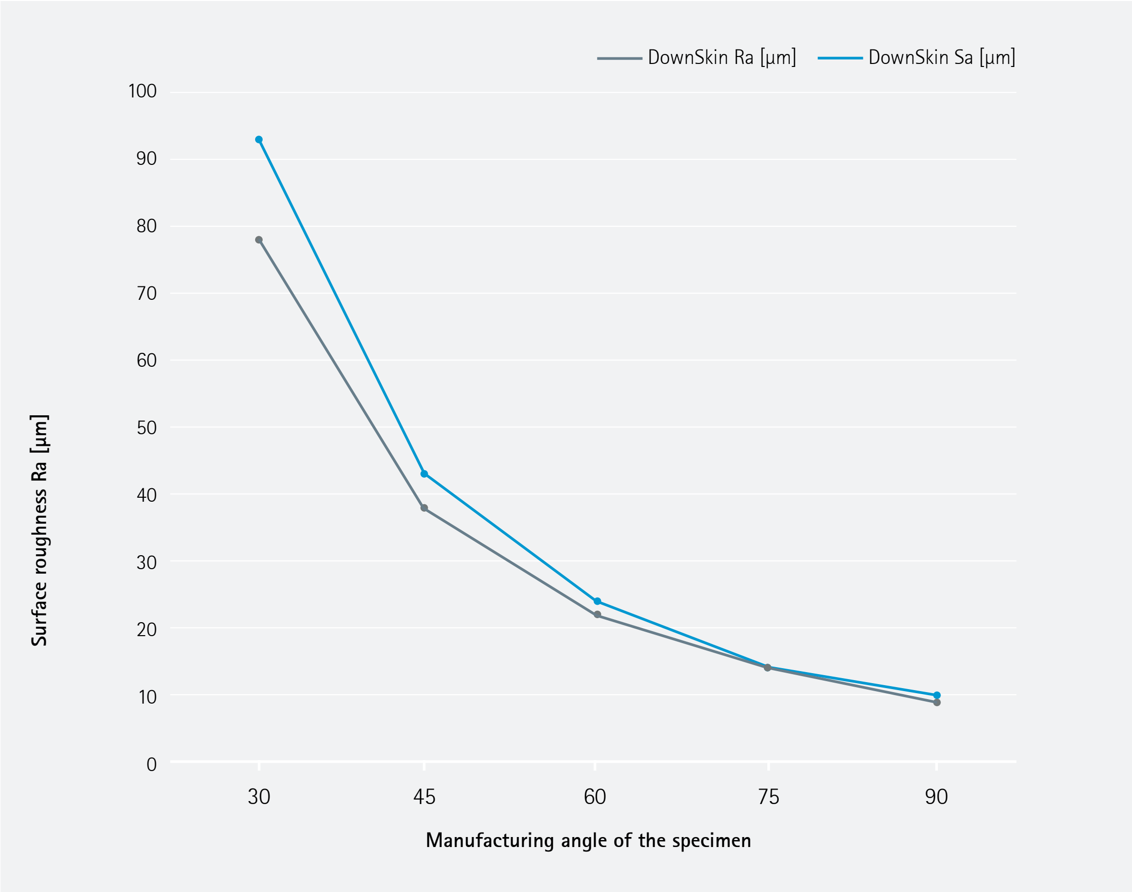
Typical mechanical properties (heat treated state, EOS T6)

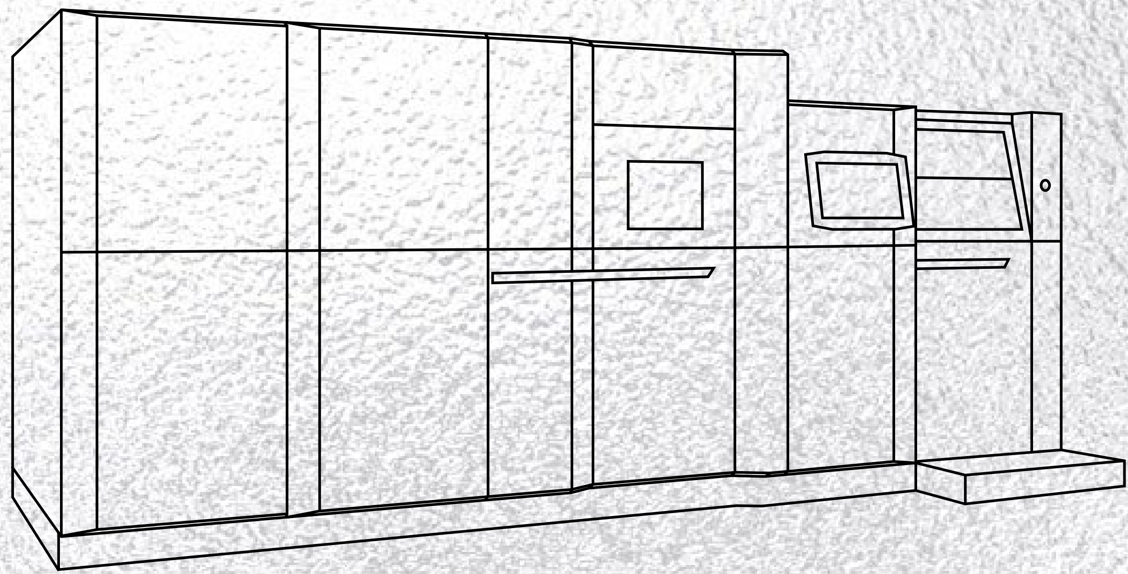
	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	250	320	8
Horizontal	260	320	9

Additional Data



Surface roughness as manufactured





EOS Core

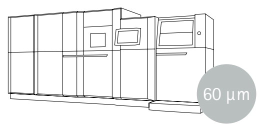
EOS Aluminium AlSi10Mg
for EOS M 300-4 | 60 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties

CR774

EOS Aluminium AlSi10Mg for EOS M 300-4 | 60 µm

Process Information



Process consists of high productivity and good mechanical properties.

Main Characteristics:

- → Good mechanical properties and high productivity combined
- → Heat treatment can be used to affect mechanical properties

System set-up	EOS M 300-4
EOS MaterialSet	AlSi10Mg_060_M304 1.00
Software requirements	EOSPRINT 2.8 or newer EOSYSTEM 2.12 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS blade, 2-sided recoating
Build platform temperature	165 °C
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	60 µm
Volume rate	up to 4 x 10.5 mm³/s

Heat Treatment

EOS T6 Heat Treatment:

EOS has developed an AM optimized heat treatment procedure that is 40 % shorter than conventional T6 heat treatment procedures.

Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.

Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties.

For complex and massive parts uniform heating and cooling needs to be arranged.

EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).

An increase in porosity due to heat treatment is possible.

A more detailed description of heat treatment is available upon request.

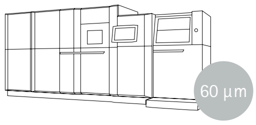
Solution Annealing:

30 minutes in 530 °C followed by immediate quenching to water.

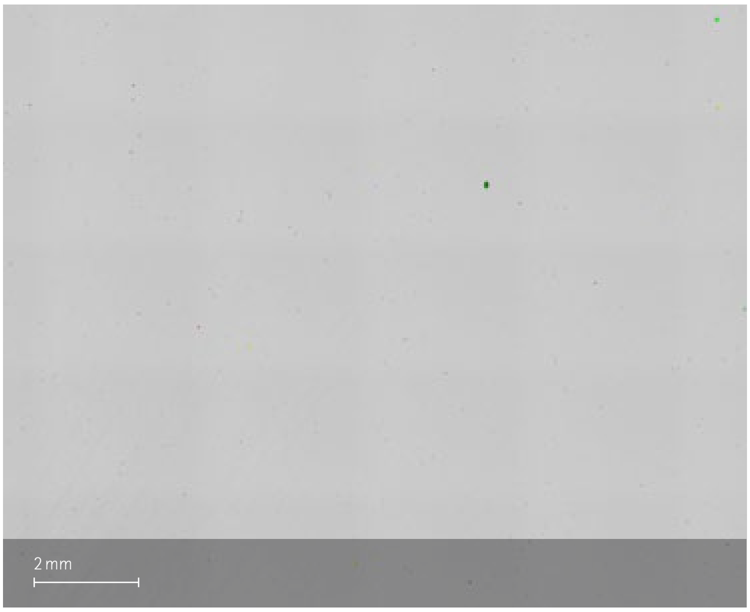
Aging:

Artificial aging of 6 hours in 165 °C followed by cooling in air.

Physical Part Properties



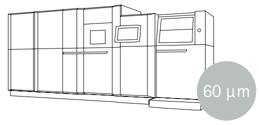
The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.



Microstructure as manufactured.

Microstructure of the produced parts (as manufactured state)

Defects	Result	Number of samples
Average defect percentage	0.08 %	16
Typical max. defect size	130 µm	16



Mechanical Properties

Typical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	210	340	4	160
Horizontal	225	375	7	63

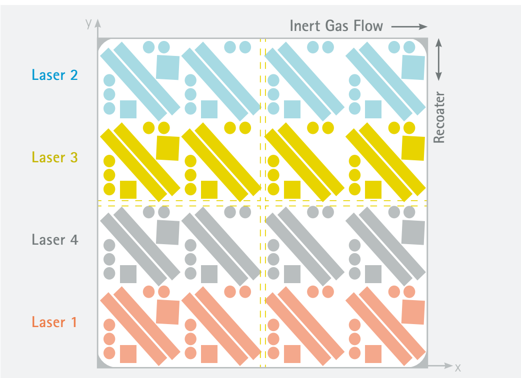
The testing was done according to EN ISO 6892-1 B10. Machined (turned) samples were used. The values in the table are average values and dependent on the build platform temperature, the thermal load of the job layout as well as the position on the build plate.

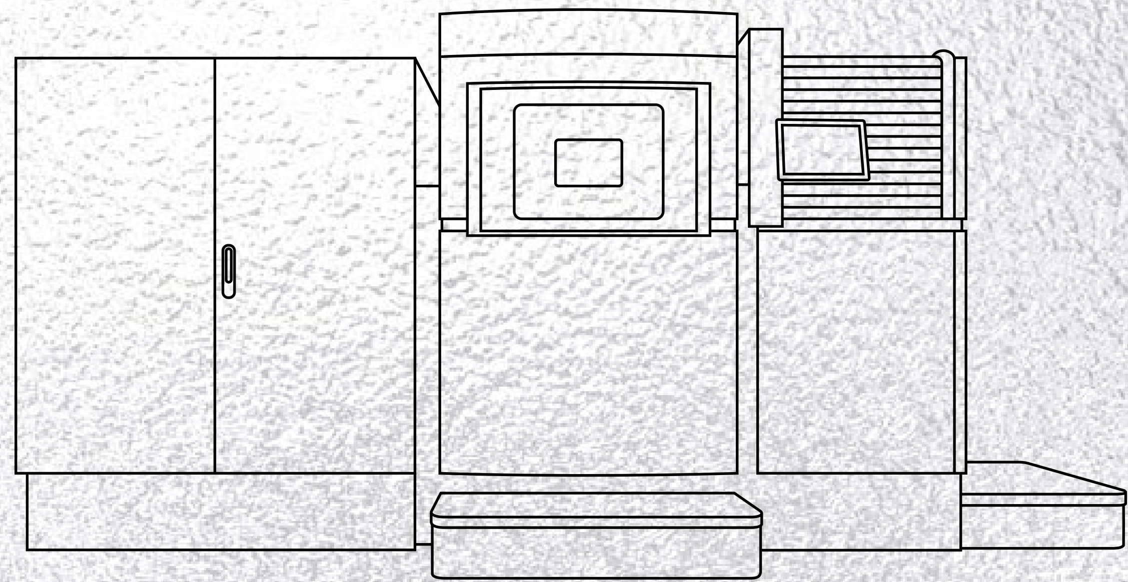
Typical properties (heat treated state, EOS T6)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	250	320	11	160
Horizontal	225	375	11	64

Layout of test job

Part properties based on one test job each for the as manufactured and heat treated data.





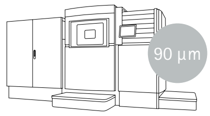
EOS Aluminium AlSi10Mg
for EOS M 400 | 90 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties

CR774

EOS Aluminium AlSi10Mg for EOS M 400 | 90 µm

Process Information



High productivity process with moderate mechanical properties. EOS T6 heat treatment is recommended for parts where higher elongation properties are required.

Main Characteristics:

- → High productivity
- → Moderate mechanical properties
- → Good buildability with uniform surface roughness

System set-up	EOS M 400
EOS MaterialSet	AlSi10Mg_090_FlexM400 1.01
Software requirements	EOSPRINT 2.6 or newer EOSYSTEM 2.6 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS or soft
Build platform temperature	165 °C
Inert gas	Nitrogen
Sieve	90 µm

Additional information	
Layer thickness	90 µm
Volume rate	27.8 mm^3/s

Heat Treatment

EOS T6 Heat Treatment:

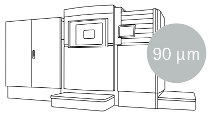
EOS has developed an AM optimized heat treatment procedure that is 40% shorter than conventional T6 heat treatment procedures.
Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.
Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties. For complex and massive parts uniform heating and cooling needs to be arranged.
EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).
An increase in porosity due to heat treatment is possible.
A more detailed description of heat treatment is available upon request.

Solution Annealing:

30 minutes in 530 °C followed by immediate quenching to water.

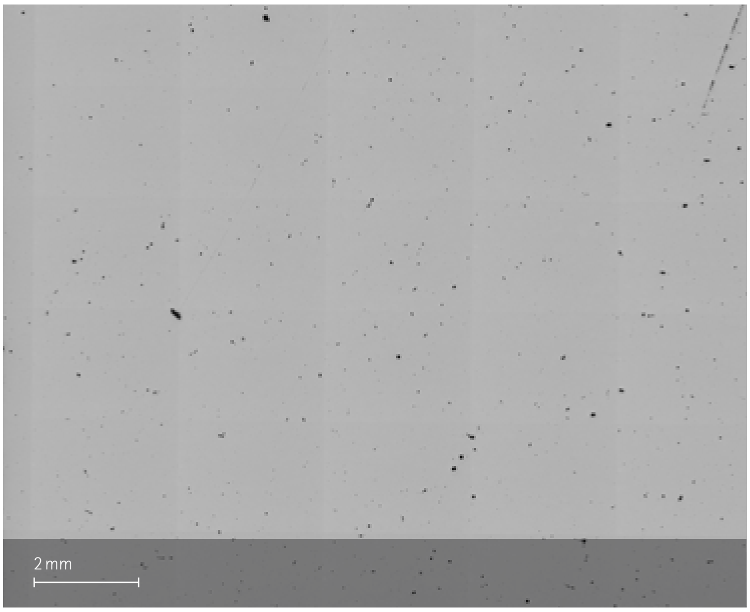
Aging:

Artificial aging of 6 hours in 165 °C followed by cooling in air.



Physical Part Properties

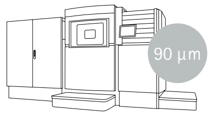
The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.



Microstructure as manufactured.

Microstructure of the produced parts (as manufactured state)

Defects	**Result**	Number of samples
Average defect percentage	0.2 %	27
Density ISO 3369	**Result**	Number of samples
Average density	≥ 2.65 g/cm³	25



Mechanical Properties

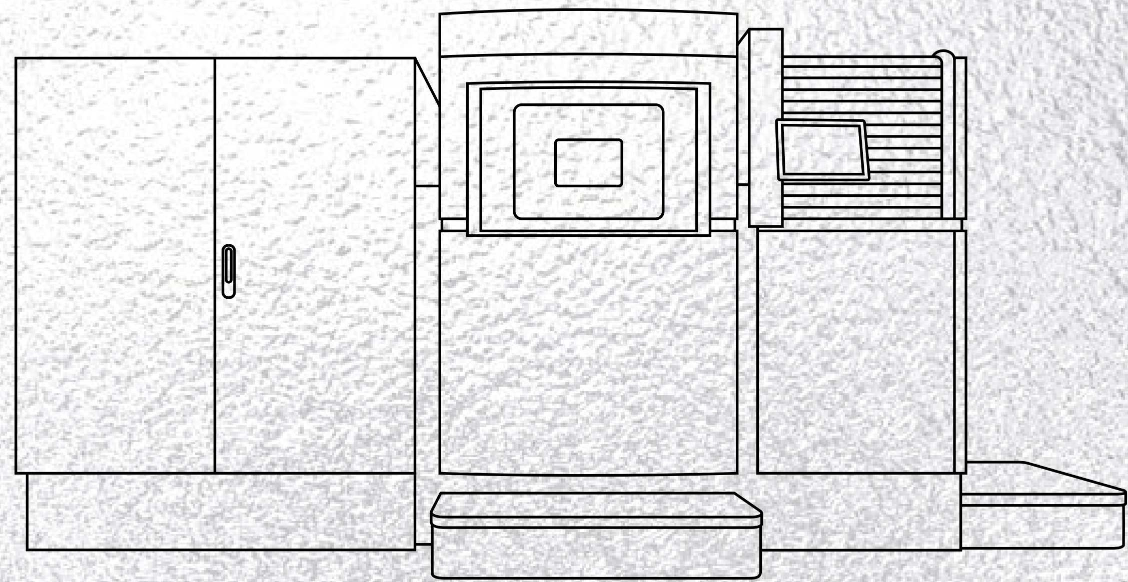
Typical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	240	380	2
Horizontal	260	400	3

The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

Typical properties (heat treated state, EOS T6)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	230	300	5
Horizontal	230	300	5

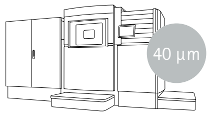


EOS Aluminium AlSi10Mg
for EOS M 400-4 | 40 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

CR774

EOS Aluminium AlSi10Mg for EOS M 400-4 | 40 µm
Process Information



High performance process with optimized quality and productivity. Good buildability with low surface roughness. EOS T6 heat treatment is recommended for parts where higher elongation properties are required.

Main Characteristics:

- → High performance AlSi10Mg process for EOS M 400-4
- → Optimized combination of mechanical properties and productivity
- → Two-sided recoating reduces building time

System set-up	EOS M 400-4
EOS MaterialSet	AlSi10MgAr_040_CoreM404 1.00
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.10 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS or soft
Build platform temperature ter blade	35 °C
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	40 µm
Volume rate	4 x 7.0 mm³/s
Minimum wall thickness	0.3 mm

Increasing build platform temperature can improve buildability but build platform temperatures >100 °C together with high energy input from laser may lead to aging / overaging of parts and thus a change in mechanical properties. This risk is relevant in builds with long duration and when heat conductivity from parts is reduced due to light support structures.

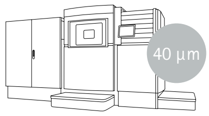
Heat Treatment

EOS T6 Heat Treatment:
EOS has developed an AM optimized heat treatment procedure that is 40% shorter than conventional T6 heat treatment procedures.
Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.
Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties. For complex and massive parts uniform heating and cooling needs to be arranged.
EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).
An increase in porosity due to heat treatment is possible.
A more detailed description of heat treatment is available upon request.

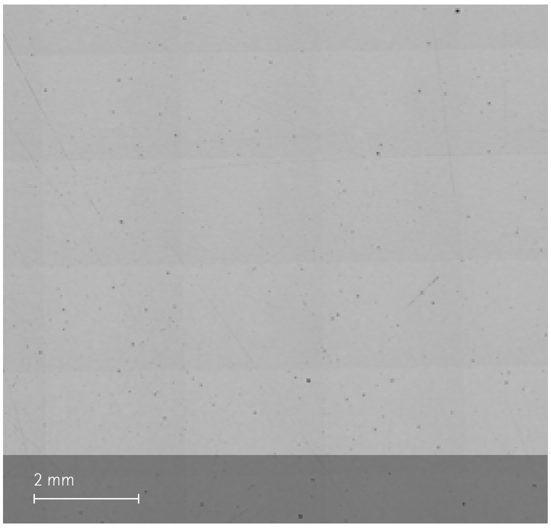
Solution Annealing:
30 minutes in 530 °C followed by immediate quenching to water.

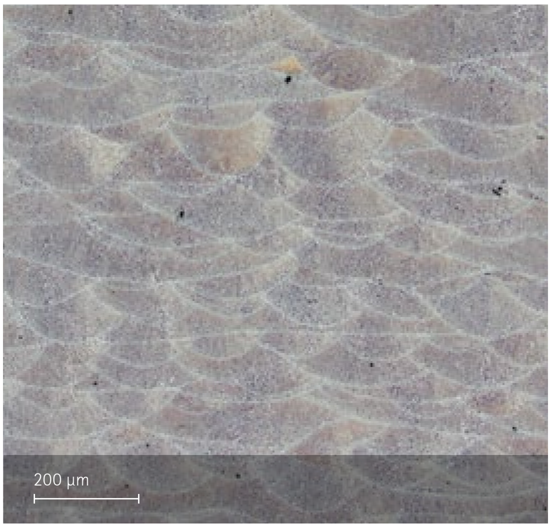
Aging:
Artificial aging of 6 hours in 165 °C followed by cooling in air.

Physical Part Properties



The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.

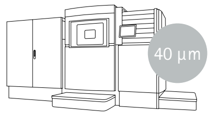




Microstructure from left to right are as manufactured and as manufactured plus etched.

Microstructure of the produced parts (as manufactured state)

Defects	Result
Average defect percentage	< 0.1 %
Density ISO 3369	**Result**
Average density	≥ 2.67 g/cm³



Mechanical Properties

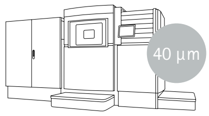
Typical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	**Tensile strength** Rm [MPa]	**Elongation at break** A [%]
Vertical	230	450	5
Horizontal	250	440	8

The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

Typical properties (heat treated state, EOS T6)

	Yield strength Rp0.2 [MPa]	**Tensile strength** Rm [MPa]	**Elongation at break** A [%]
Vertical	230	300	10
Horizontal	250	300	10



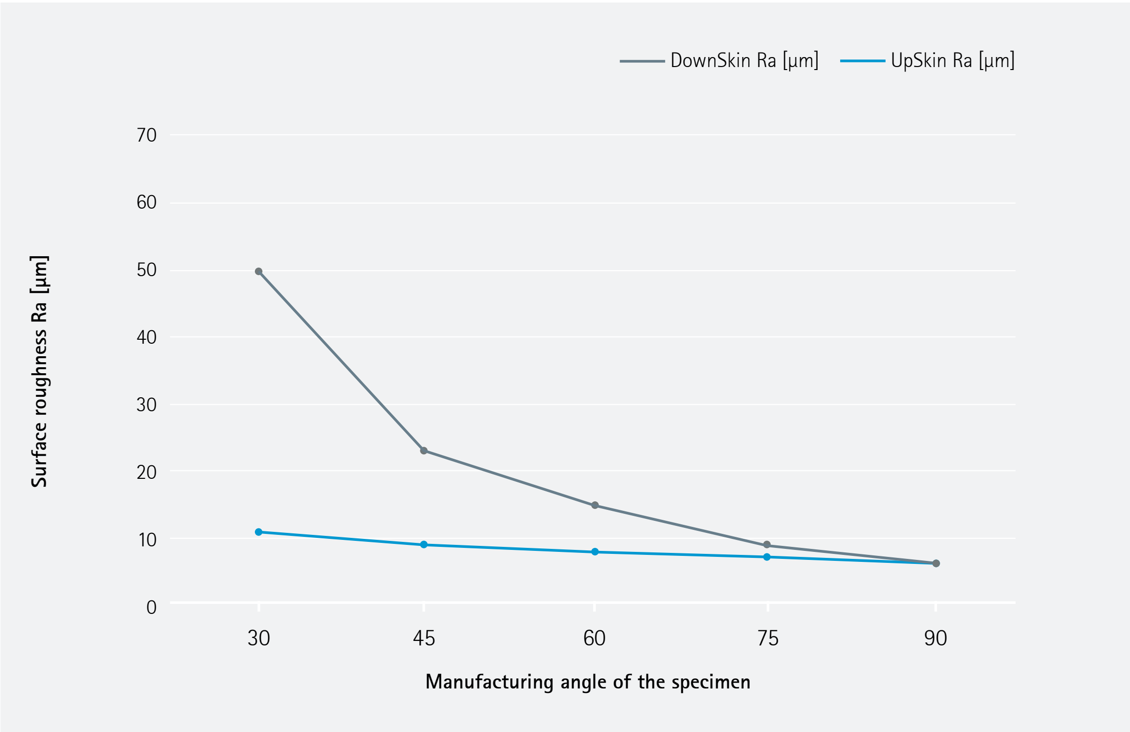
Additional Data

Lower limit of fatigue strength	
[MPa] as manufactured	110

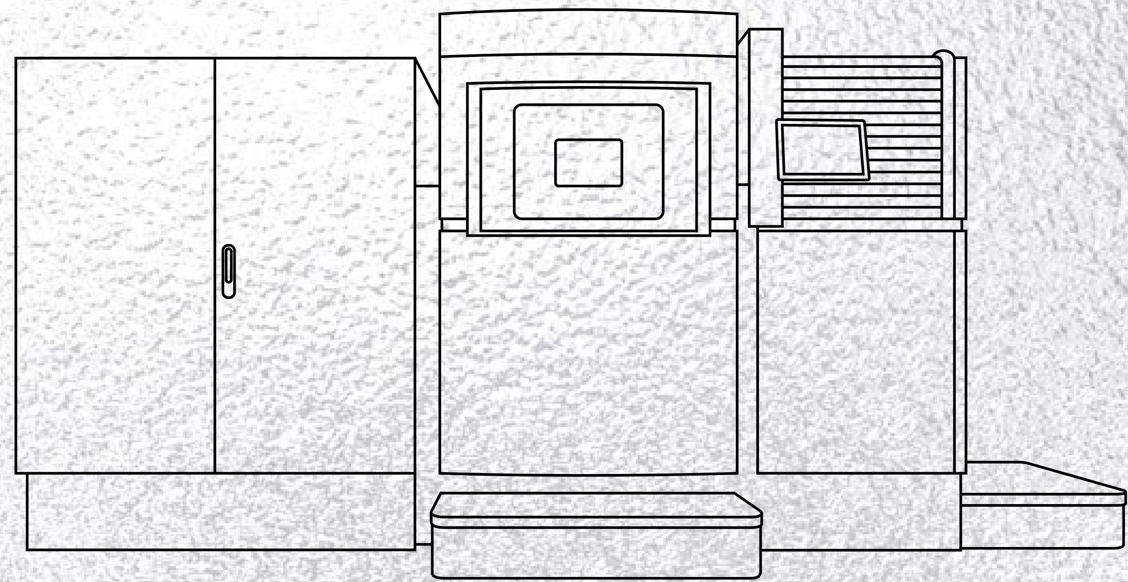
Method:
HCF, ASTM E466-15, 10 million cycles, fully reversed

Aluminum alloys do not have fatigue limit. Actual fatigue values depend on sample geometry and specially surface finish.

Surface roughness as manufactured



TRL 5
EOS Core



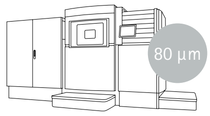
EOS Aluminium AlSi10Mg
for EOS M 400-4 | 80 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties

CR774

EOS Aluminium AlSi10Mg for EOS M 400-4 | 80 µm

Process Information



This process parameter is developed specifically for fast and cost-efficient production of aluminum parts with similar mechanical properties as conventionally produced casting parts. EOS T6 heat treatment is recommended for parts where higher elongation properties are required.

Main Characteristics:

- Highest productivity of aluminum parts on the EOS M 400-4: Up to 261 cm^3/h build rate
- Excellent buildability for challenging parts
- Two different parameter set options available for surface exposure

System set-up	EOS M 400-4
EOS MaterialSet	AlSi10Mg_080_HiProM404 1.00
Software requirements	EOSPRINT 2.6 or newer EOSYSTEM 2.10 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS or soft
Build platform temperature	165 °C
Inert gas	Nitrogen
Sieve	90 µm

Additional information	
Layer thickness	80 µm
Volume rate	4 x 18.1 mm^3/s
Minimum wall thickness	0.4 mm
Surface roughness	R_a = 15 µm

Heat Treatment

EOS T6 Heat Treatment:

EOS has developed an AM optimized heat treatment procedure that is 40 % shorter than conventional T6 heat treatment procedures.

Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.

Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties.

For complex and massive parts uniform heating and cooling needs to be arranged.

EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).

An increase in porosity due to heat treatment is possible.

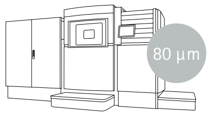
A more detailed description of heat treatment is available upon request.

Solution Annealing:

30 minutes in 530 °C followed by immediate quenching to water.

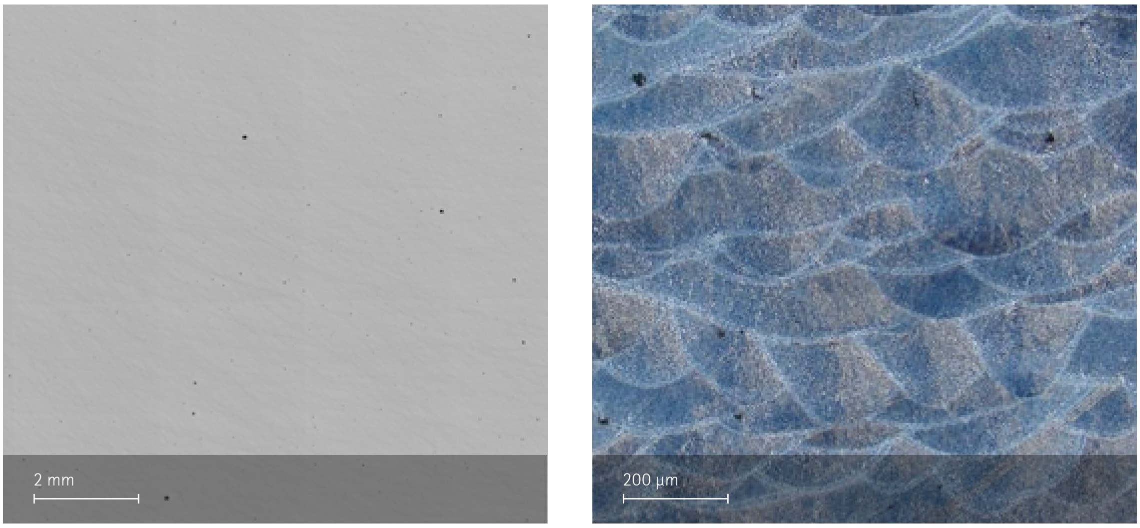
Aging:

Artificial aging of 6 hours in 165 °C followed by cooling in air.



Physical Part Properties

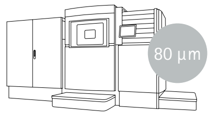
The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.



Microstructure from left to right are as manufactured and as manufactured plus etched.

Microstructure of the produced parts (as manufactured state)

Defects	**Result**
Average defect percentage	0.3 %
Density ISO 3369	**Result**
Average density	≥ 2.65 g/cm^3



Mechanical Properties

Typical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	220	360	2
Horizontal	250	380	2

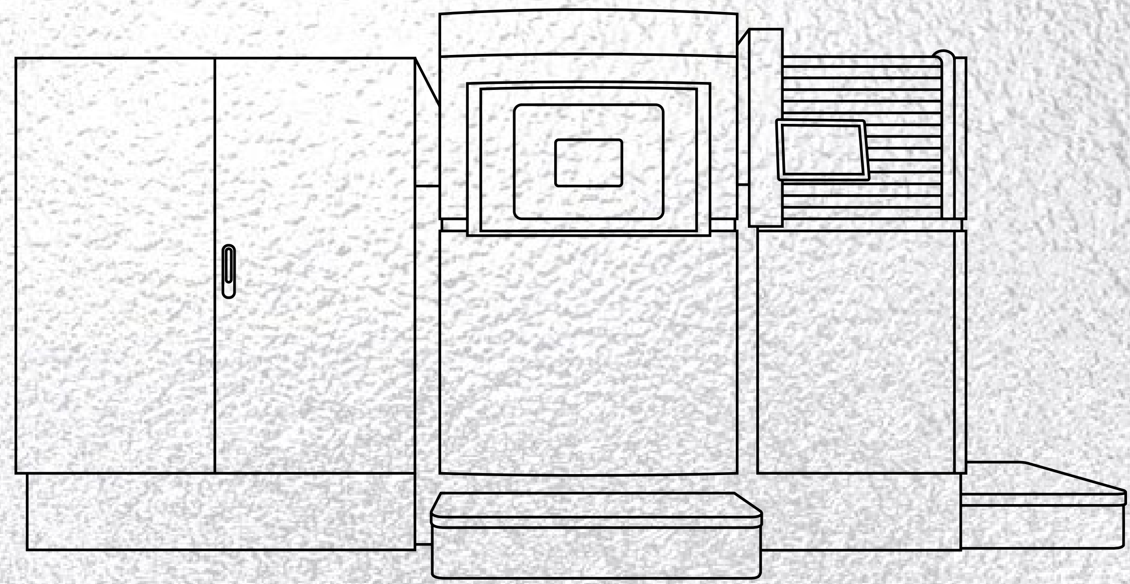
The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

Typical properties (heat treated state, EOS T6)

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Vertical	210	300	6
Horizontal	220	310	8

TRL 3

EOS Core



EOS Aluminium AlSi10Mg
for EOS M 400-4 | 30 µm

Process Information

Heat Treatment

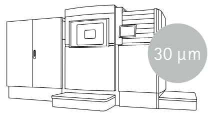
Physical Part Properties

Mechanical Properties

CR774

EOS Aluminium AlSi10Mg for EOS M 400-4 | 30 µm

Process Information



Earlier generation AlSi10Mg M400-4 process. One-sided recoating enables optimizing powder usage in larger parts.

EOS T6 heat treatment is recommended for parts where higher elongation properties are required.

System set-up	EOS M 400-4
EOS MaterialSet	AlSi10Mg_030_FlexM404 1.00
Software requirements	EOSPRINT 2.6 or newer EOSYSTEM 2.6 or newer
Powder part no.	9011-0024
Recoater blade	EOS HSS blade, one-sided recoating
Build platform temperature	165 °C
Inert gas	Nitrogen
Sieve	90 µm

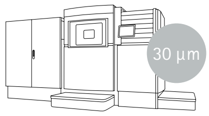
Additional information	
Layer thickness	30 µm
Volume rate	4 x 7.4 mm³/s

Heat Treatment

EOS T6 Heat Treatment:
EOS has developed an AM optimized heat treatment procedure that is 40 % shorter than conventional T6 heat treatment procedures.
Solution annealing 30 min @ 530 °C, water quench. Artificial aging 6 h @ 165 °C, cooling in air.
Parts to preheated oven. Maximum overheating 5 °C. Delay between SA and quenching maximum 30 s. Oven type & configuration may have impact on the mechanical properties.
For complex and massive parts uniform heating and cooling needs to be arranged.
EOS T6 treatment is recommended to obtain controlled mechanical properties and lower variation in mechanical values (for example in long build jobs if heat transfer from parts is limited by low amount of support and after stress relief heat treatment).
An increase in porosity due to heat treatment is possible.
A more detailed description of heat treatment is available upon request.

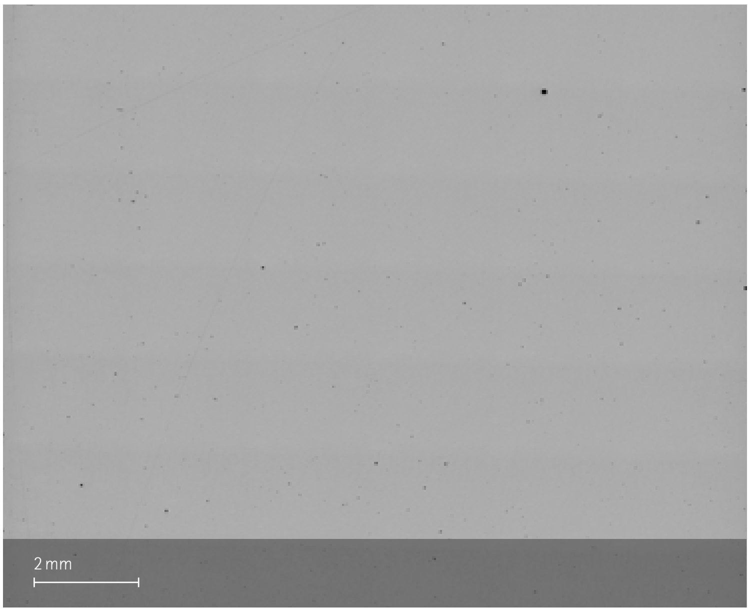
Solution Annealing:
30 minutes in 530 °C followed by immediate quenching to water.

Aging:
Artificial aging of 6 hours in 165 °C followed by cooling in air.



Physical Part Properties

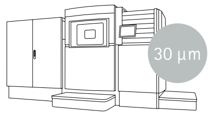
The chemical composition of the EOS Aluminium AlSi10Mg parts is in compliance with the DIN EN 1706 (EN AC–43000) standard.



Microstructure as manufactured.

Microstructure of the produced parts (as manufactured state)

Defects	**Result**
Average defect percentage	0.15 %
Density ISO 3369	**Result**
Average density	≥ 2.64 g/cm^3



Mechanical Properties

Typical properties (as manufactured state)

	Yield strength Rp0.2 [MPa]	**Tensile strength** Rm [MPa]	**Elongation at break** A [%]
Vertical	230	430	3
Horizontal	250	400	5

The testing was done according to ISO 6892-1, B10. Machined (turned) samples were used.

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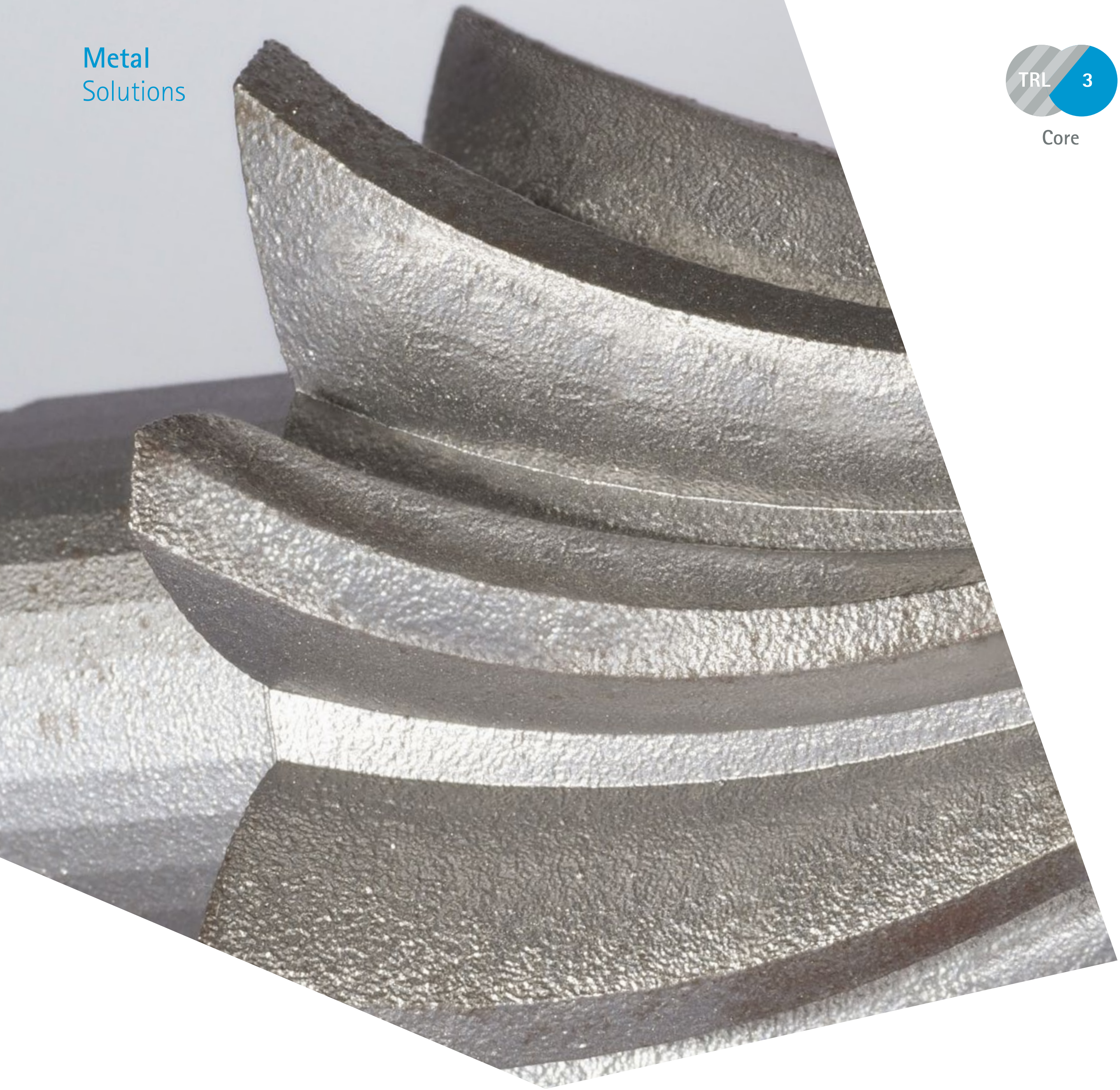
Metal
Solutions

TRL 3
Core



EOS CaseHardeningSteel 20MnCr5
Material Data Sheet

EOS CaseHardeningSteel 20MnCr5

Case hardening steel with good hardenability reaching good wear resistance due to high surface hardness after heat treatment.

Main Characteristics:

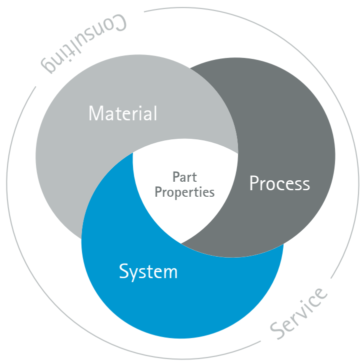
- → Good wear resistance
- → Excellent surface hardness after carburizing
- → Material according to EN-10084 alloy number 1.7147
- → Carburizable to achieve surface hardness of 60 HRC

Typical Applications:

- → Automotive and general engineering applications
- → Gears, mechanical part

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process. The data resulting from each combination is assigned a Technology Readiness Level (TRL) which makes the expected performance and production capability of the solution transparent.



EOS incorporates these TRLs into the following two categories:

- → Premium products (TRL 7-9): offer highly validated data, proven capability and reproducible part properties.
- → Core products (TRL 3 and 5): enable early customer access to newest technology still under development and are therefore less mature with less data.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

EOS CaseHardeningSteel 20MnCr5 powder material is in accordance with EN-10084 alloy number 1.7147.

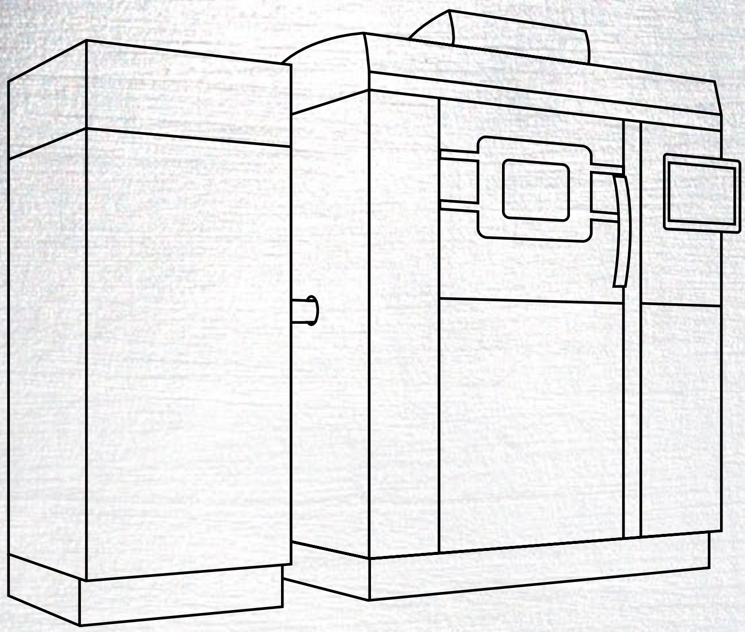
Powder chemical composition (wt.-%)

Element	Min.	Max.
Fe	Balance	
Mn	1.10	1.40
Cr	1.00	1.30
C	0.17	0.22
Si	-	0.40
S	-	0.035

Powder particle size

Generic particle size distribution	15-55 µm

TRL 3
Core



EOS CaseHardeningSteel 20MnCr5
for EOS M 290 | 40 µm

Process Information
Physical Part Properties
Heat Treatment
Additional Data

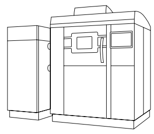
EOS CaseHardeningSteel 20MnCr5 for EOS M 290 | 40 µm

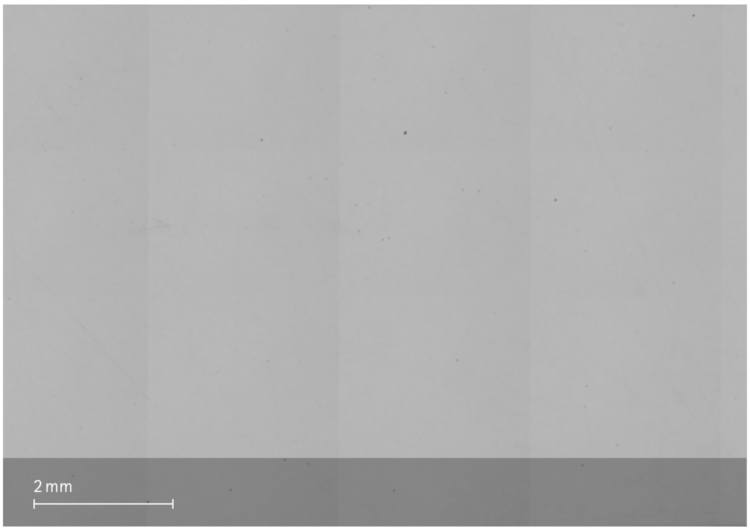
Process Information

System set-up	EOS M 290
EOS ParameterSet	20MnCr5_040_CoreM291 1.X
EOSPAR name	20MnCr5_040_CoreM291_100.eospar
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9030-0004
Recoater blade	EOS ceramic blade
Nozzle	EOS grid nozzle
Inert gas	Nitrogen
Sieve	75 µm

Additional information	
Layer thickness	40 µm
Volume rate	3.84 mm^3/s

Chemical and Physical Properties of Parts





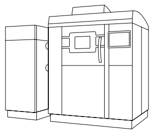
Micrograph of polished surface

Defects	Result
Porosity	< 0.5 %

Typical part properties

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
Heat treated horizontal	1 265	1 480	9
Heat treated vertical	1 265	1 480	9

Heat Treatment



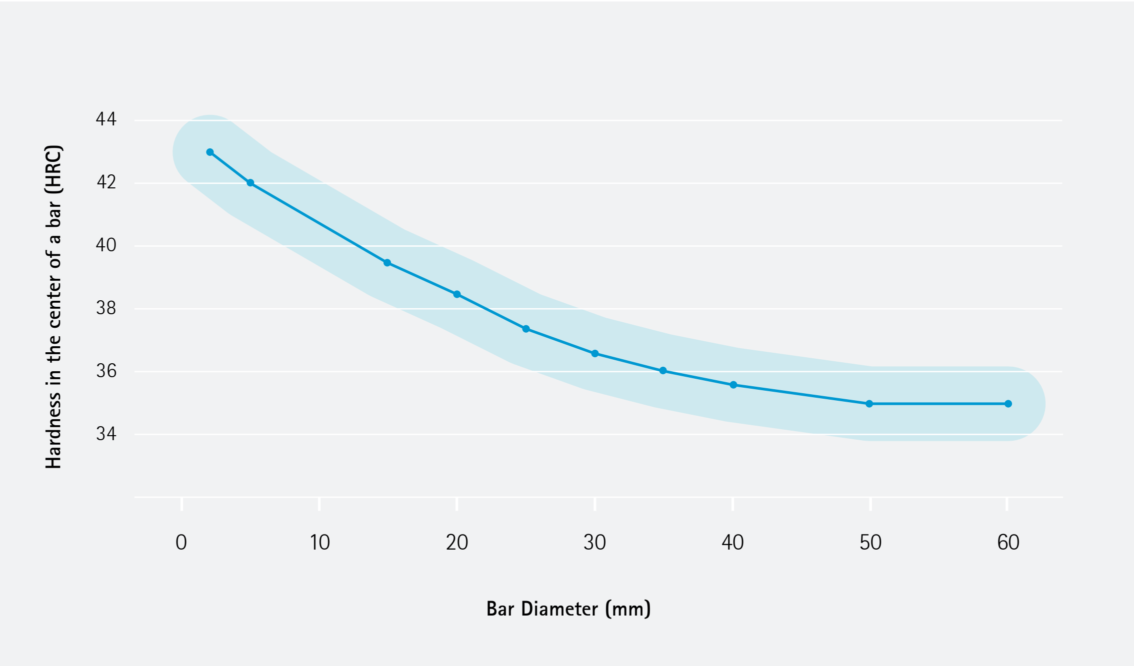
Hardening:
840 - 870 °C, hold time 30 min when thoroughly heated, water or oil quenching

Tempering:
160 - 200 °C, hold time 2 h when thoroughly heated, air cooling

Optional softening treatment:
Normalizing 870 °C, hold time 1 h when thoroughly heated, air cooling

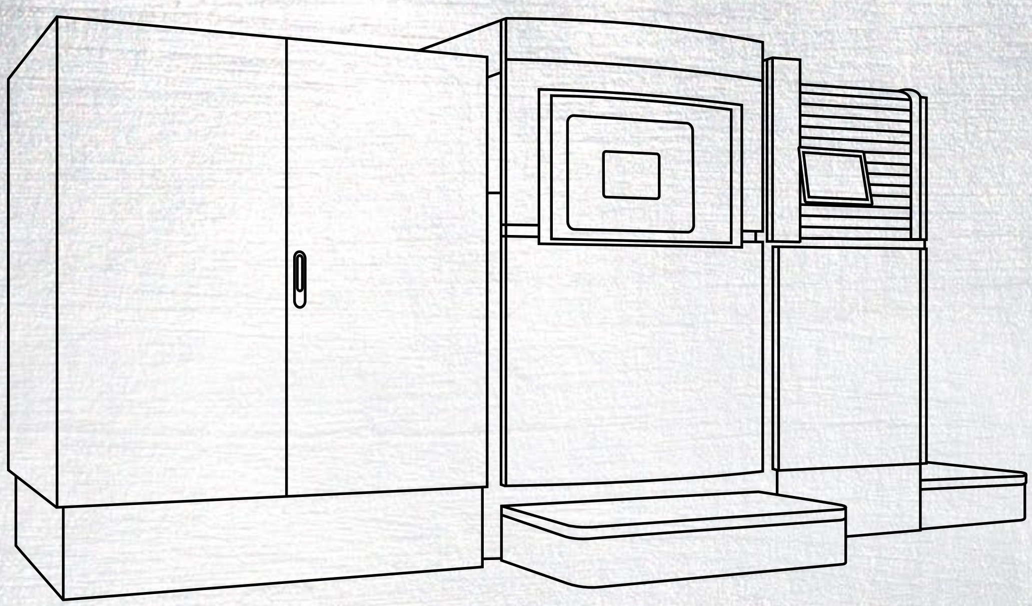
Additional Data

Hardness



Hardness in the center of a bar as a function of its diameter

TRL 3
Core



EOS CaseHardeningSteel 20MnCr5
for EOS M 400-4 | 40 µm

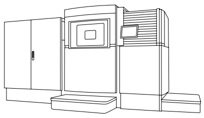
Process Information Physical
Part Properties
Heat Treatment
Additional Data

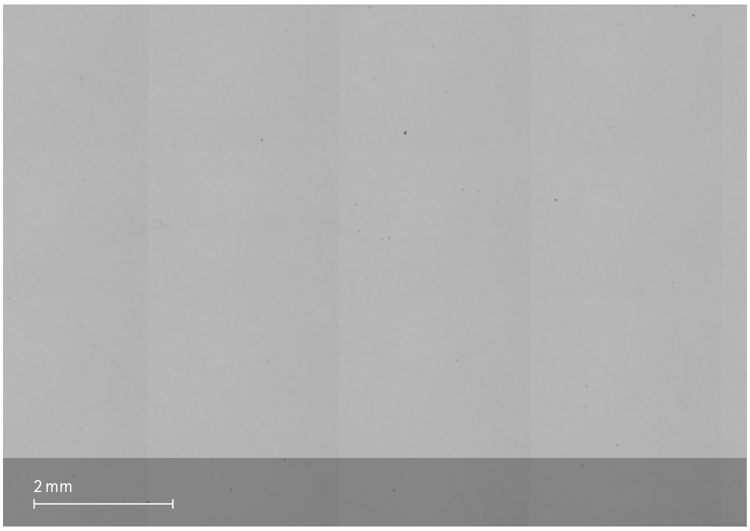
EOS CaseHardeningSteel 20MnCr5 for EOS M 400-4 | 40 µm
Process Information

System set-up	EOS M 400-4
EOS ParameterSet	20MnCr5_040_Core M404 1.X
EOSPAR name	20MnCr5_040_CoreM404_100.eospar
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9030-0004
Recoater blade	EOS ceramic blade
Inert gas	Nitrogen
Sieve	75 µm

Additional information	
Layer thickness	40 µm
Volume rate	4 x 3.84 mm^3/s

Chemical and Physical Properties of Parts





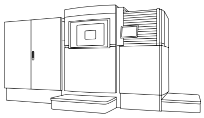
Micrograph of polished surface

Defects	Result
Porosity	< 0.5 %

Typical part properties

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
Heat treated horizontal	1 265	1 480	9
Heat treated vertical	1 265	1 480	9

Heat Treatment



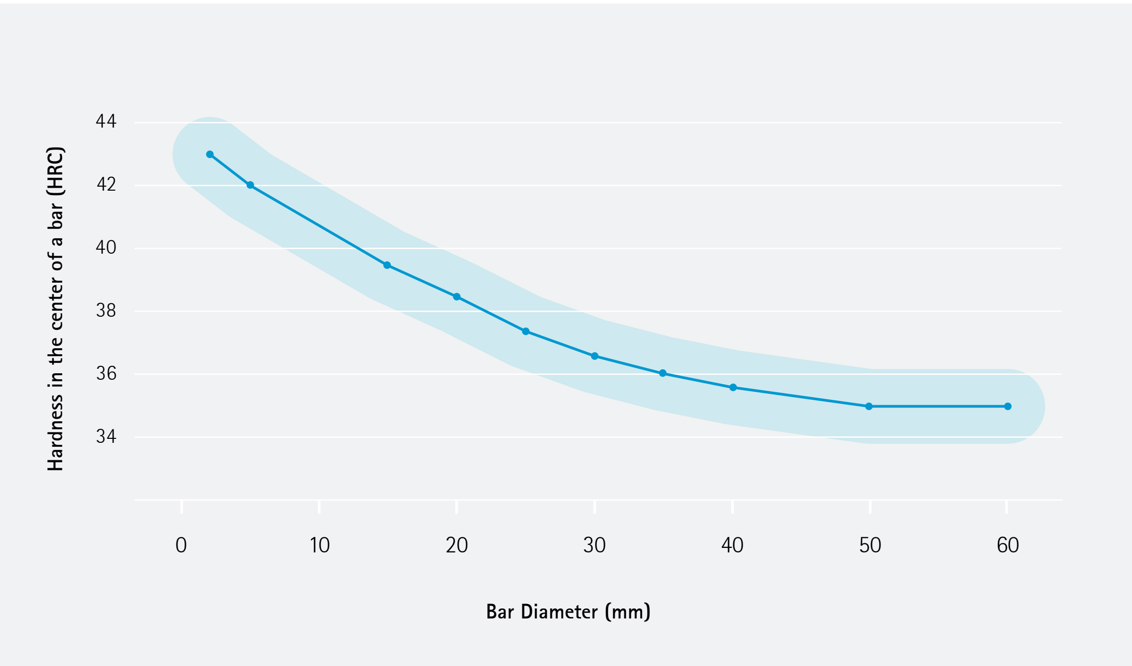
Hardening:
840 - 870 °C, hold time 30 min when thoroughly heated, water or oil quenching

Tempering:
160 - 200 °C, hold time 2 h when thoroughly heated, air cooling

Optional softening treatment:
Normalizing 870 °C, hold time 1 h when thoroughly heated, air cooling

Additional Data

Hardness



Hardness in the center of a bar as a function of its diameter

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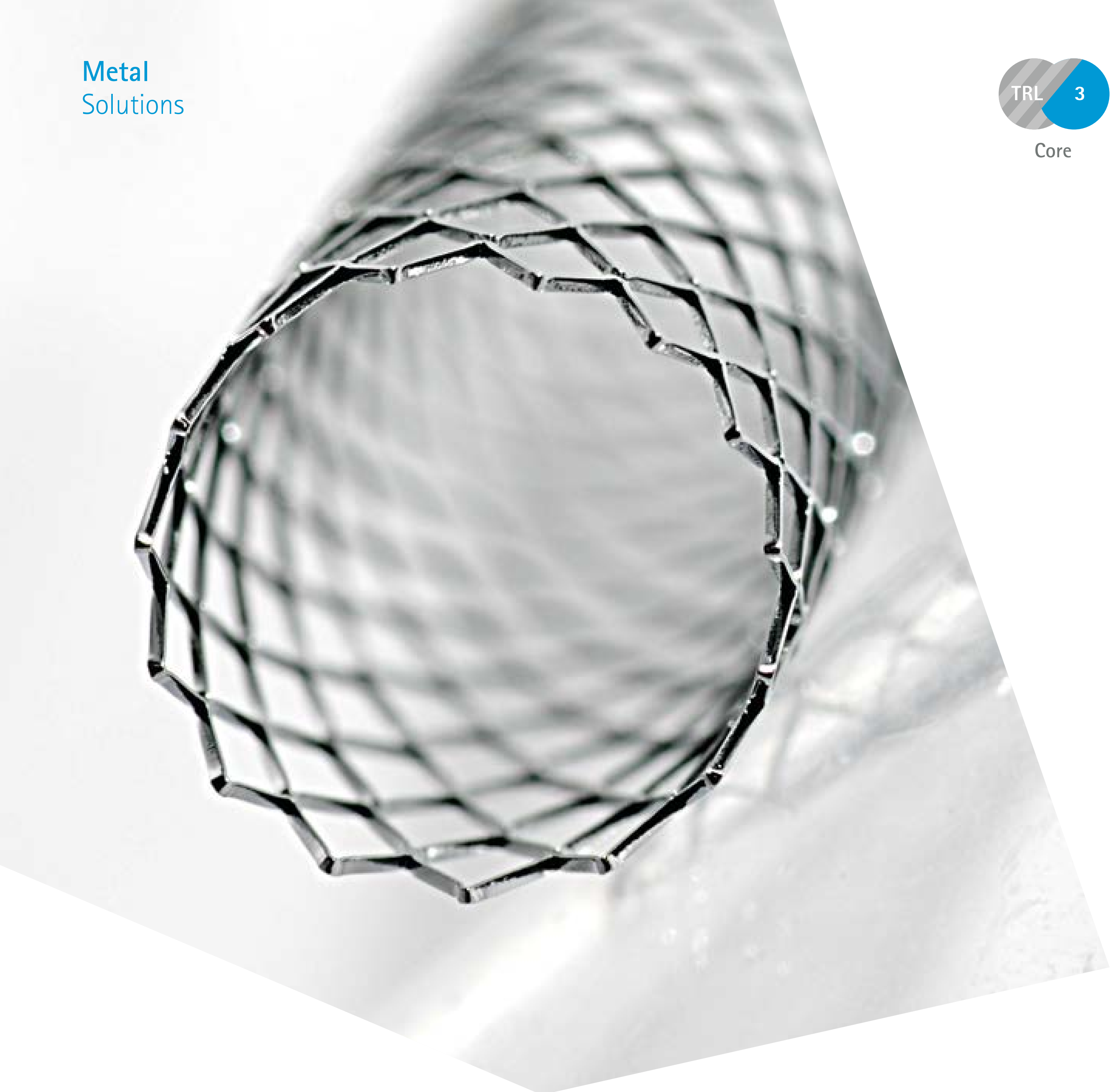
Status 10/2020

Cover: This image shows a possible application.

Metal
Solutions

TRL 3
Core



EOS CobaltChrome MP1
for EOS M 100

EOS CobaltChrome MP1
EOS M 100 | 30 µm

EOS CoCr MP1 conforms to chemical composition UNS R31538. Parts built can be machined, welded, polished and coated as required. They are suitable for a wide variety of applications.

Main Characteristics

- → High carbon CoCrMo based superalloy
- → Good corrosion and wear resistance
- → Good mechanical properties

Typical Applications

- → Orthopedic implants
- → Gas turbines
- → Engine components
- → Jewelry

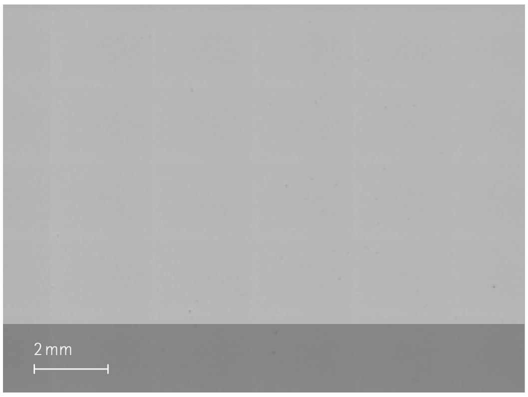
Product Information

Current TRL	3
DMLS System	EOS M 100
Material	EOS CobaltChrome MP1
Process	CoCr_030_100 M100

Layer thickness 30 µm

Volume rate 1.5 mm^3/s

Porosity <0,2 %



Typical part properties	Tensile strength Rm [MPa]	Yield strength $Rp_{0.2}$ [MPa]	Elongation at break A [%]
As manufactured vertical	830	1,200	13
As manufactured horizontal	1,040	1,340	11

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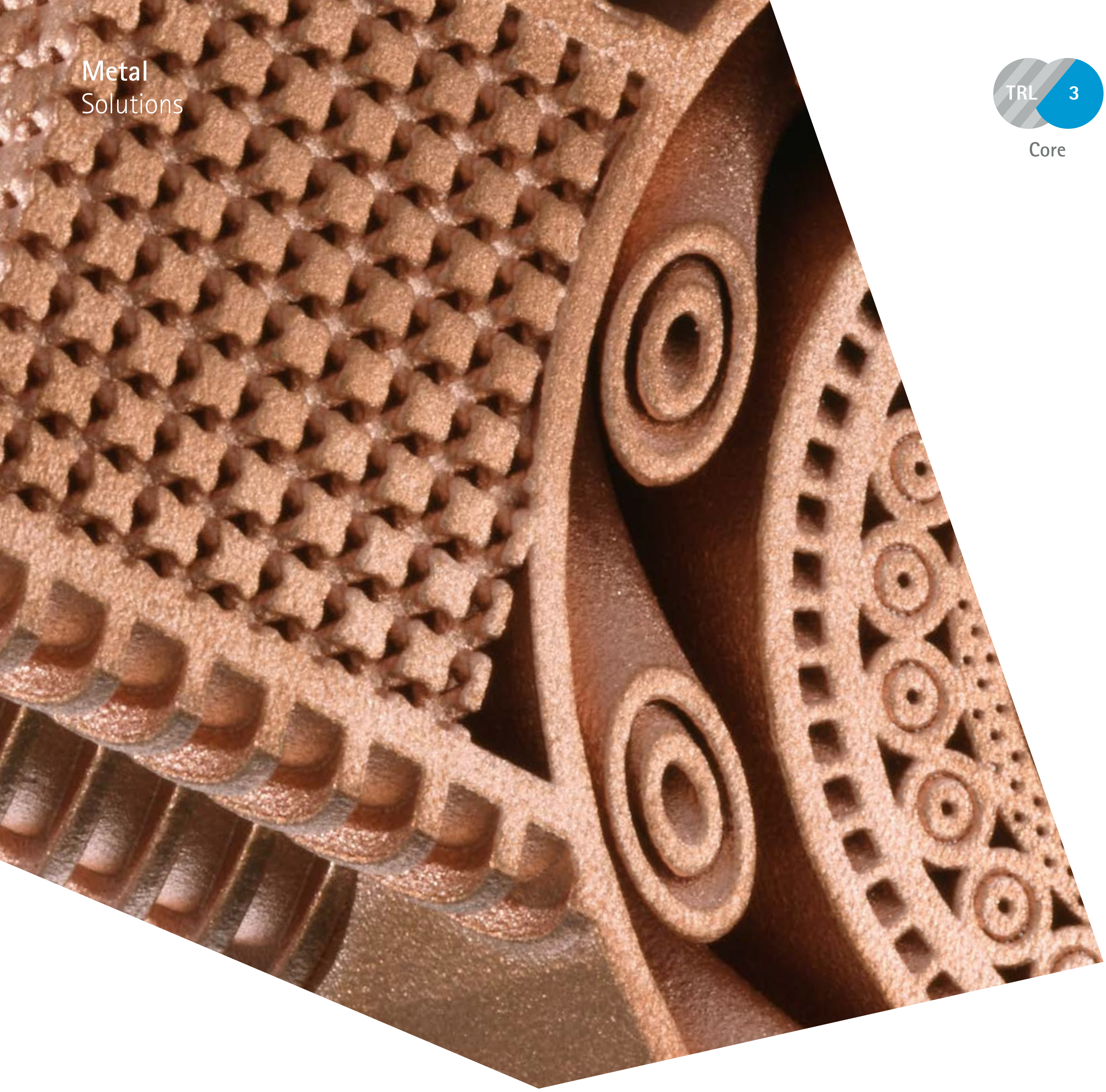
Status 03/2020

Metal
Solutions



TRL 3
Core

EOS Copper Cu
for EOS M 290

EOS Copper Cu
EOS M 290 | 20 µm

High purity copper for EOS M 290 platform to reach good electrical and thermal conductivity. Suitable for a wide variety of applications.

Main Characteristics

- → High purity copper
- → Good electrical and heat conductivity
- → Process developed to achieve best possible conductivity using the EOS M 290

Typical Applications

- → Heat exchangers
- → Electronics
- → Variety of industry applications requiring good conductivity

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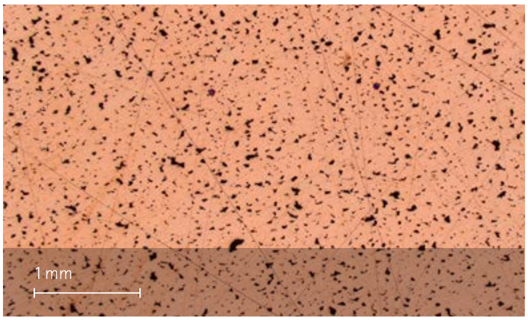
Product Information	
Current TRL	3
DMLS System	EOS M 290
Material	EOS Copper Cu
Process	Cu_020_CoreM291_100

Layer thickness 20 µm

Volume rate 1.7 mm^3/s Porosity < 5 %*



* depending on job load and part geometry

Typical part properties	Yield strength $Rp_{0.2}$ [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Mechanical properties as manufactured	180	200	5
Mechanical properties heat treated	140	190	20
Conductivity as manufactured	> 80 % IACS (tested acc. ASTM E1004-17)		
Conductivity heat treated	> 90 % IACS (tested acc. ASTM E1004-17)		

Copper can be heat treated to reach different mechanical properties and conductivity values. Properties in the table have been achieved with following heat-treatment:
Hold 1 h at ~ 1,000 °C in argon atmosphere, slow cooling with argon

Copper and its alloys have high conductivity; hence high power is required for processing. The achieved density, which influences the mechanical properties, is typical for a 400 W laser. Please refer to the application notes for EOS Copper products for further information.

Status 11/2019

Metal
Solutions

TRL 3
Core

EOS CopperAlloy CuCrZr
for EOS M 400

EOS CopperAlloy CuCrZr
EOS M 400 | 80 µm

Copper alloy CuCrZr has a favorable combination of electrical and thermal conductivity accompanied with good mechanical properties. This alloy reaches its good properties during heat treatment.

Main Characteristics

→ High productivity 12 mm³/s with 80 µm layer thickness

→ Moderate to high conductivity in heat treated condition together with good mechanical properties

→ Chemical composition corresponds to C18150 and CW106C

Typical Applications

→ Rocket engine parts

→ Heat exchangers

→ Induction coils

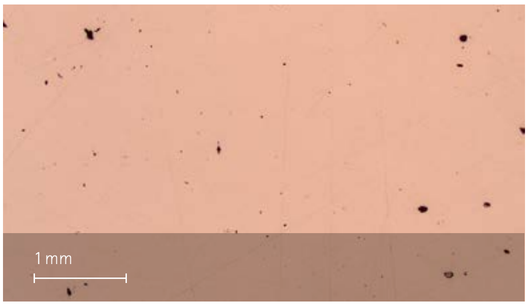
Product Information

Current TRL	3
DMLS System	EOS M 400
Material	EOS CopperAlloy CuCrZr
Process	CuCrZr_080_CoreM400_100

Layer thickness 80 µm

Volume rate 12 mm³/s

Porosity < 0.5 %



Typical part properties	Yield strength $Rp_{0.2}$ [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Mechanical properties as manufactured	160	210	40
Mechanical properties heat treated	200	300	30
Conductivity as manufactured	> 20 % IACS (tested acc. ASTM E1004-17)		
Conductivity Heat-treated	> 85 % IACS (tested acc. ASTM E1004-17)		

CuCrZr can be heat treated to reach different mechanical properties and conductivity values. Properties in the table have been achieved with following heat-treatment:
1. Hold 30 min at ~ 980 °C in argon atmosphere, water cooling to room temperature.
2. Hold 3 h at ~ 430 °C in argon atmosphere, slow cooling in argon by taking the samples out of the furnace and rest in air.

Please refer to the application notes for EOS Copper products for further information.

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Status 11/2019

Metal
Solutions

TRL 3
Core

EOS CopperAlloy CuCrZr
for AMCM M 290 1 kW

EOS CopperAlloy CuCrZr
AMCM M 290 1kW | 80 µm

Copper alloy CuCrZr has a favorable combination of electrical and thermal conductivity accompanied with good mechanical properties. This alloy reaches its good properties during heat treatment.

Main Characteristics

- High productivity 15.4 mm³/s with 80 µm layer thickness
- Moderate to high conductivity in heat treated condition together with good mechanical properties
- Designed for an EOS M 290 with a 1 kW laser which is the AMCM M 290 1 kW sold by AMCM GmbH

Typical Applications

- Rocket engine parts
- Heat exchangers
- Induction coils

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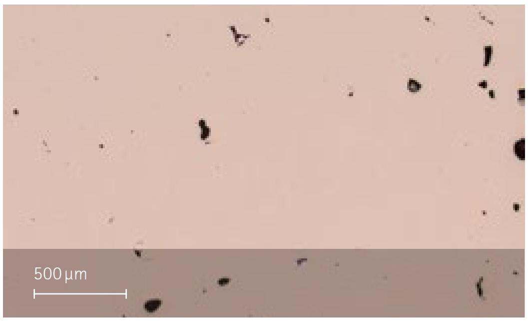
Product Information

DMLS System	EOS M 290 with 1kW laser
Recoater type	HSS blade
Protective gas	Argon
Material	EOS CopperAlloy CuCrZr
Process	CuCrZr_080_CoreM291_1kW_100

Layer thickness 80 µm
Volume rate 15.4 mm³/s — Porosity < 0.5 %



Typical part properties	Yield strength $Rp_{0.2}$ [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]
Mechanical properties as manufactured	160	210	40
Mechanical properties heat treated	210	340	25
Conductivity as manufactured	> 20 % IACS (tested acc. ASTM E1004-17)		
Conductivity heat treated	> 80 % IACS (tested acc. ASTM E1004-17)		

CuCrZr can be heat treated to reach different mechanical properties and conductivity values. Properties in the table have been achieved with following heat-treatment:
1. Hold 30 min at ~ 980 °C in argon atmosphere, water cooling to room temperature.
2. Hold 3 h at ~ 430 °C in argon atmosphere, slow cooling in argon by taking the samples out of the furnace and rest in air.

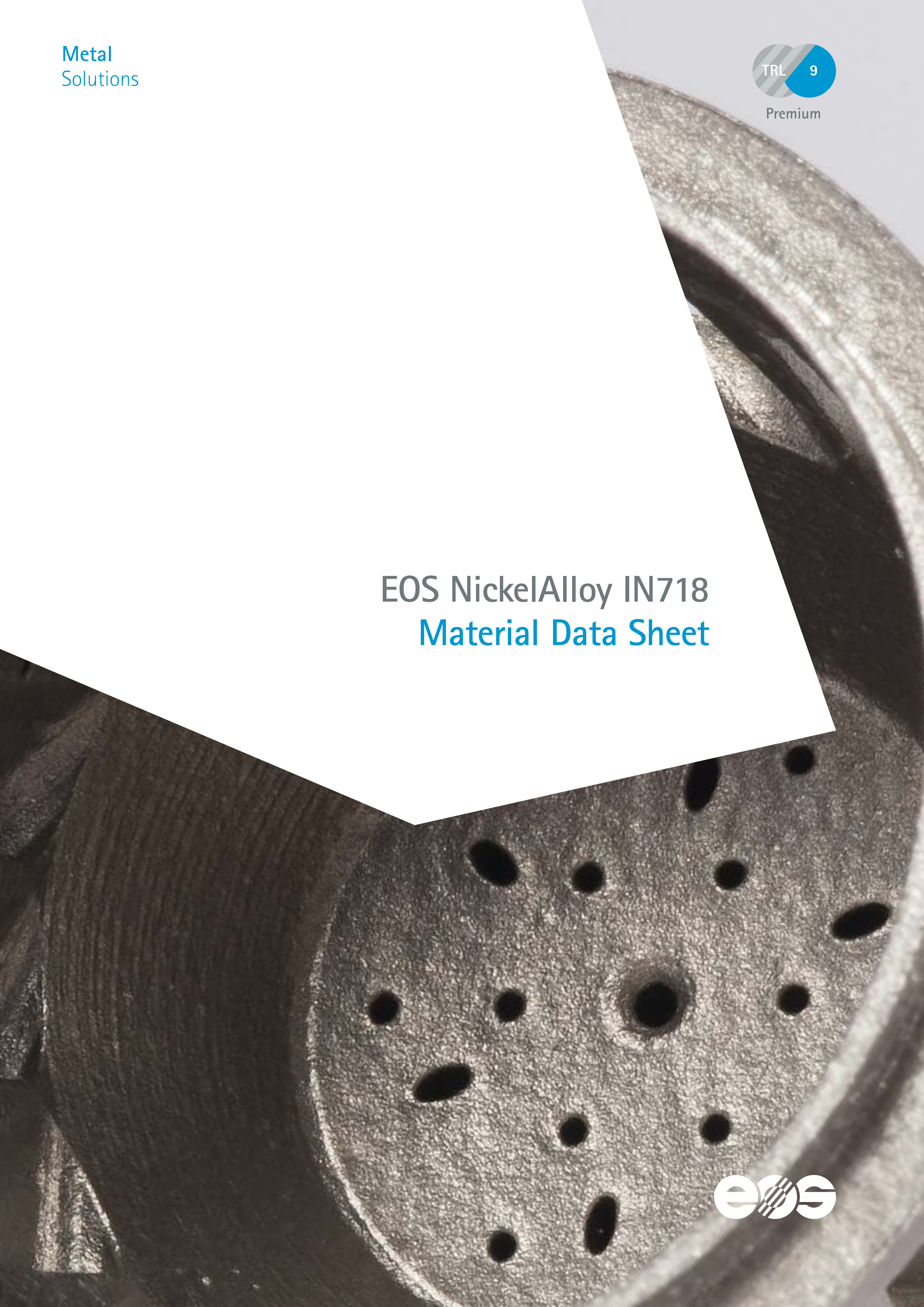
Please refer to the application notes for EOS Copper products for further information.

Status 12/2020

Metal
Solutions

TRL 9
Premium

EOS NickelAlloy IN718
Material Data Sheet



EOS NickelAlloy IN718
High Temperature Strength and Corrosion Resistance

EOS NickelAlloy IN718 is a precipitation-hardening nickel-chromium alloy that is characterized by having good tensile, fatigue, creep and rupture strength at temperatures up to 700 °C (1.290 °F). Parts built from EOS NickelAlloy IN718 can be easily post-hardened by precipitation-hardening heat treatments.

Main Characteristics:

- Good tensile, fatigue, creep and rupture strength at temperatures up to 700 °C (1.290 °F)
- Parts are easily precipitation hardened
- Parts can be machined, spark-eroded, welded, micro shot-peened, polished and coated in both as-built and age-hardened states

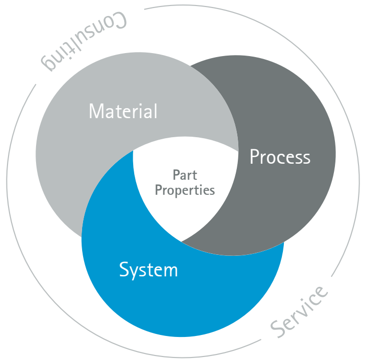
Typical Applications:

- Gas turbine components
- Instrumentation parts
- Power industry parts
- Process industry parts

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.



Powder Properties

The chemical composition of EOS NickelAlloy IN718 is in compliance with UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, DIN NiCr19Fe19NbMo3.

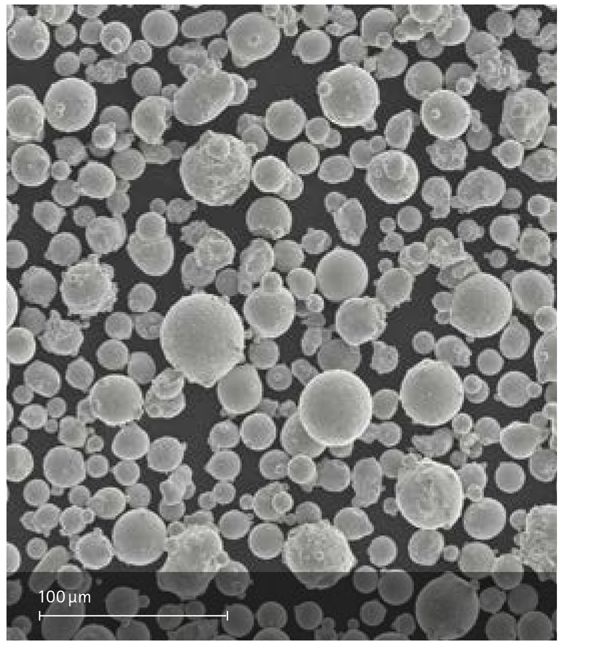
Powder chemical composition (wt.-%)

Element	Min.	Max.
Fe	Rem.	
Ni	50.00	55.00
Cr	17.00	21.00
Nb	4.75	5.50
Mo	2.80	3.30
Ti	0.65	1.15
Al	0.20	0.80
Co	-	1.00
Cu	-	0.30
Si	-	0.35
Mn	-	0.35
Ta	-	0.05
C	-	0.08
S	-	0.015
P	-	0.015
B	-	0.006
Pb	-	0.0005
Se	-	0.0020
Bi		0.00003

Powder particle size

Generic particle size distribution	20–55 µm

SEM picture of EOS NickelAlloy IN718 powder.



Process Information

System set-up	EOS M 290
EOS material set	IN718 Performance 2.0
EOSPAR name	IN718_040_PerformanceM291_2xx
Software requirements	EOSPRINT 1.7 or newer, EOSPRINT 2.6 or newer, EOSYSTEM 2.9 or newer
Powder part no.	9011-0020
Recoater blade	EOS HSS Blade
Nozzle	EOS Grid Nozzle
Inert gas	Argon
Sieve	63 µm

Additional information	
Layer thickness	40 µm
Volume rate	4.2 mm^3/s
Min. wall thickness	Typical 0.3 - 0.4 mm

Heat Treatment

Heat treatment procedure conform to Aerospace Material Specification AMS 2774 and AMS 5662.
As manufactured microstructure for additively manufactured IN718 consists of gamma phase (γ). Heat treatment for IN718 is required to produce desired microstructure and part properties (gamma double prime precipitates, γ''). Heat treatment is also used to relieve stresses.

Step 1:
Solution Annealing: hold at 954 °C (1.750 °F) for 1 hour per 25 mm (0.98 inch) of thickness, air (/argon) cool

Step 2:
Ageing Treatment: hold at 718 °C (1.325 °F) 8 hours, furnace cool to 621 °C (1.150 °F) and hold at 621 °C (1.150 °F) for total precipitation time of 18 hours, air (/argon) cool

Chemical and Physical Properties of Parts

Heat treated microstructure. Etched according to ASTM E407-07.

Defects	Result	Number of samples
Average defect percentage	0.03 %	10
Density, ISO3369	**Result**	**Number of samples**
Average density	min 8.15 g/cm^3	10

Mechanical Properties in Heat Treated State

Tensile properties heat treated (acc. AMS 2774 and AMS 5662)

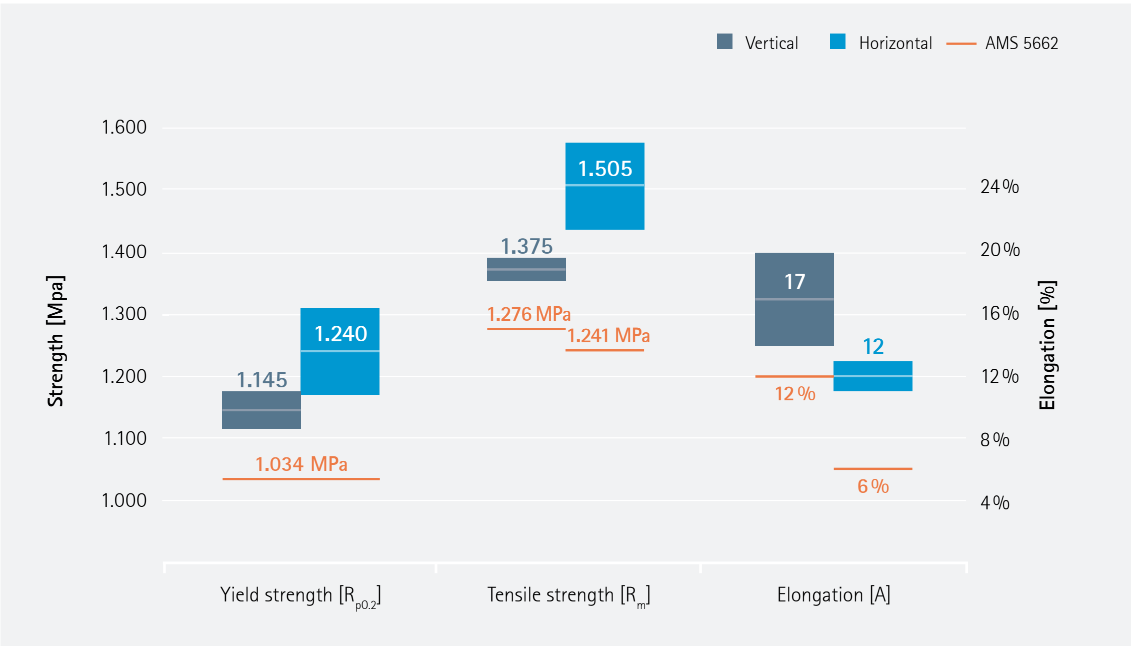
	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	1.145	1.375	17	54
Horizontal	1.240	1.505	12	26

Hardness as per ISO 6508-1

Hardness, HRC	47
Number of samples	45

Hardness as per DIN EN ISO 6506-1:2014

Hardness, HB	466
Number of samples	10



** T90: Tolerance intervals provide upper and lower bounds where 90 % of the population falls with 95 % confidence. Tolerance intervals are based on validation data / QA statistics and are not directly transferrable to other systems.*

Tensile properties as manufactured

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	650	970	32	41
Horizontal	800	1090	25	36

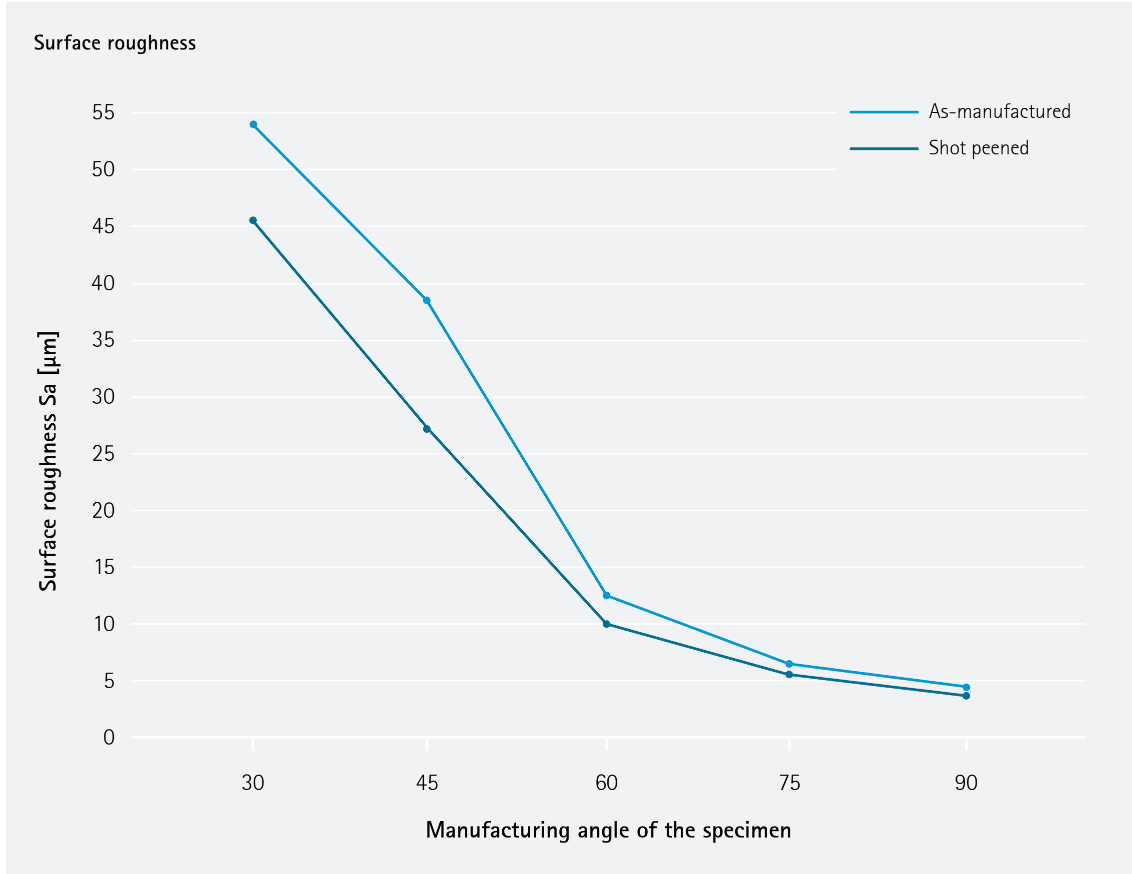
Additional Data

Coefficient of Thermal Expansion ASTM E228-17

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C	25-500 °C	25-600 °C	25-700 °C
CTE	13,1*10⁻⁶/K	13,7*10⁻⁶/K	14,1*10⁻⁶/K	14,4*10⁻⁶/K	14,7*10⁻⁶/K	15,0*10⁻⁶/K	15,5*10⁻⁶/K

Surface Roughness

Horizontal surface	As-manufactured Sa 4.5 µm	Shot Peened Sa 3.8 µm
Vertical and angled surfaces according to figure		



The surface quality was characterized by optical measurement method according to internal procedure. The 90 degree angle corresponds to vertical surface.

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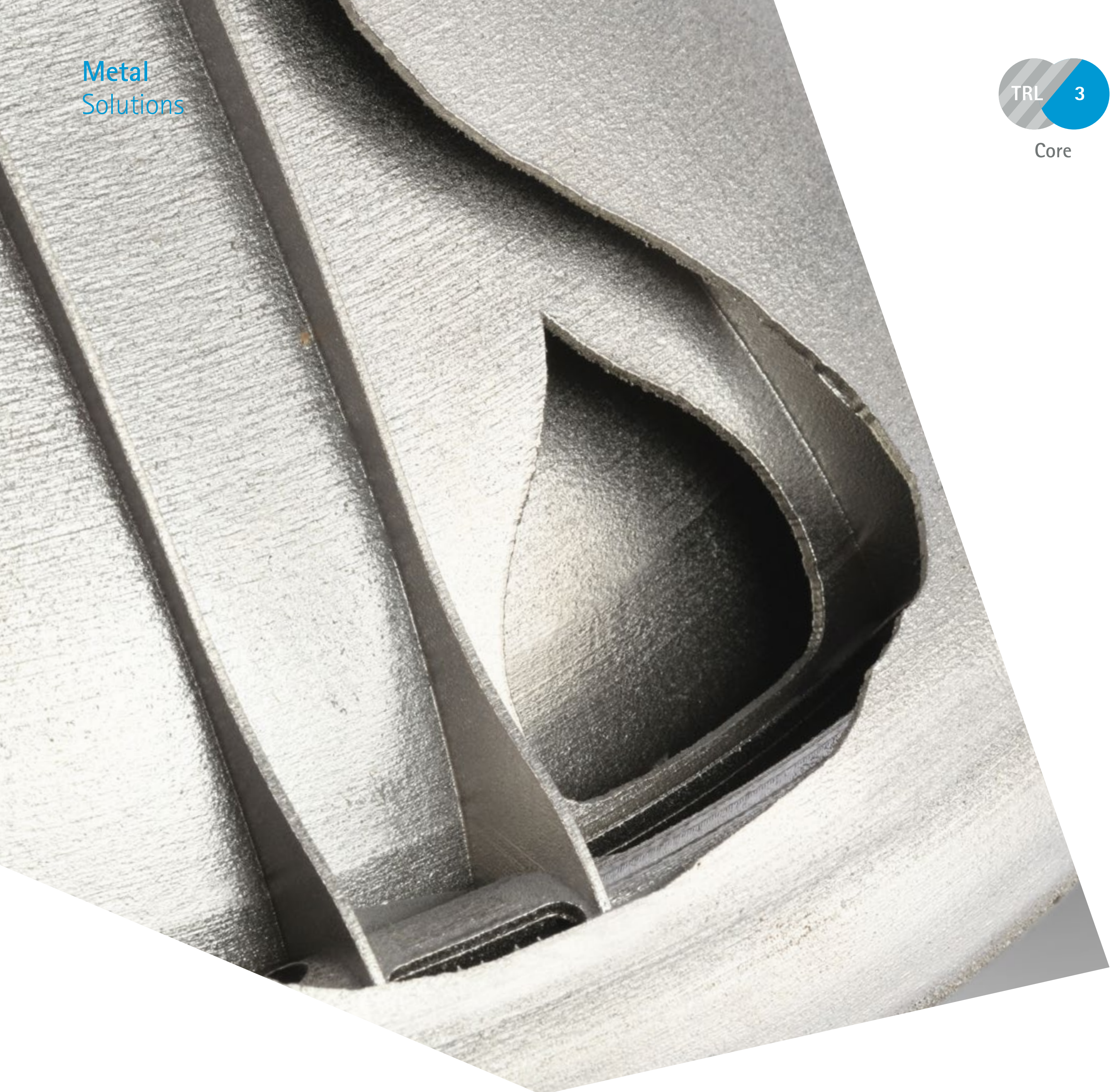
Status 02/2020 (V1.0, CR696, 2020-02)

Metal
Solutions



TRL 3
Core

EOS NickelAlloy IN718
for EOS M 300-4

EOS NickelAlloy IN718
EOS M 300-4 | 40 µm

EOS NickelAlloy IN718 is a precipitation-hardening nickel-chromium alloy that is characterized by having good tensile, fatigue, creep and rupture strength at temperatures up to 700 °C (1,290 °F).

Project Partner Isar Aerospace

Main Characteristics

- → Parts are easily precipitation hardened
- → Parts can be machined, spark-eroded, welded, micro shot-peened, polished and coated
- → Chemical composition corresponding to UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, DIN NiCr19Fe19NbMo3

Typical Applications

- → Gas turbine components
- → Instrumentation parts
- → Power industry parts
- → Process industry parts

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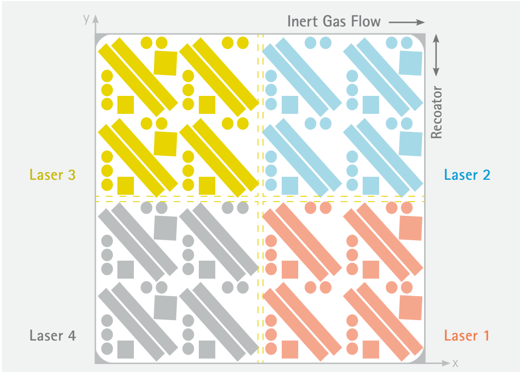
Product Information

DMLS System	EOS M 300-4
Material	EOS NickelAlloy IN718
Process	40 µm layer thickness
Inert Gas	Argon
Recoater blade	HSS, two-sided recoating
Volume rate	up to 4 x 4.2 mm³/s

Layout of test job

Part properties based on 2 test jobs each for the as manufactured and heat treated data.



Typical part properties	Yield strength $Rp_{0.2}$ [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
As manufactured vertical	634	957	36	158
As manufactured horizontal	796	1,092	27	62
Heat treated vertical	1,141	1,370	20	159
Heat treated horizontal	1,267	1,531	15	44
Max. pore size	< 100 µm			64
Porosity	< 0.05 %			64

Mechanical properties tested according to EN ISO 6892-1 B10. The values in the table are average values. Heat treatment procedure in accordance with AMS 5662.

Status 11/2020

Metal
Solutions

TRL 7
Premium

EOS NickelAlloy IN939
Material Data Sheet

EOS NickelAlloy IN939
Excellent High Temperature Performance with Corrosion Resistance

EOS NickelAlloy IN939 is a nickel-chromium alloy which provides an outstanding balance of high temperature strength, corrosion and oxidation resistance, fatigue performance and creep strength at temperatures up to 850 °C (1 560 °F). Parts built from EOS NickelAlloy IN939 can be hardened after manufacture by application of precipitation-hardening heat treatments.

Main Characteristics:

- Excellent mechanical properties
- Excellent corrosion and oxidation resistance
- High tensile, fatigue, creep and rupture strength at temperatures up to 850 °C (1 560 °F)
- Maintains good ductility in age-hardened condition
- Crack-free in as-built condition and resistant to strain-age cracking

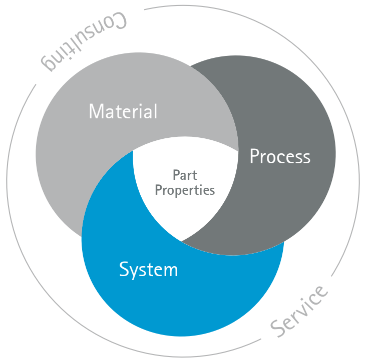
Typical Applications:

- Industrial gas turbines (vanes, blades, heat-shields)
- Microturbines
- Turbochargers
- Instrumentation parts
- Power industry parts
- Process industry parts

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.



Part on title page: PSM Ansaldo, USA

Powder Properties

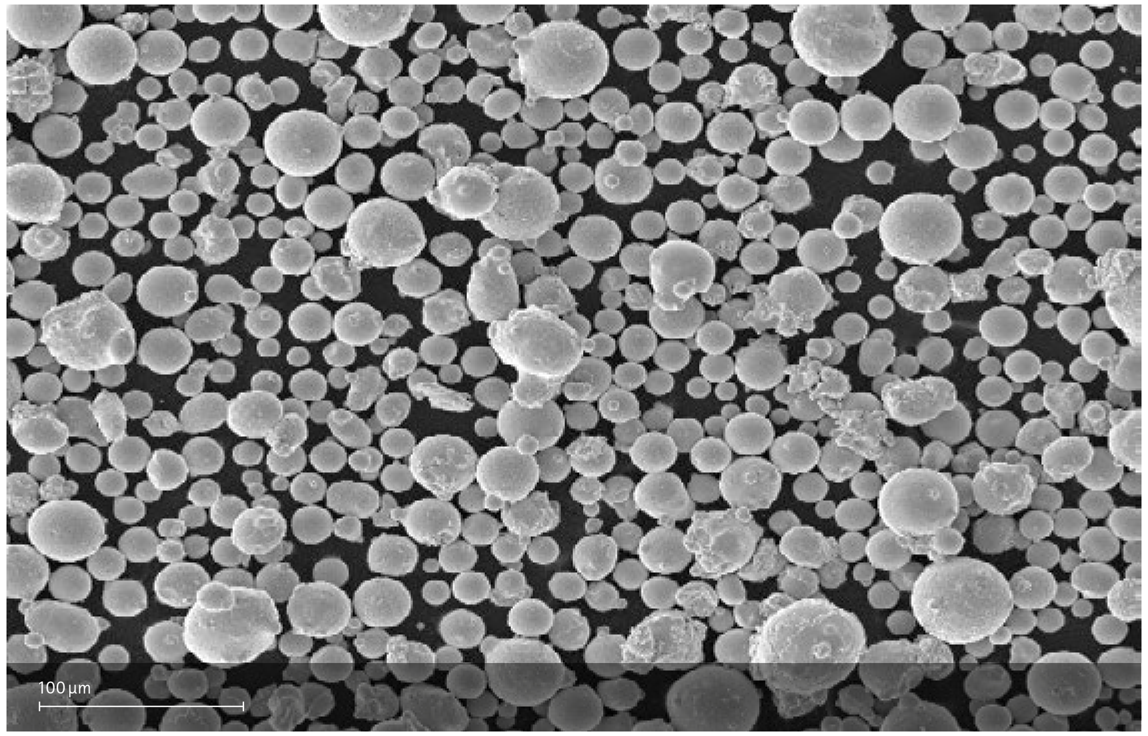
Powder chemical composition (wt.-%)

Element	Typical
Cr	22.5
Co	19
W	2.0
Nb	1.0
Ti	3.7
Al	1.9
Ta	1.4
Zr	0.1
C	0.15
B	0.01
Ni	Balance

Powder particle size

Generic particle size distribution	20-55 µm

SEM of EOS NickelAlloy IN939 powder.



Process Information

System set-up	EOS M 290
EOS MaterialSet	IN939 40µm HiPer M290/400W
EOSPRINT Material Set	IN939_040_HiPerM291_1.00
Software requirements	EOSPRINT 2.6 or newer EOSYSTEM 2.10 or newer
Powder part no.	9011-0030
Recoater blade	EOS HSS Blade
Nozzle	EOS Grid Nozzle
Inert gas	Argon
Sieve	63 µm

Additional information	
Layer thickness	40 µm
Volume rate	3.6 mm^3/s
Min. wall thickness	Typical 0.3 - 0.4 mm

Heat Treatment

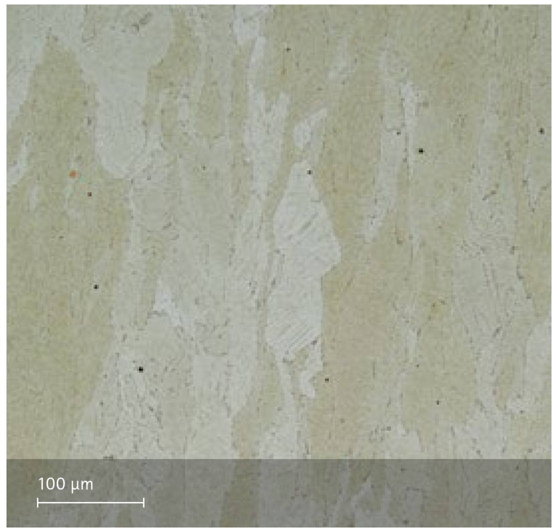
The as-built microstructure of additively-manufactured IN939 consists of gamma phase (γ) and primary carbides. Heat treatment is required for the material to reach the desired microstructure and part properties through precipitation of the gamma prime (γ') strengthening phase. EOS has developed a short, AM-optimized 3-step heat treatment (14 hours at temperature), which results in similar or better properties than the commonly used 4-step heat treatment (50 hours at temperature). The gamma prime (γ') volume fraction after heat-treatment is in the range of 30 to 40 %.

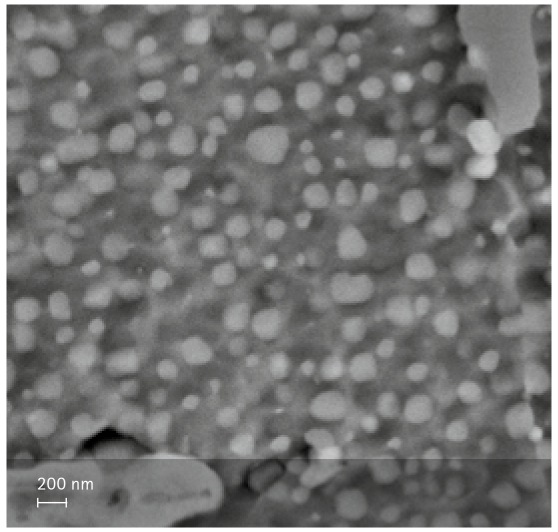
Solution treatment:
Step 1: The purpose of this treatment is to homogenize the gamma matrix: Hold at 1 190 °C for 4 hours followed by fast air / argon cooling.

Aging treatment:
The purpose of aging steps is the precipitation and growth of gamma prime (γ') and carbides.
Step 2: Hold at 1 000 °C for 6 hours, followed by fast air / argon cooling.
Step 3: Hold at 800 °C for 4 hours, followed by cooling in still air / argon.

Chemical and Physical Properties of Parts

Chemical composition of built parts is compliant to EOS NickelAlloy IN939 powder chemical composition.





Images show the microstructure of the alloy at two magnifications.

The image on the left shows the grain structure, while the image on the right shows the strengthening phases (gamma prime) at a much higher magnification.

Defects	Result	Number of samples
Average defect percentage	0.01 %	50
Density ISO3369	**Result**	**Number of samples**
Average density	min 8.15 g/cm^3	NA

The areal defect percentage was determined from cross-sections of built parts using an optical microscope fitted with a camera and analysis software. The analysis was carried out for sample area of 15 x 15 mm². The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images.

Mechanical Properties in Heat Treated Condition

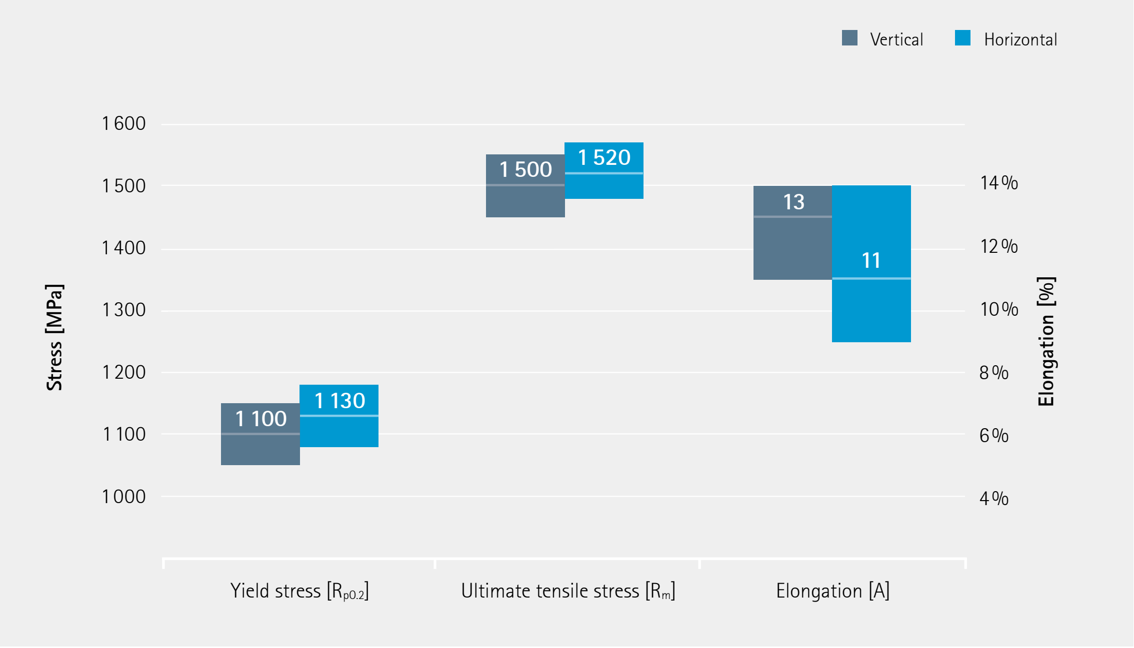
Tensile properties ISO 6892-1
Room temperature

	Yield strength $R_{p0.2}$ [MPa]	Ultimate tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	1 100	1 500	13	187
Horizontal	1 130	1 520	11	160

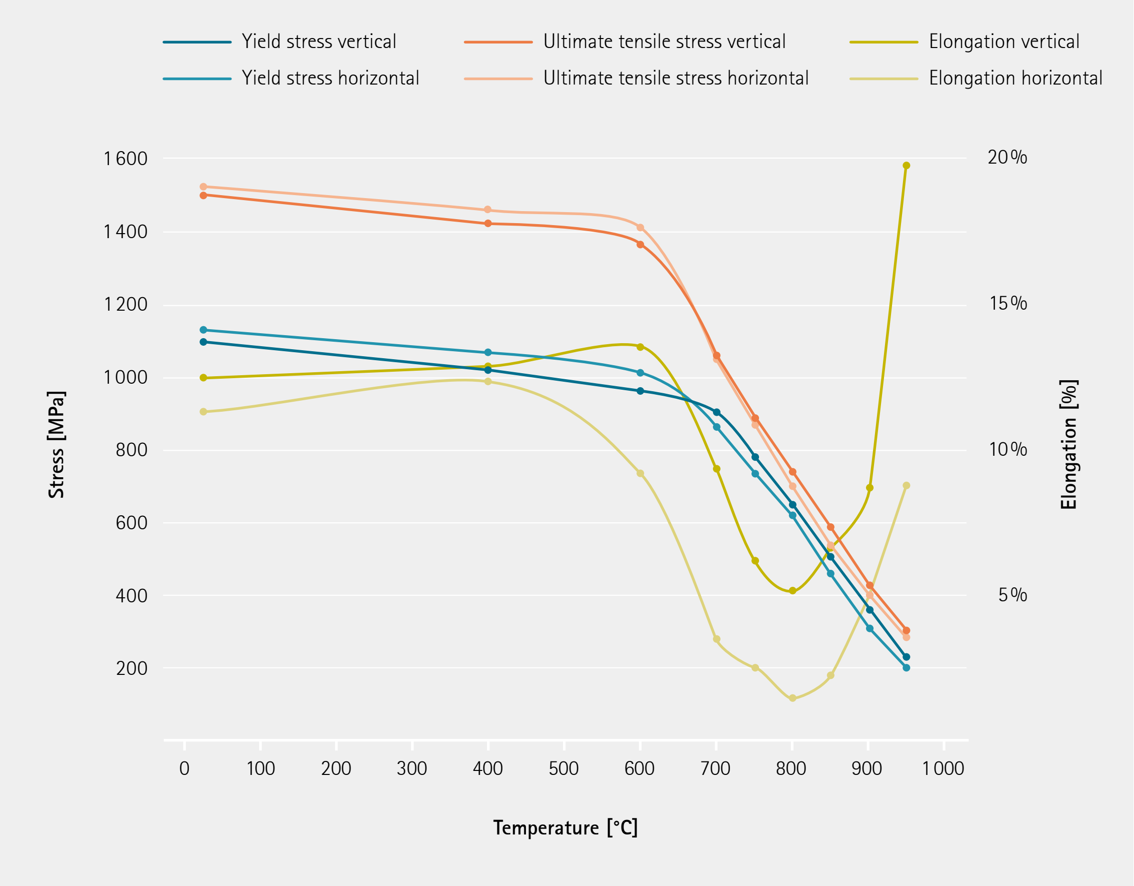
Hardness at room temperature ISO 6508

Hardness, HRC	48
Number of samples	10

Validation with three powder lots and three EOS M 290 systems. Data presented with tolerance interval limits that 90 % of the population fullfill with 95 % level of confidence.



Tensile Properties ISO 6892-2 at Elevated Temperature in Heat Treated Condition



Mechanical Properties As-Manufactured

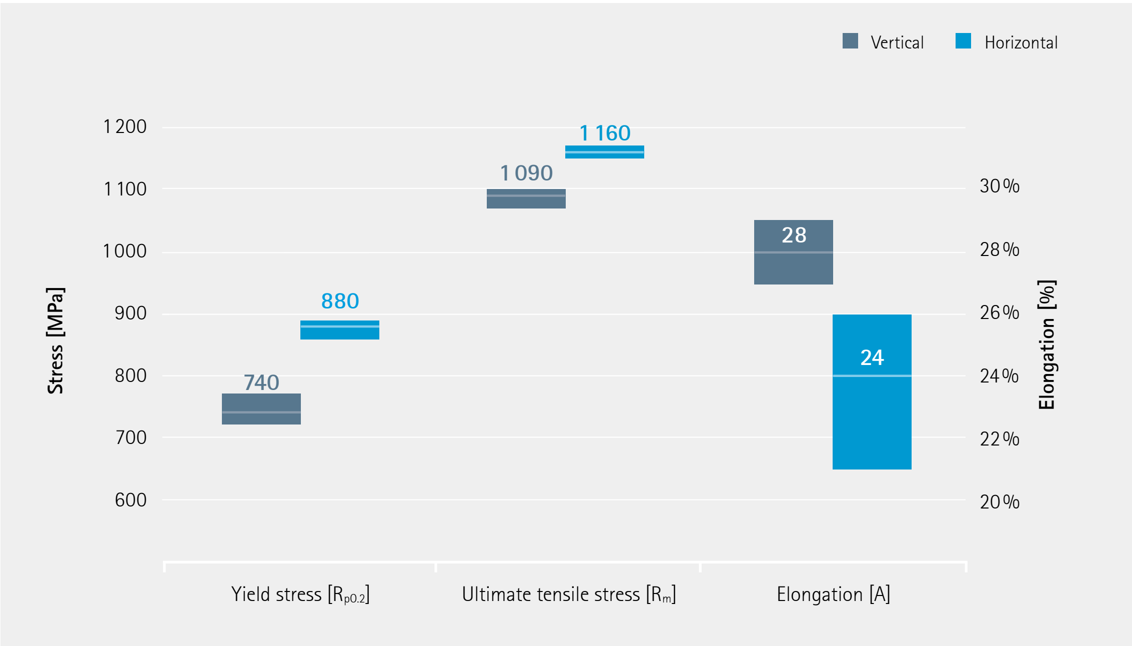
Tensile properties as manufactured ISO 6892-1

	Yield strength $R_{p0.2}$ [MPa]	Ultimate tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	740	1 090	28	21
Horizontal	880	1 160	24	18

Hardness as manufactured ISO 6508

Hardness, HRC	33
Number of samples	10

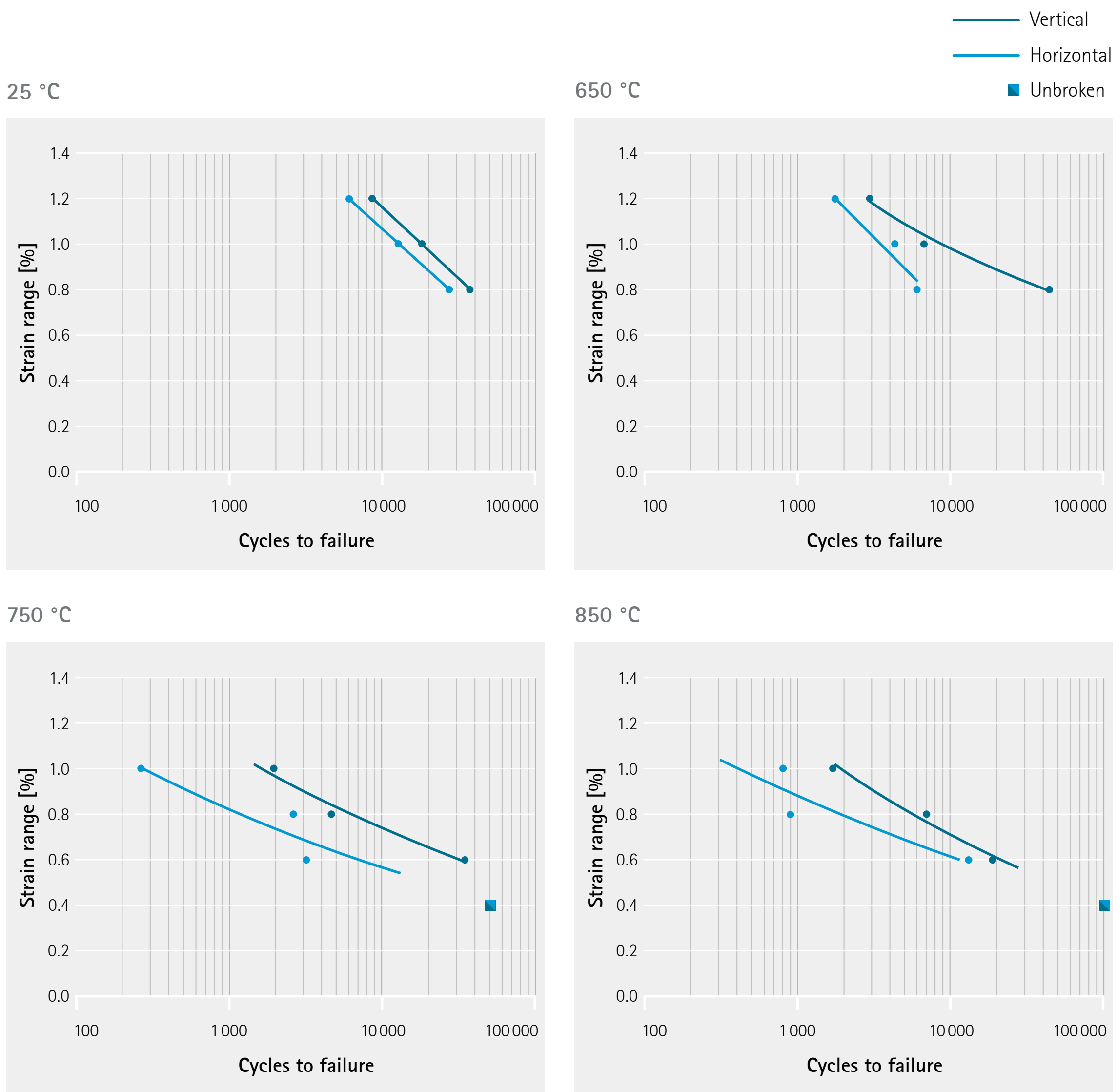
Data collected on a standard validation job with one powder lot and one EOS M 290 system. Data presented with tolerance interval limits that 90 % of the population fullfill with 95 % level of confidence.



Additional Data

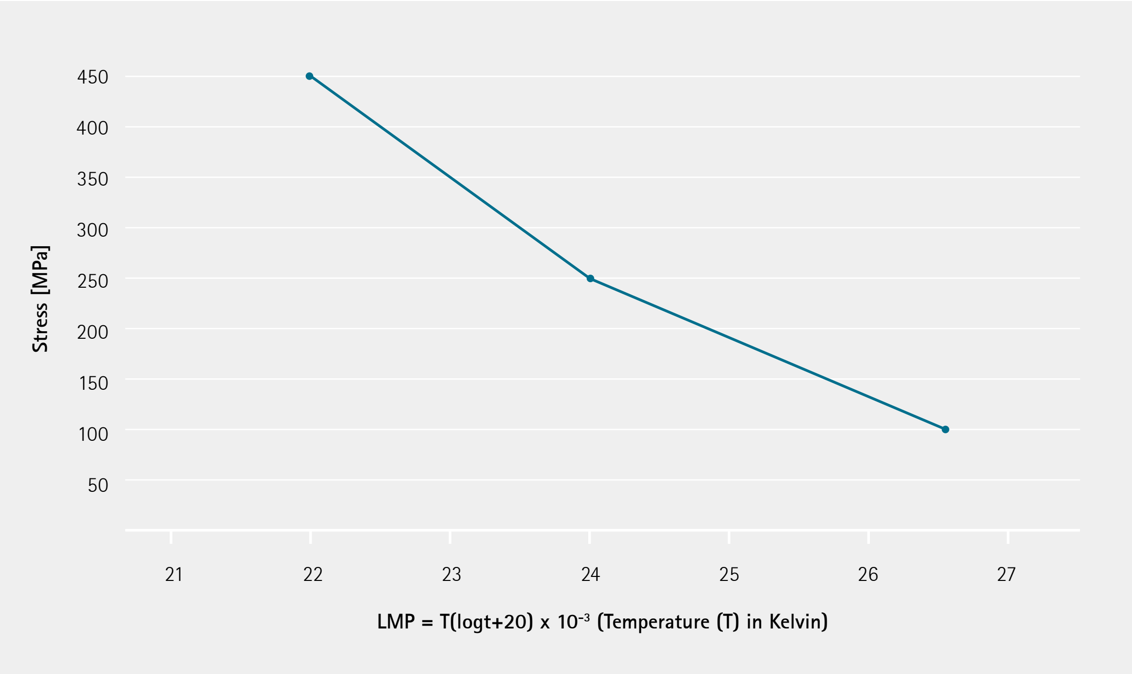
Low Cycle Fatigue

Low cycle fatigue performance of horizontally and vertically oriented samples at temperatures of 25 °C, 650 °C, 750 °C and 850 °C. The data represents cycles to failure for different strain amplitudes. No HIP was applied.
Method, standard, cycles: axial, strain controlled testing according to ASTM E606



Creep Performance

The stress-rupture performance of EOS NickelAlloy IN939 was tested on vertically oriented samples, in heat-treated condition. No HIP was applied. The data presents the Larson-Miller Parameter values achieved at stress levels of 100 MPa, 250 MPa and 450 MPa.
Standard: ASTM E606



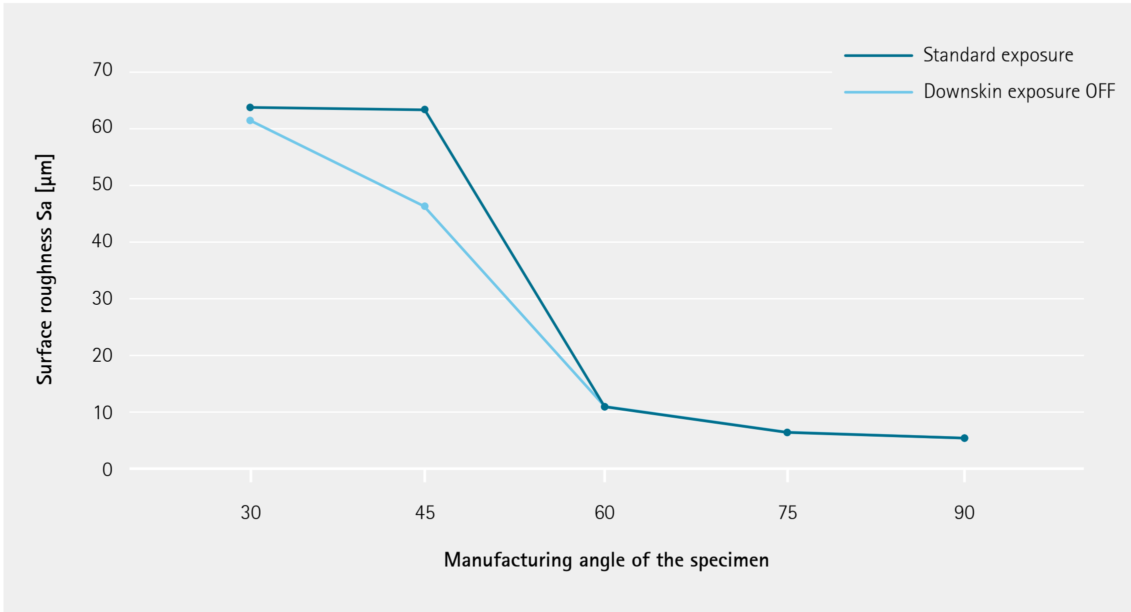
Coefficient of Thermal Expansion (as manufactured) ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25-400 °C	25-600 °C	25-800 °C	25-900 °C
CTE	12.18*10^{-6}/K	12.89*10^{-6}/K	13.78*10^{-6}/K	13.49*10^{-6}/K	13.99*10^{-6}/K	15.06*10^{-6}/K

Coefficient of Thermal Expansion (heat treated) ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25-400 °C	25-600 °C	25-800 °C	25-900 °C
CTE	11.79*10^{-6}/K	12.64*10^{-6}/K	13.64*10^{-6}/K	14.27*10^{-6}/K	15.29*10^{-6}/K	16.32*10^{-6}/K

Surface Roughness of Downskin (as manufactured)



EOS NickelAlloy IN939 parameters were developed for optimized dimensional accuracy of internal cooling features, which are essential to hot gas path components in gas turbines. This comes with a compromise on downskin roughness. Whenever possible, for parts where optimized dimensional accuracy of internal cooling features is not needed, EOS recommends to switch off downskin exposure, to improve downskin roughness and buildability at low angles, and to increase process speed.

The surface quality was characterized by optical measurement method according to internal procedure. The 90 degree angle corresponds to vertical surface.

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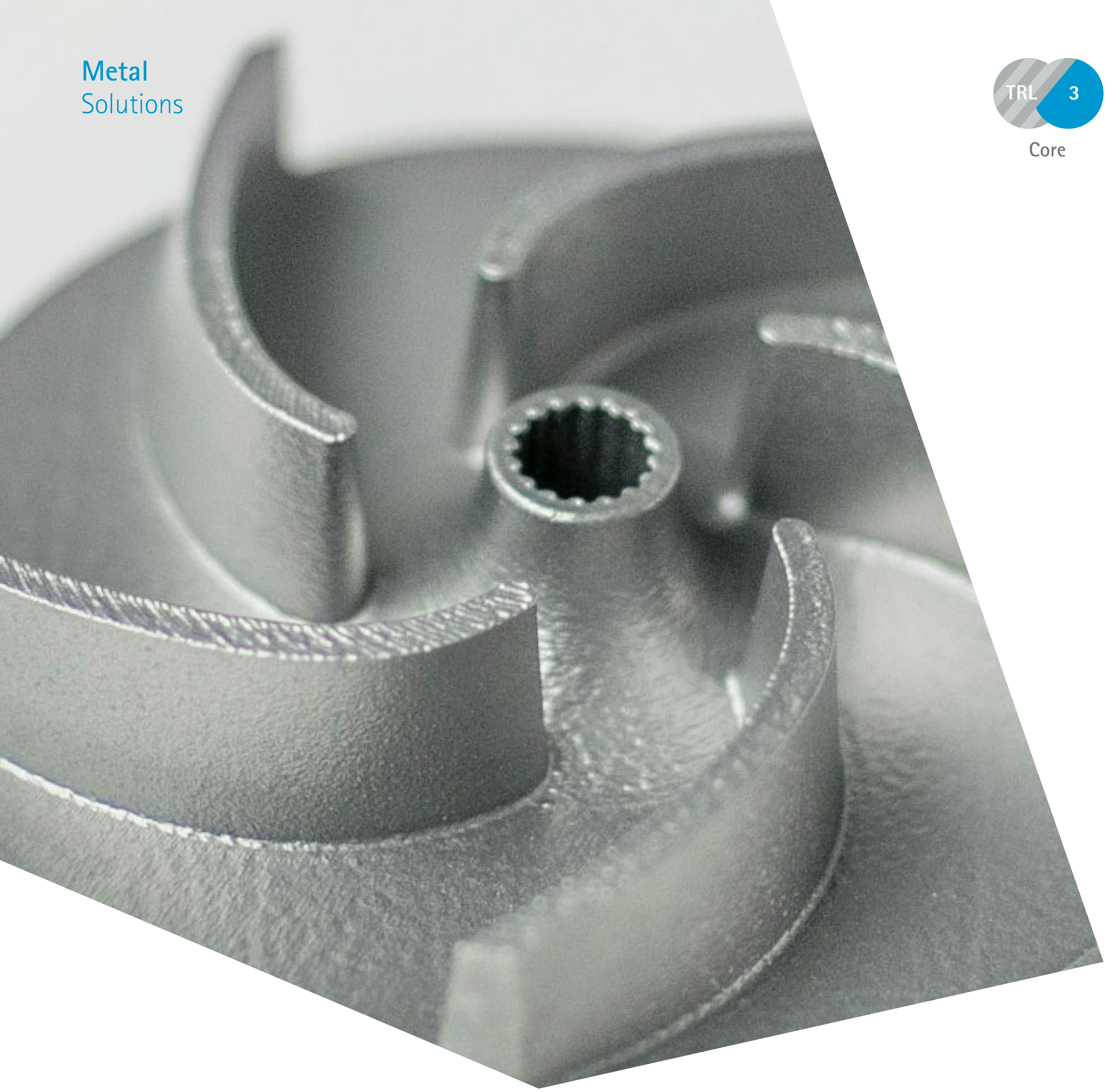
01/2021 (V2, CR759, 2020-11)

Metal
Solutions



TRL 3
Core

EOS StainlessSteel 254
Material Data Sheet

EOS StainlessSteel 254

EOS StainlessSteel 254 is an austenitic stainless steel for extreme conditions. The high chromium, molybdenum and nitrogen alloying give excellent corrosion resistance in many difficult environments. The general pitting resistance equivalent PREN for 254 is 43 (PREN = %Cr + 3.3 X %Mo + 16 X %N).

Main Characteristics:

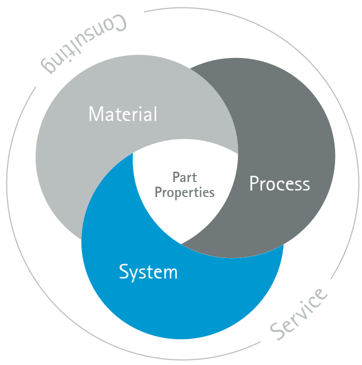
- Excellent resistance to uniform, pitting and crevice corrosion
- High resistance to stress corrosion cracking
- Higher strength than conventional austenitic stainless steels

Typical Applications:

- Chlorinated seawater handling equipment
- Pulp and paper manufacturing devices
- Chemical handling equipment

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process. The data resulting from each combination is assigned a Technology Readiness Level (TRL) which makes the expected performance and production capability of the solution transparent.



EOS incorporates these TRLs into the following two categories:

- Premium products (TRL 7-9): offer highly validated data, proven capability and reproducible part properties.
- Core products (TRL 3 and 5): enable early customer access to newest technology still under development and are therefore less mature with less data.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

EOS StainlessSteel 254 powder material is in accordance with DIN EN 10088-3, EN 1.4547

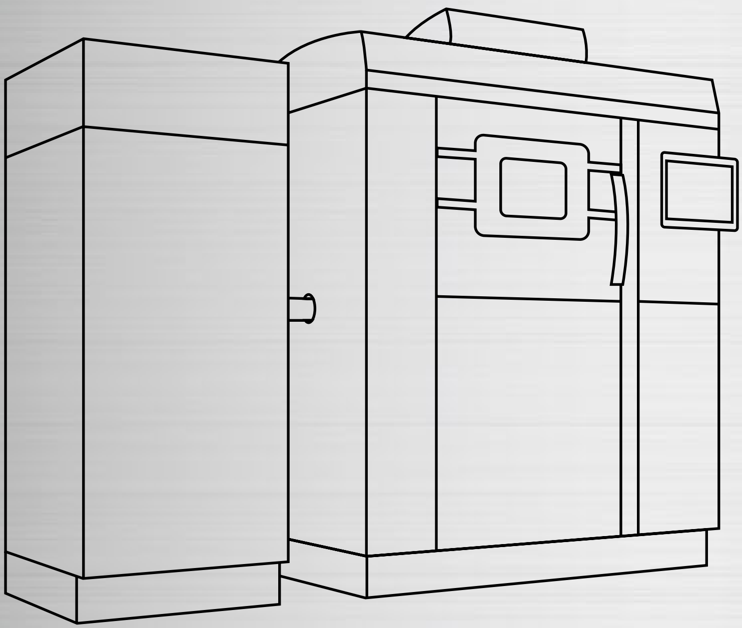
Powder chemical composition (wt.-%)

Element	Min.	Max.
Cr	19.5	20.5
Ni	17.5	18.5
Mo	6.0	7.0
Cu	0.5	1.0
N	0.18	0.25

Powder particle size

Generic particle size distribution	20-65 µm

TRL 3
Core



EOS StainlessSteel 254
for EOS M 290 | 40 µm

Process Information
Physical Part Properties
Heat Treatment
Additional Data

EOS StainlessSteel 254 for EOS M 290 | 40 µm

Process Information

System set-up	EOS M 290
EOSPAR name	254_040_CoreM291_100
Software requirements	EOSPRINT 2.8 or newer EOSYSTEM 5.20 or newer
Powder part no.	9030-0007
Recoater blade	HSS
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	75 µm

Additional information	
Layer thickness	40 µm
Volume rate	4.1 mm^3/s

Chemical and Physical Properties of Parts

Micrograph etched as manufactured
Etchant: ASTM E407-07, etchant 12

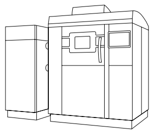
Defects	Result
Porosity	0.01 %
Density, ISO3369	≥ 8.07 g/cm³

Typical mechanical properties

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
Heat treated horizontal	360	700	43
Heat treated vertical	360	660	48
As manufactured horizontal	680	810	29
As manufactured vertical	600	720	35

Tensile testing as per ISO 6892-1

Heat Treatment



Optional solution annealing

At 1 180 °C for 2 h after parts have fully heated through, water quenching

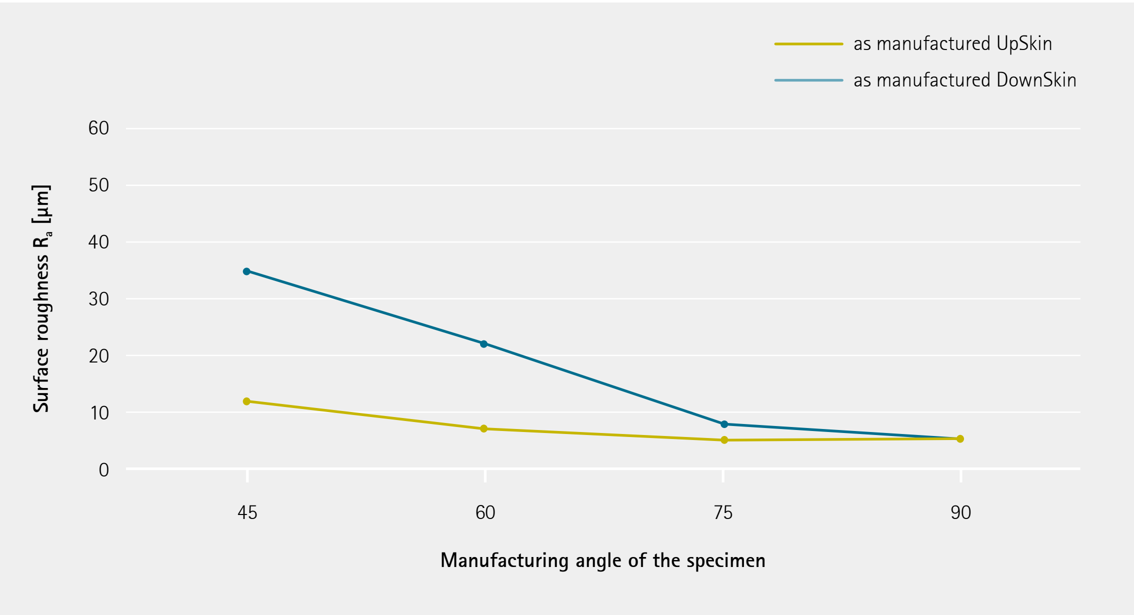
Typical dimensional change after heat treatment: 0.06 %

Additional Data

Coefficient of Thermal Expansion ASTM E228

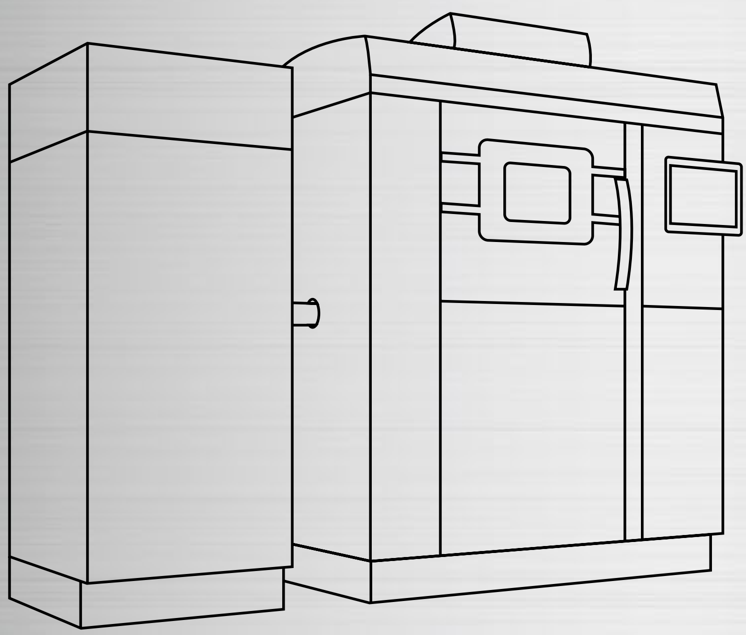
Temperature	25 – 100 °C	25 – 200 °C	25-300 °C	25-400 °C
CTE	14.8*10^{-6}/K	15.7*10^{-6}/K	16.3*10^{-6}/K	16.7*10^{-6}/K

Surface Roughness



TRL 3

Core



EOS StainlessSteel 254
for EOS M 290 | 60 µm

Process Information

Physical Part Properties

Heat Treatment

Additional Data

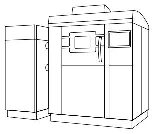
EOS StainlessSteel 254 for EOS M 290 | 60 µm

Process Information

System set-up	EOS M 290
EOSPAR name	254_060_CoreM291_100
Software requirements	EOSPRINT 2.8 or newer EOSYSTEM 5.20 or newer
Powder part no.	9030-0007
Recoater blade	HSS
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	75 µm

Additional information	
Layer thickness	60 µm
Volume rate	6.1 mm^3/s

Chemical and Physical Properties of Parts



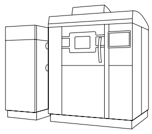
Micrograph etched as manufactured
Etchant: ASTM E407-07, etchant 12

Defects	**Result**
Porosity	0.02 %
Density, ISO3369	≥ 8.07 g/cm³

Typical mechanical properties

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
Heat treated horizontal	360	700	44
Heat treated vertical	360	660	48
As manufactured horizontal	660	800	30
As manufactured vertical	580	730	36

Tensile testing as per ISO 6892-1



Heat Treatment

Optional solution annealing

At 1 180 °C for 2 h after parts have fully heated through, water quenching

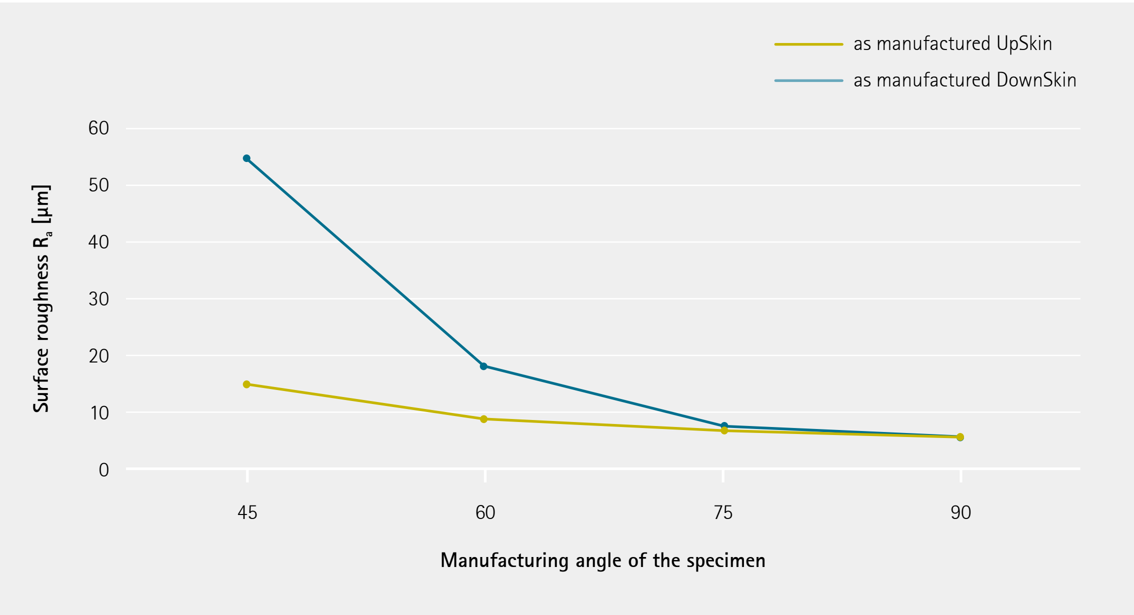
Typical dimensional change after heat treatment: 0.06 %

Additional Data

Coefficient of Thermal Expansion ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25-300 °C	25-400 °C
CTE	$14.8*10^{-6}/K$	$15.7*10^{-6}/K$	$16.3*10^{-6}/K$	$16.7*10^{-6}/K$

Surface Roughness



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Status 02/2021

Cover: This image shows a possible application.

The quoted values refer to the use of this material with above specified type of EOS DMLS system, EOSYSTEM and EOSPRINT 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. EOS does not warrant any properties or fitness for a specific purpose, unless explicitly agreed upon. This also applies regarding any rights of protection as well as laws and regulations.

Metal
Solutions

EOS StainlessSteel 316L
Material Data Sheet

EOS StainlessSteel 316L

EOS StainlessSteel 316L is a high performance marine-grade austenitic stainless steel that is molybdenum alloyed for enhanced corrosion resistance in chloride environments. 316L is a standard material for numerous applications in process, energy, paper, transportation and other industries.

Main Characteristics:

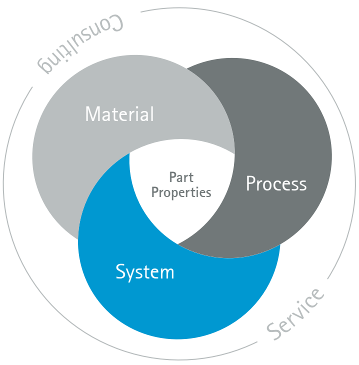
- High ductility and toughness
- High strength
- High corrosion resistance

Typical Applications:

- Chemical industry
- Food processing
- Medical devices

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.



All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

The chemical composition of EOS StainlessSteel 316L corresponds to ASTM F138 material standard for Surgical Implants (UNS S31673).

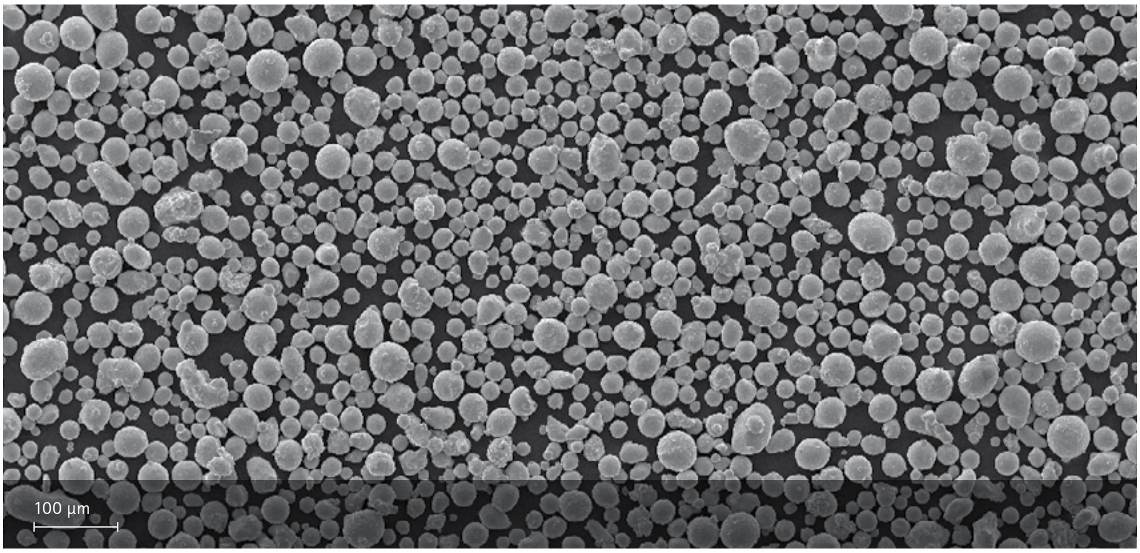
Powder chemical composition (wt.-%)

Element	Min.	Max.
Fe	Balance	
Cr	17.00	19.00
Ni	13.00	15.00
Mo	2.25	3.00
C	-	0.03
N	-	0.10

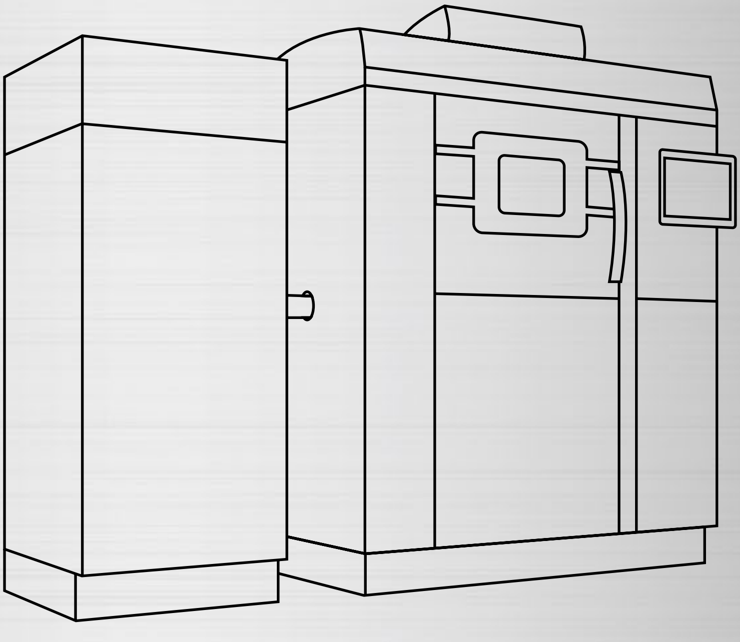
Powder particle size

Generic particle size distribution	20 – 65 µm

SEM picture of EOS StainlessSteel 316L powder.



TRL 8
Premium



EOS StainlessSteel 316L
for EOS M 290 | 20 µm

Process Information
Chemical and Physical Part Properties
Heat Treatment
Mechanical Properties
Additional Data

HHE/05.2014

EOS StainlessSteel 316L for EOS M 290 | 20 µm

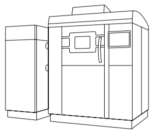
Process Information

This process product is optimized for robustly building parts with EOS M 290 system using EOS StainlessSteel 316L. The mechanical properties have been validated to TRL8 level.

System set-up	EOS M 290
EOS ParameterSet	316L 20µm Surface M290/400W
EOSPAR name	316L_Surface_1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0032
Recoater blade	EOS HSS blade
Nozzle	Standard nozzle
Inert gas	Argon
Sieve	63 µm

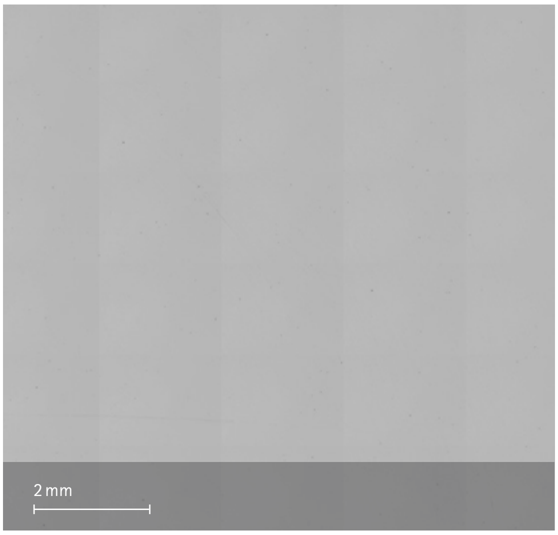
Additional information	
Layer thickness	20 µm
Min. wall thickness	0.3 - 0.4 mm
Typical dimensional change after HT	+0.02 %
Volume rate	2.0 mm^3/s

Chemical and Physical Properties of Parts



Chemical composition of built parts
is compliant to EOS StainlessSteel
316L powder chemical composition.

Micrograph of polished surface



Microstructure solution annealed
Etched with etchant Kallings 2

Defects	Result	Number of samples
Average defect percentage	0.018 %	45
Density, ISO3369	**Result**	**Number of samples**
Average density	≥ 7.97 g/cm^3	45

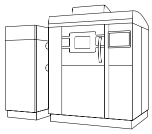
Heat Treatment

Heat treatment according to
AMS 2759 is optional.

Stress relief: Hold temperature 900 °C, hold time minimum 2 h when thoroughly heated, water quenching

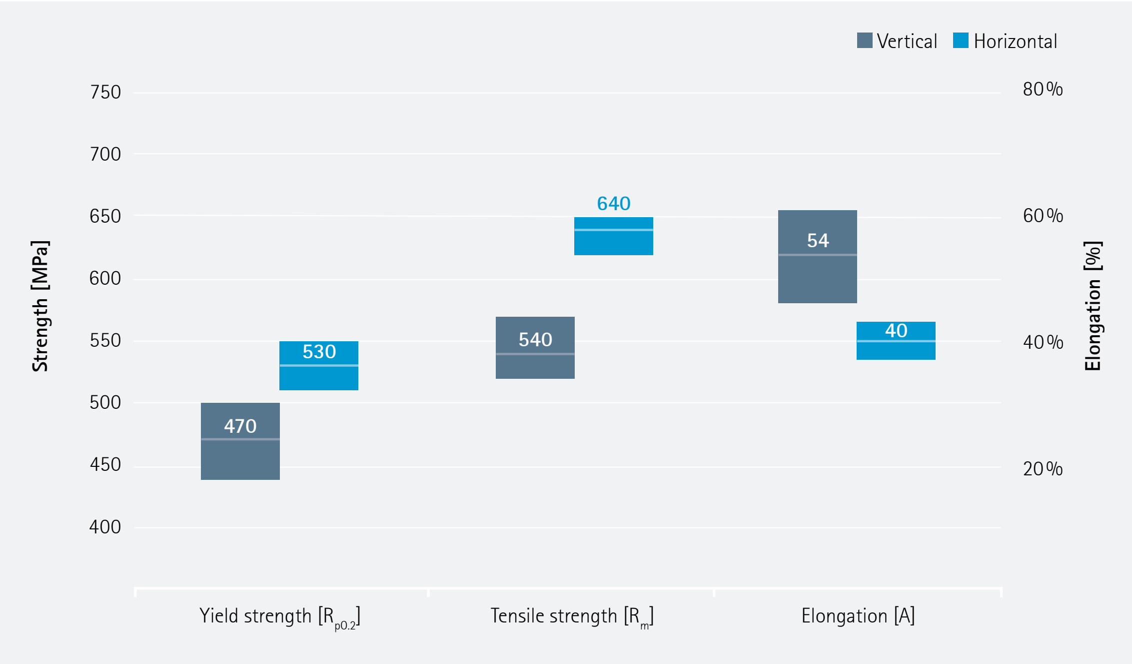
Solution annealing: Hold temperature 1 150 °C, hold time minimum 1.5 h when thoroughly heated, water quenching

Mechanical Properties as manufactured

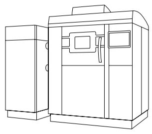


Mechanical properties ISO6892-1

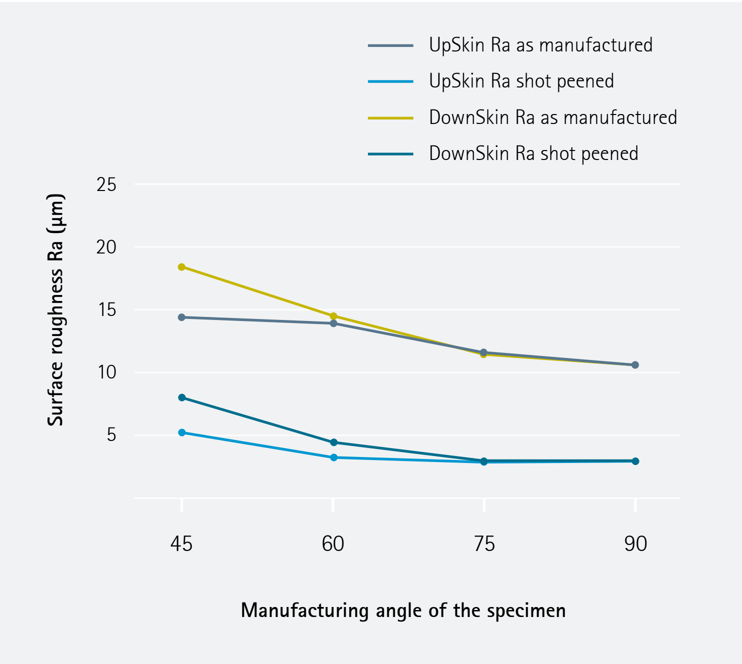
	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	470	540	54	189
Horizontal	530	640	40	162



Additional Data

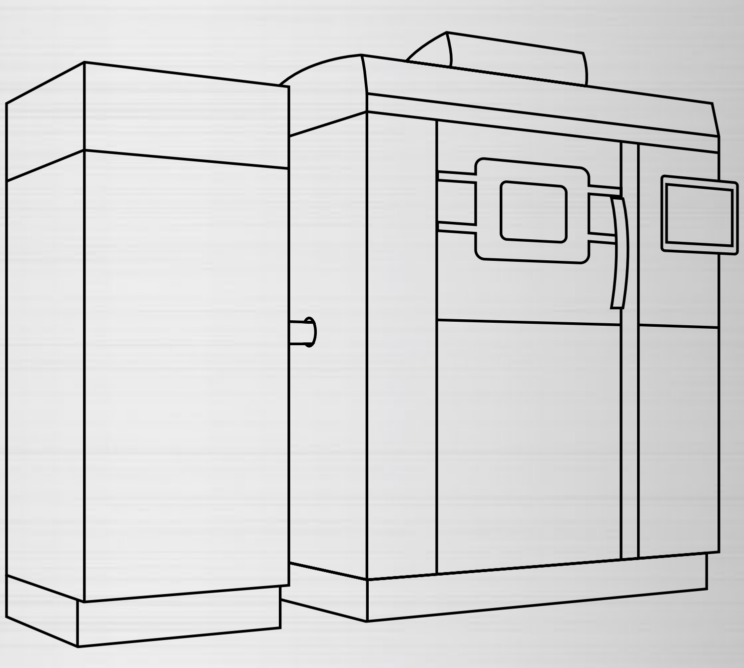


Surface Roughness



Coefficient of Thermal Expansion ASTM E228

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C
CTE	15.72 $*10^{-6}$/K	16.75 $*10^{-6}$/K	17.27 $*10^{-6}$/K	17.70 $*10^{-6}$/K



EOS StainlessSteel 316L
for EOS M 290 | 40 µm

Process Information
Chemical and Physical Part Properties
Heat Treatment
Mechanical Properties
Additional Data

CR365 v03/12.2016

EOS StainlessSteel 316L for EOS M 290 | 40 µm

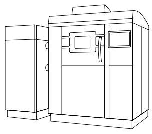
Process Information

This process product is optimized for building high quality parts with EOS M 290 system reliably using EOS StainlessSteel 316L. Mechanical properties have been validated to TRL7 level.

System set-up	EOS M 290
EOS ParameterSet	316L 40µm FlexLine
EOSPAR name	316L_040_FlexM291_1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0032
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	63 µm

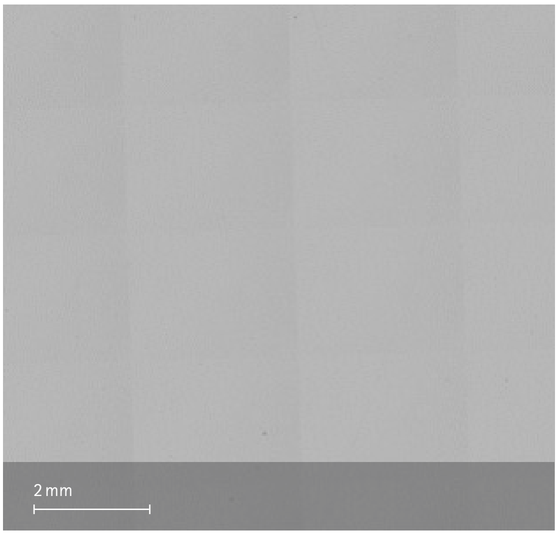
Additional information	
Layer thickness	40 µm
Min. wall thickness	0.1 mm
Typical dimensional change after HT	+0.2 %
Volume rate	3.7 mm^3/s

Chemical and Physical Properties of Parts



Chemical composition of built parts is compliant to EOS StainlessSteel 316L powder chemical composition.

Micrograph of polished surface



Microstructure solution annealed
Etched with etchant Kallings 2

Defects	Result	Number of samples
Average defect percentage	0.015 %	20

Density, ISO3369	Result	Number of samples
Average density	≥ 7.97 g/cm^3	20

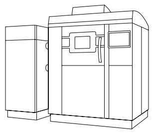
Heat Treatment

Heat treatment according to AMS 2759 is optional.

Stress relief: Hold temperature 900 °C, hold time minimum 2 h when thoroughly heated, water quenching

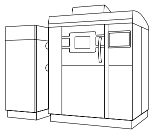
Solution annealing: Hold temperature 1 150 °C, hold time minimum 1.5 h when thoroughly heated, water quenching

Mechanical Properties as manufactured



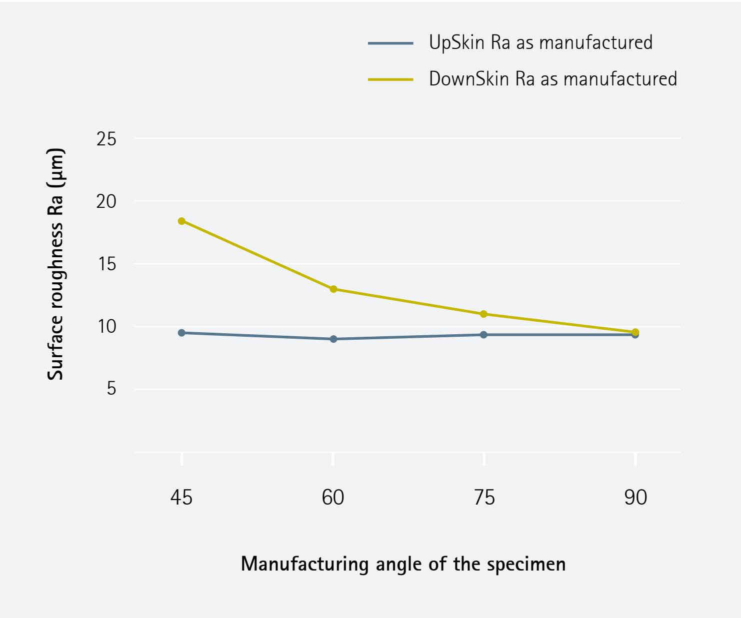
Mechanical properties ISO6892-1

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	480	570	51	105
Horizontal	540	640	40	90



Additional Data

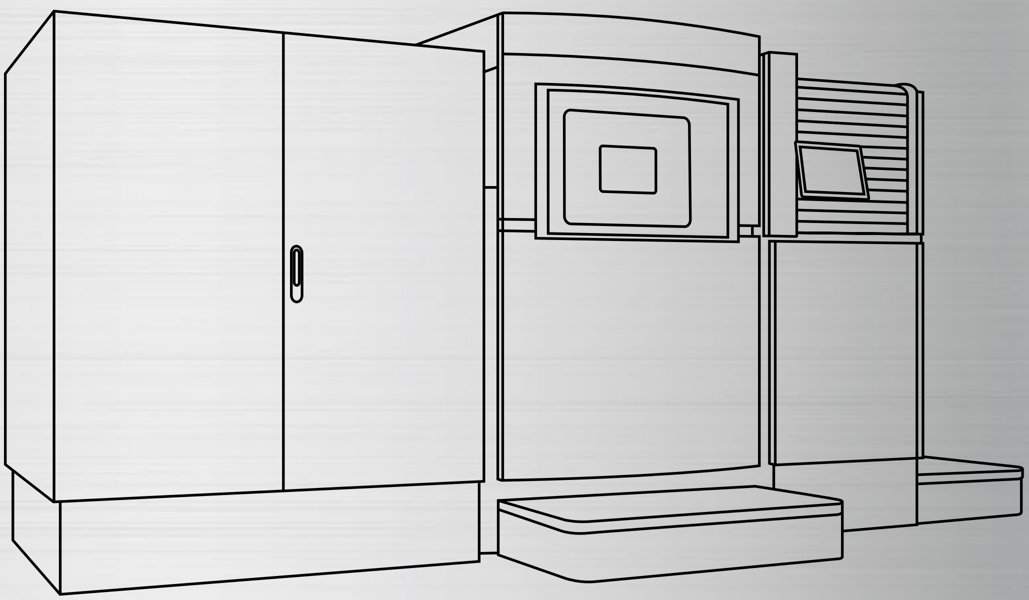
Surface Roughness



Coefficient of Thermal Expansion ASTM E228

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C
CTE	15.72 $*10^{-6}$/K	16.75 $*10^{-6}$/K	17.27 $*10^{-6}$/K	17.70 $*10^{-6}$/K

TRL 7
Premium



EOS StainlessSteel 316L
for EOS M 400-4 | 40 µm

Process Information
Chemical and Physical Part Properties
Heat Treatment
Mechanical Properties
Additional Data

CR543/06-18

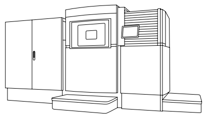
EOS StainlessSteel 316L for EOS M 400-4 | 40 µm
Process Information

This process product is optimized for building high quality parts with EOS M400-4 system using EOS StainlessSteel.

System set-up	EOS M 400-4
EOS ParameterSet	316L 40µm Flex M 400-4
EOSPAR name	316L_040_FlexM404_1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0032
Recoater blade	EOS HSS blade
Inert gas	Argon
Sieve	63 µm

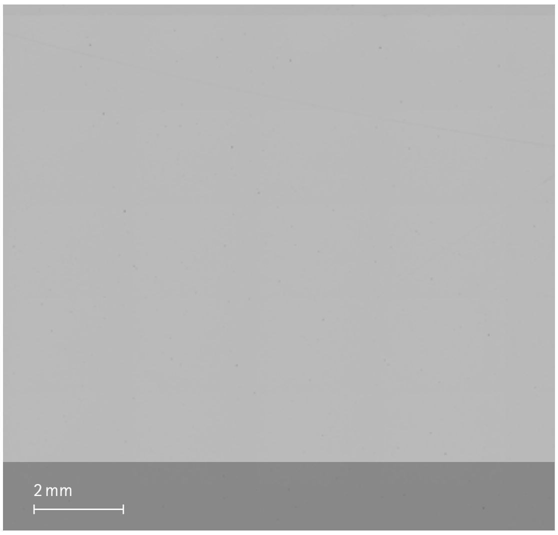
Additional information	
Layer thickness	40 µm
Volume rate	14.8 mm^3/s

Chemical and Physical Properties of Parts



Chemical composition of built parts is compliant to EOS StainlessSteel 316L powder chemical composition.

Micrograph of polished surface



Microstructure solution annealed
Etched with etchant Kallings 2

Defects	Result	Number of samples
Average defect percentage	0.015 %	40

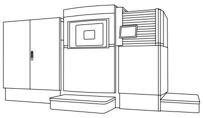
Density, ISO3369	Result	Number of samples
Average density	≥ 7.9 g/cm^3	40

Heat Treatment

Heat treatment according to AMS 2759 is optional.

Stress relief: Hold temperature 900 °C, hold time minimum 2 h when thoroughly heated, water quenching

Solution annealing: Hold temperature 1 150 °C, hold time minimum 1.5 h when thoroughly heated, water quenching



Mechanical Properties as manufactured

Mechanical properties ISO6892-1

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Number of samples
Vertical	490	590	45	120
Horizontal	550	650	40	96

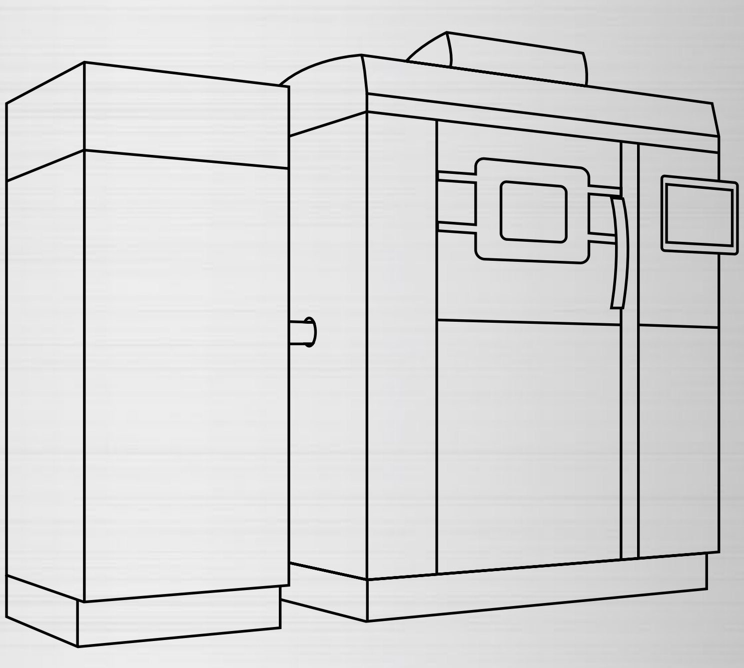
Additional Data

Coefficient of Thermal Expansion ASTM E228

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C
CTE	15.72 $*10^{-6}$/K	16.75 $*10^{-6}$/K	17.27 $*10^{-6}$/K	17.70 $*10^{-6}$/K

TRL 3

Core



EOS StainlessSteel 316L
for EOS M 290 | 40/80 µm

Process Information

Chemical and Physical Part Properties

Heat Treatment

Mechanical Properties

Additional Data

EOS StainlessSteel 316L for EOS M 290 | 40/80 µm
Process Information

This process product is optimized for flexible and fast production of 316L parts with the EOS M 290 system. The parameter set has three different layer thickness options that can all be utilized within the same build: 40 µm, 80 µm and 40/80 µm Skin.

The 40µm parameter set is ideal for parts needing great detail resolution and more dense structure. The 80 µm parameter set offers a build rate that is more than double that of the long established 40 µm parameter set.

With the 40/80 µm Skin parameter set, the total build time can be reduced with the same surface quality. The parameter sets are assigned to different sections in the same build job depending on the requirements.

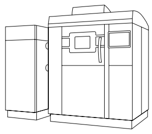
Main characteristics:

- → Parameter set for fast and cost efficient production of 316L parts in small series or serial production
- → With 80 µm parameter 100 % increase in productivity compared to the 40 µm FlexLine parameter set
- → Faster production without compromising the part quality

System set-up	EOS M 290
EOS ParameterSet	316L 40µm+80µm Core M290/400W
EOSPAR name	316L_040_080_Core M291 1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0032
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	63 µm

Additional information	
Layer thickness	40 µm, 80 µm & 40/80 µm Skin
Volume rate*	3.7 mm^3/s (40 µm), 8.4 mm^3/s (80 µm), 3.7 - 8.4 (40/80 µm Skin)

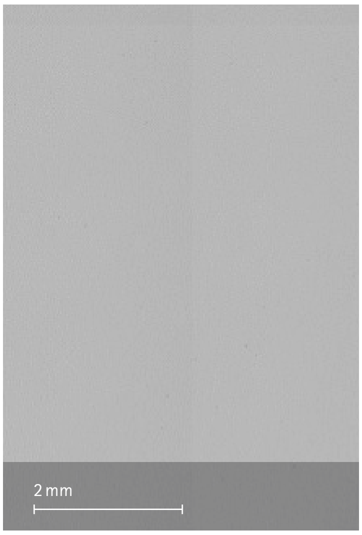
** Volume rate depends on the part dimensions and skin thickness.*



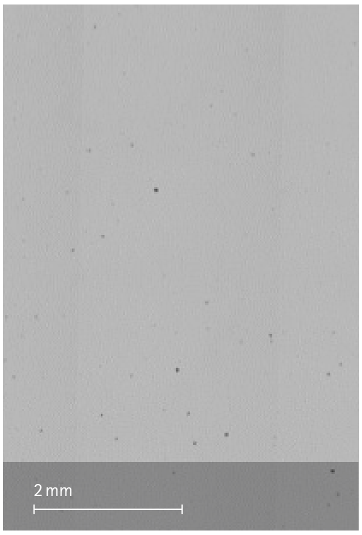
Chemical and Physical Properties of Parts

Chemical composition of built parts
is compliant to EOS StainlessSteel
316L powder chemical composition.

Micrograph of polished surface (40 µm)



Micrograph of polished surface (80 µm)



Microstructure solution annealed
Etched with etchant Kallings 2

Defects	Result
Average defect percentage	0.1 %* (40 µm), < 0.2 %* (80 µm)

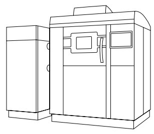
** Defect% varies with platform position.*

Heat Treatment

Heat treatment according to AMS 2759 is optional.

Stress relief: Hold temperature 900 °C, hold time minimum 2 h when thoroughly heated, water quenching

Solution annealing: Hold temperature 1 150 °C, hold time minimum 1.5 h when thoroughly heated, water quenching



Mechanical Properties as manufactured

Typical properties as manufactured ISO 6892-1

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
40 µm horizontal	500	600	35
40 µm vertical	450	550	50
80 µm horizontal	500	600	35
80 µm vertical	450	550	45

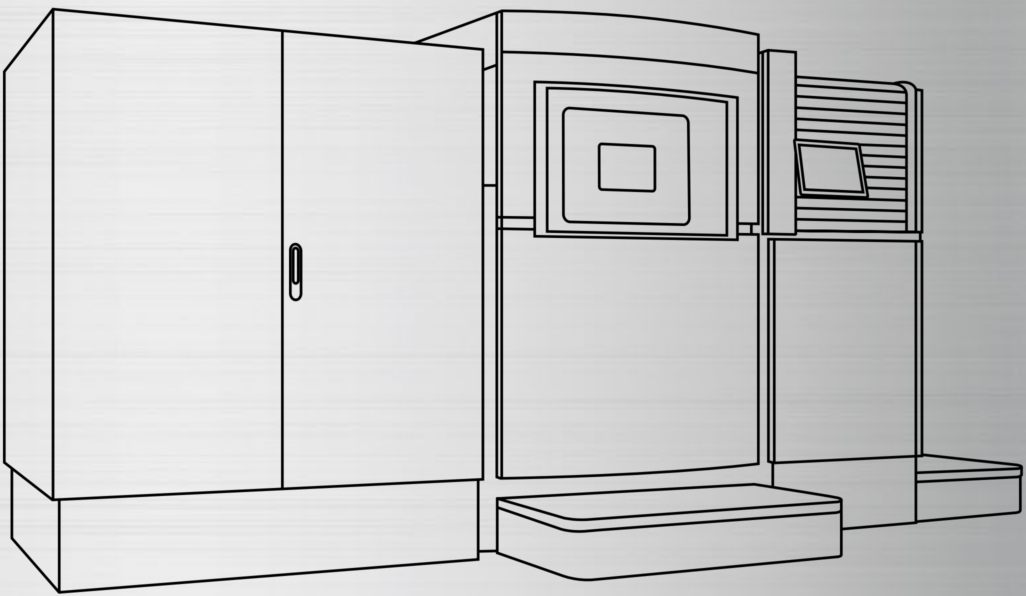
Additional Data

Surface Roughness

Surface roughness	9 - 15 Ra
Surface roughness shot-peened	<5 Ra

Coefficient of Thermal Expansion ASTM E228

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C
CTE	15.72 $*10^{-6}$/K	16.75 $*10^{-6}$/K	17.27 $*10^{-6}$/K	17.70 $*10^{-6}$/K



TRL 3

Core

EOS StainlessSteel 316L
for EOS M 400-4 | 40/80 µm

Process Information

Chemical and Physical Part Properties

Heat Treatment

Mechanical Properties

Additional Data

EOS StainlessSteel 316L for EOS M 400-4 | 40/80 µm

Process Information

This process product is optimized for flexible and fast production of 316L parts with the EOS M 400-4 system. The parameter set has three different layer thickness options that can all be utilized within the same build: 40 µm, 80 µm and 40/80 µm Skin.

The 40 µm parameter set is ideal for parts needing great detail resolution and more dense structure. The 80 µm parameter set offers a build rate that is more than double that of the long established 40µm parameter set.

With the 40/80 µm Skin parameter set, the total build time can be reduced with the same surface quality. The parameter sets are assigned to different sections in the same build job depending on the requirements.

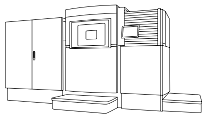
Main Characteristics:

- → Parameter set for fast and cost efficient production of 316L parts in small series or serial production
- → With 80 µm parameter 100 % increase in productivity compared to the 40 µm FlexLine parameter set
- → Faster production without compromising the part quality

System set-up	EOS M 400-4
EOS ParameterSet	316L 40µm+80µm Core M400-4
EOSPAR name	316L_040_080_Core M404 1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0032
Recoater blade	EOS HSS blade
Inert gas	Argon
Sieve	63 µm

Additional information	
Layer thickness	40 µm, 80 µm & 40/80 µm Skin
Volume rate*	14.8 mm^3/s (40µm), 33.6 mm^3/s (80µm) and 14.8 – 33.6 mm^3/s (40/80 µm Skin)

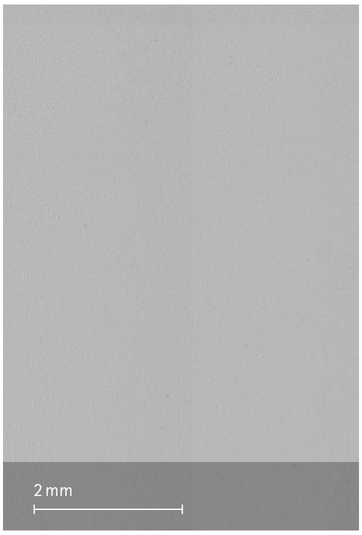
** Volume rate depends on the part dimensions and skin thickness.*



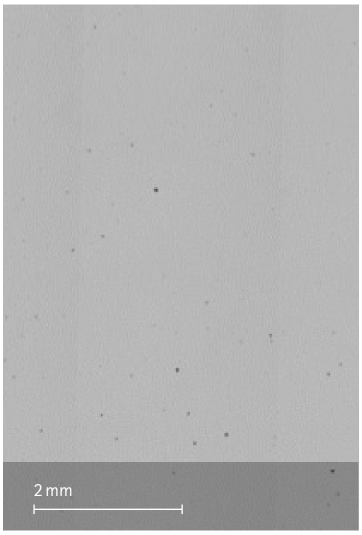
Chemical and Physical Properties of Parts

Chemical composition of built parts is compliant to EOS StainlessSteel 316L powder chemical composition.

Micrograph of polished surface (40 µm)



Micrograph of polished surface (80 µm)



Microstructure solution annealed
Etched with etchant Kallings 2

Defects	Result
Average defect percentage	0.1 %* (40 µm), < 0.2 %* (80 µm)

** Defect% varies with platform position.*

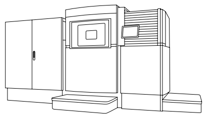
Heat Treatment

Heat treatment according to AMS 2759 is optional.

Stress relief: Hold temperature 900 °C, hold time minimum 2 h when thoroughly heated, water quenching

Solution annealing: Hold temperature 1 150 °C, hold time minimum 1.5 h when thoroughly heated, water quenching

Mechanical Properties as manufactured



Typical properties as manufactured ISO 6892-1

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]
40 µm horizontal	500	600	35
40 µm vertical	450	550	50
80 µm horizontal	500	600	35
80 µm vertical	450	550	45

Additional Data

Surface Roughness

Surface roughness	9 - 15 Ra
Surface roughness shot-peened	<5 Ra

Coefficient of Thermal Expansion ASTM E228

Temperature	25-100 °C	25-200 °C	25-300 °C	25-400 °C
CTE	15.72 *10^{-6}/K	16.75 *10^{-6}/K	17.27 *10^{-6}/K	17.70 *10^{-6}/K

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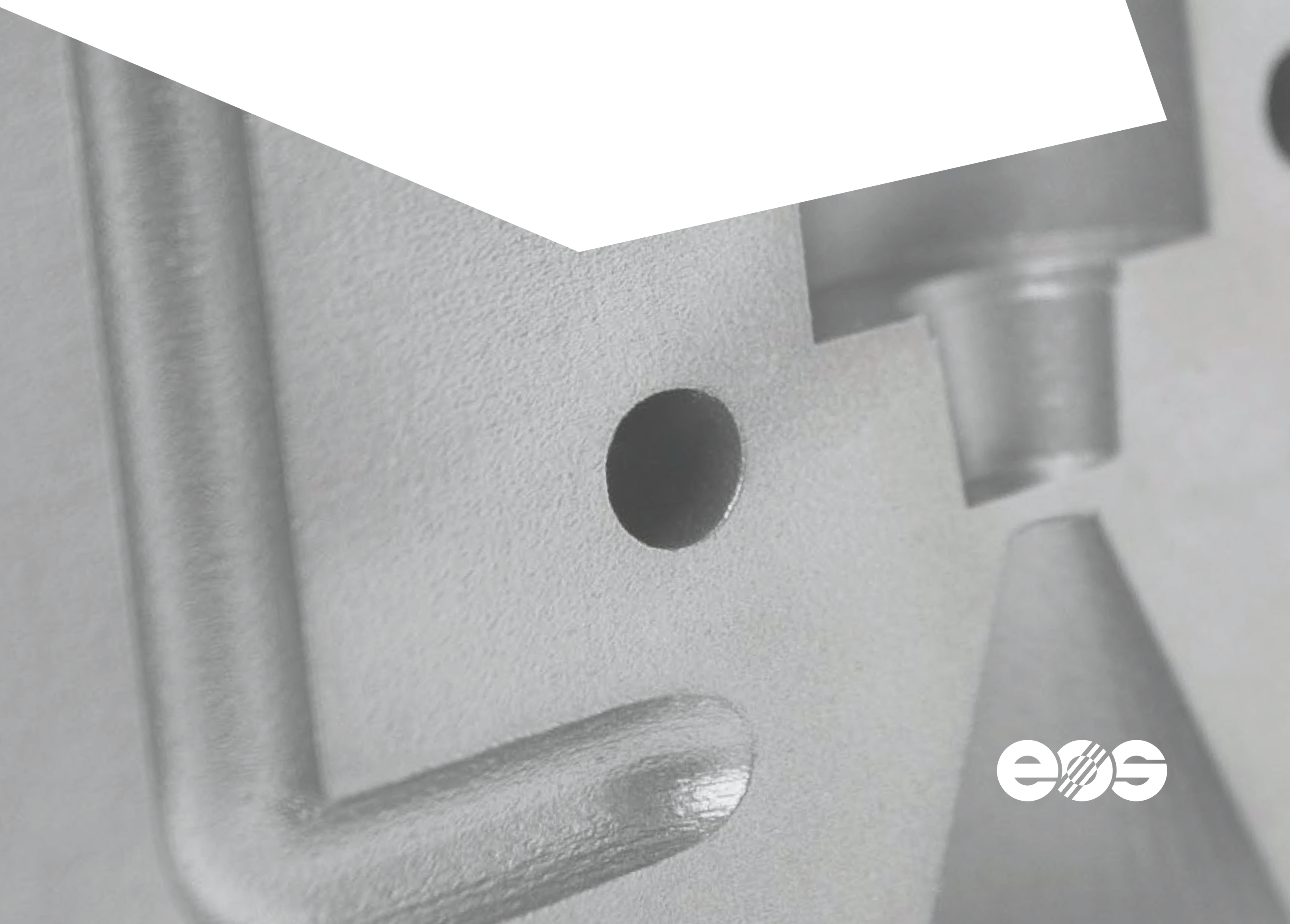
Status 09/2020

Metal
Solutions

TRL 8
Premium

EOS StainlessSteel CX
Material Data Sheet



EOS StainlessSteel CX
Combines Corrosion Resistance with High Strength and Hardness

EOS StainlessSteel CX is a tooling grade steel characterized by having a good corrosion resistance combined with high strength and hardness. Parts built from EOS StainlessSteel CX can be machined, shot-peened and polished in as manufactured or heat treated state.

Main Characteristics:

- Stainless steel with excellent corrosion resistance combined with high strength and hardness
- The parts are easily machinable and offer excellent polishability
- The parts offer excellent wear and fatigue resistance

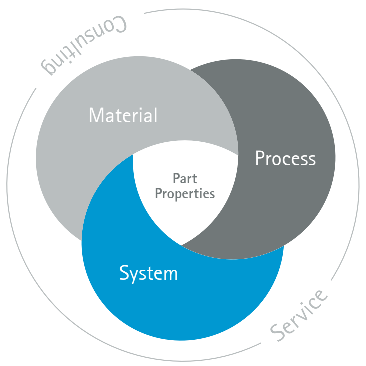
Typical Applications:

- Plastic injection molding tools and tool parts for demanding applications
- Rubber molding tools and tool parts
- Molding tools and tool parts for corrosive plastics
- Other industrial applications where high strength and hardness are required

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.

All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.



Powder Properties

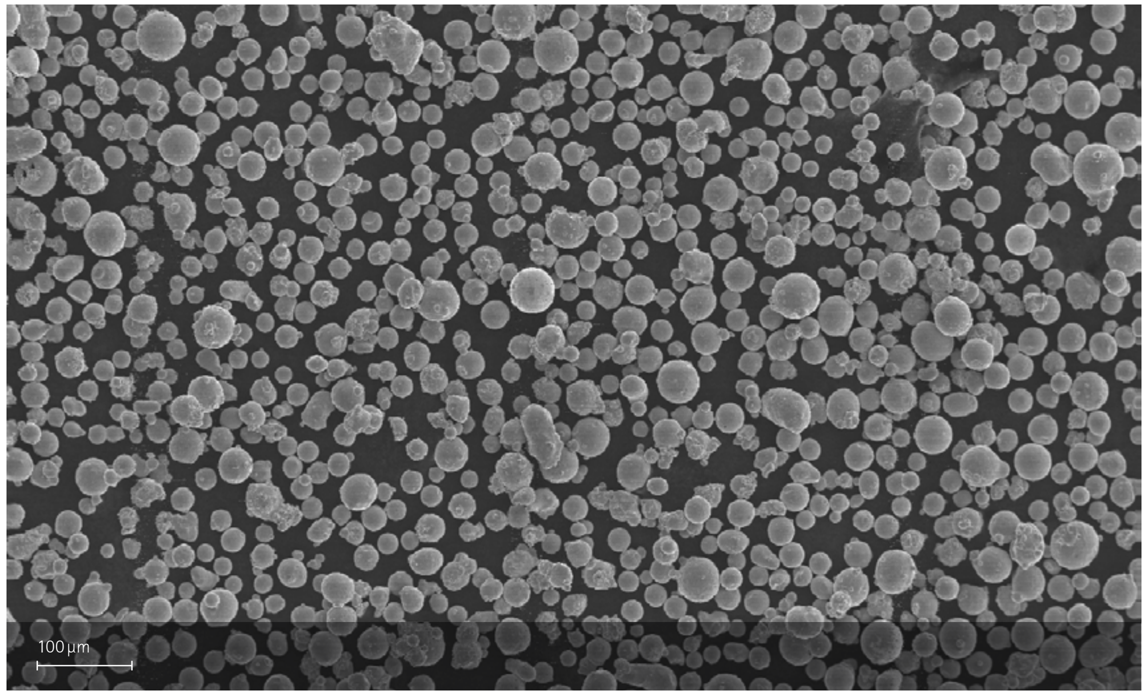
Powder chemical composition (wt.-%)

Element	Min.	Max.
Fe	Balance	
Cr	11.00	13.00
Ni	8.40	10.00
Mo	1.10	1.70
Al	1.20	2.00
Mn	–	0.40
Si	–	0.40
C	–	0.05

Powder particle size

Generic particle size distribution	20 – 65 µm

SEM image of EOS StainlessSteel CX powder.



Process Information

System set-up	EOS M 290
EOS ParameterSet	M 290 CX 030 V1
EOSPAR name	CX_030_HiPerM291_100
Software requirements	EOSPRINT 2.3 or newer EOSYSTEM 2.8 or newer
Powder part no.	9011-0037
Recoater blade	EOS ceramic blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	63 µm

Additional information	
Layer thickness	30 µm
Volume rate	3.2 mm³/s
Min. wall thickness	Approx. 0.4 mm
Typical dimensional change after HT (for parts ø 50 mm)	0.1 %

Heat Treatment

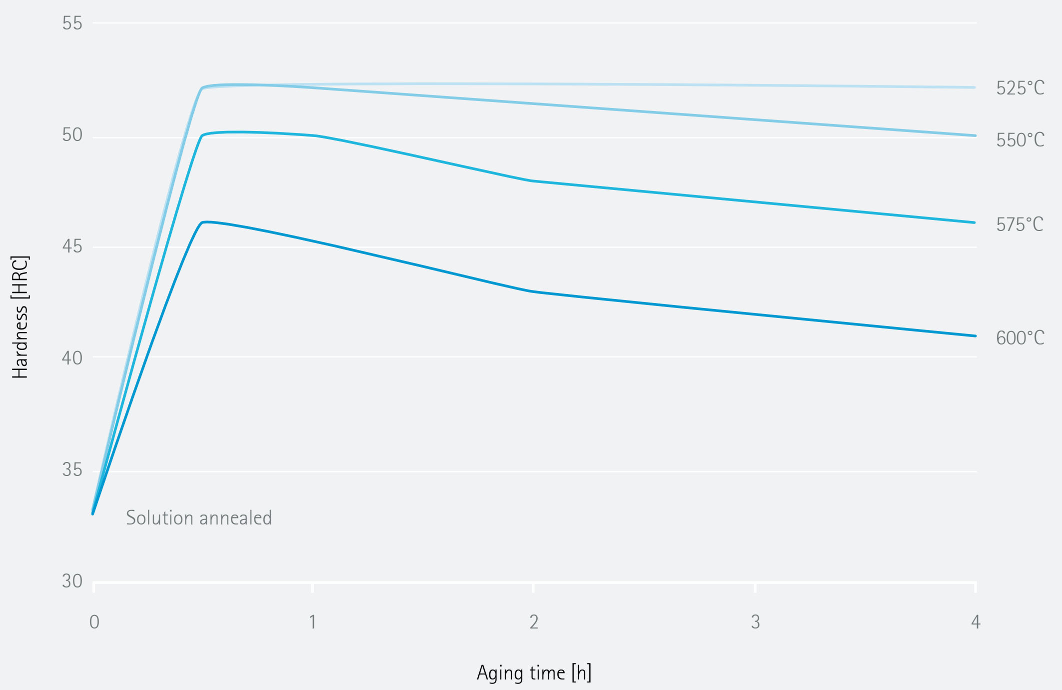
EOS StainlessSteel CX can be heat treated to match various needs of different applications. The two step heat treatment can be performed under vacuum or inert gas atmosphere. First step is solution annealing to minimize amount of austenite in the martensitic matrix. The needed hardness and strength is achieved through aging treatment where precipitation hardening takes place.

Solution Annealing:
30 minutes at 850 °C (±10 °C) measured from the part followed by rapid air cooling to room temperature (below 32 °C). Cooling rate 20-60 °C/min.
Reaching room temperature before starting aging treatment is required to achieve desired microstructure.

Aging:
For peak hardness and strength 2 h at 525 °C (±10 °C) measured from the part followed by air cooling. Mechanical properties presented in this document achieved through this aging procedure.

If lower hardness and improved toughness is required aging temperature can be increased according to figure below.

Hardness after heat treatment



Chemical and Physical Properties of Parts

Chemical composition of built parts is compliant to EOS StainlessSteel CX powder chemical composition.

Heat treated microstructure. Etching; ASTM E407-94

Defects	Result	Number of samples
Average defect percentage	0.03 %	65
Density, ISO3369	**Result**	**Number of samples**
Average density	7.69 g/cm³	65

The areal defect percentage was determined from cross-cuts of the built parts using an optical microscope fitted with a camera and analysis software. The analysis was carried out for sample area of 15 x 15 mm. The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images. The density of the built specimen was measured according to ISO3369.

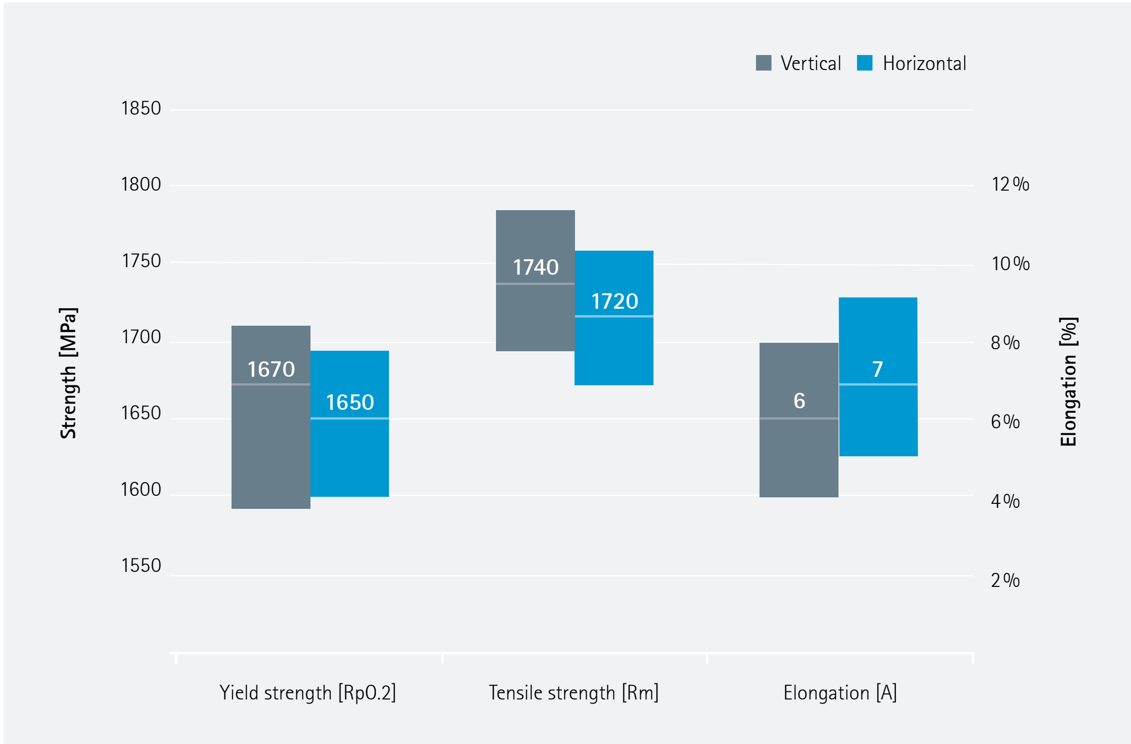
Mechanical Properties in Heat Treated State

Mechanical properties ISO6892-1

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Number of samples
Vertical	1670	1740	6	189
Horizontal	1650	1720	7	162

Hardness in heat treated state ISO6508

Hardness, HRC	50
Number of samples	45



Additional Data

Fatigue Strength

Fatigue strength determines a stress level where specimen fails at a defined number of stress cycles [ISO 12107]. Fatigue strength was estimated statistically according to ISO 12107.

Testing was done according to ASTM E466. Fatigue results typically show large deviations due to the nature of the fatigue process [ISO 12107].

Fatigue strength at 1 x 10^7 cycles in heat treated state ASTM E466	
Fatigue strength, MPa	695

Corrosion Resistance Comparison of Tooling and Precipitation Hardening Steels

EOS Material	Hardness [HRC]	Corrosion resistance
EOS MaragingSteel MS1	55	–
EOS StainlessSteel CX	50	●●●●
EOS StainlessSteel PH1	43	●●●●
EOS StainlessSteel 17-4PH	42	●●●●●

Corrosion Resistance
Corrosion resistance comparison between EOS tooling and precipitation hardening steels based on potentiodynamic measurement data.

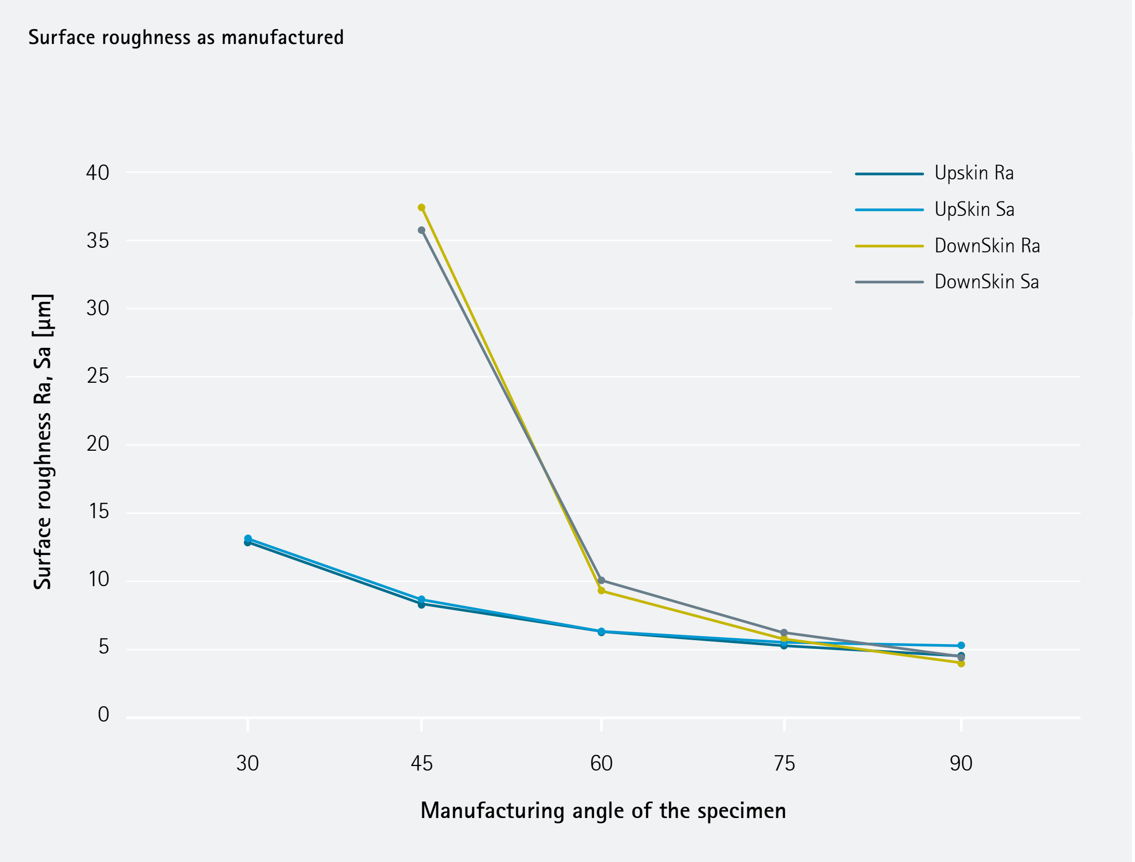
Coefficient of Thermal Expansion ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25 – 300 °C	25 – 400 °C
CTE	11.1 *10^{-6}/K	11.6 *10^{-6}/K	11.9 *10^{-6}/K	12.0 *10^{-6}/K

Additional Data

Surface Roughness

Horizontal surface	Ra 7.5 µm, Sa 9.0 µm
Vertical and angled surfaces according to figure	



The surface quality was characterized by optical measurement method according to internal procedure. The 90 degree angle corresponds to vertical surface.

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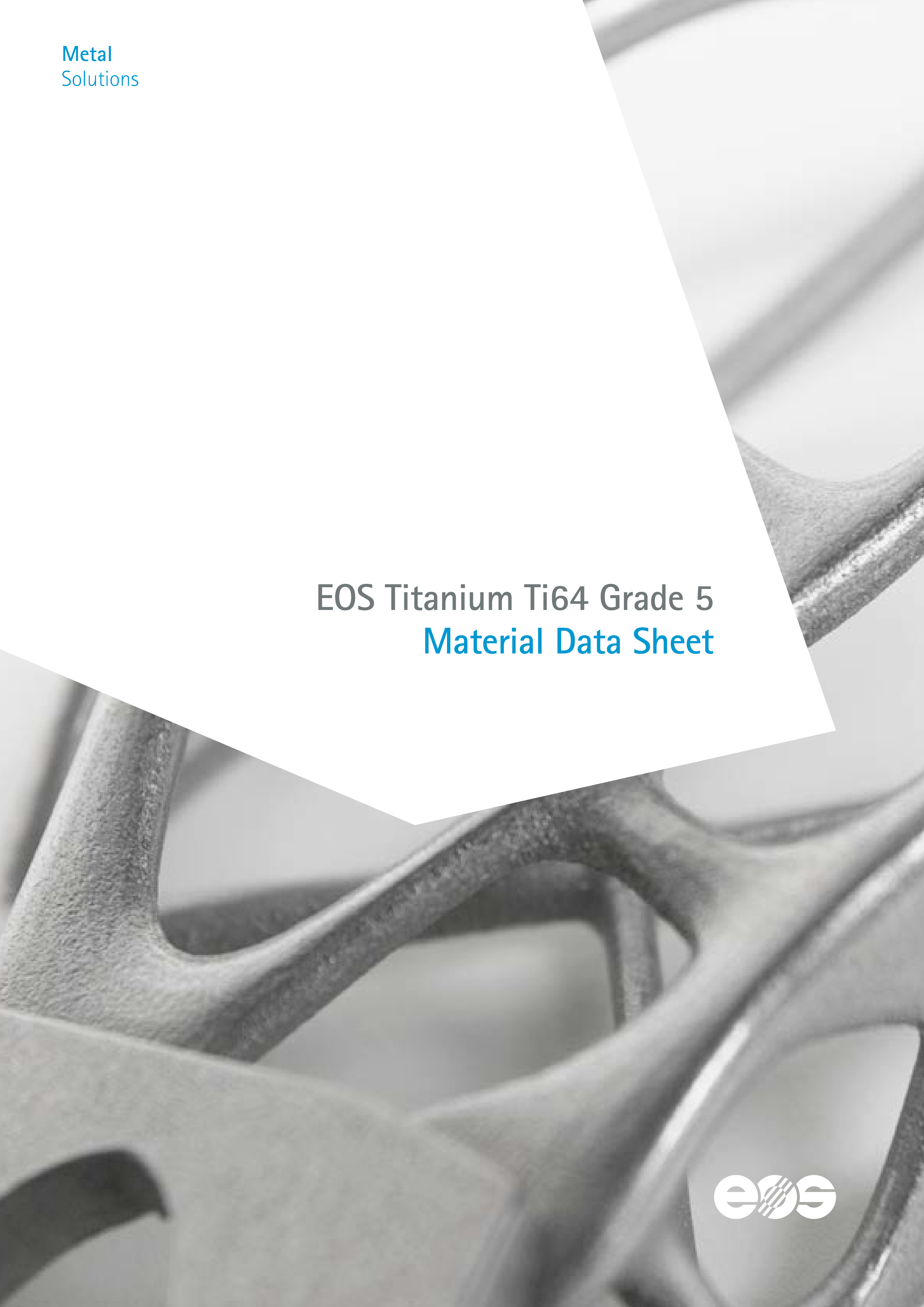
Status 07/2019 (V2.0, CR681, 2019-05)

Cover: This image shows a possible application.

Metal
Solutions



EOS Titanium Ti64 Grade 5
Material Data Sheet

EOS Titanium Ti64 Grade 5

EOS Titanium Ti64 Grade 5 is a Ti6Al4V alloy, which is well-known for having excellent mechanical properties: low density with high strength and excellent corrosion resistance. The alloy has low weight compared to superalloys and steels and higher fatigue resistance compared to other lightweight alloys.

Parts built with EOS Titanium Ti64 Grade 5 powder can be machined, shot-peened and polished in as manufactured and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy. Heat treatment is recommended to reduce internal stresses and increase ductility.

EOS Titanium Ti64 Grade 5 powder can be used on the EOS M 290 with a 40 µm and 80 µm process and on the EOS M 400-4 with an 80 µm process.

Main Characteristics:

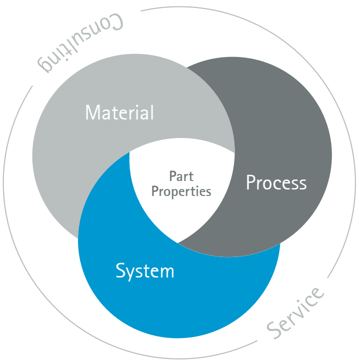
- → Low weight combined with high strength
- → Excellent corrosion resistance
- → High fatigue resistance compared to other lightweight alloys
- → The parts fulfill chemical requirements for Grade 5 alloy

Typical Applications:

- → Aerospace components
- → Automotive components
- → Other industrial applications where low weight in combination with high strength are required

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.



All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

EOS Titanium Ti64 Grade 5 powder is classified as Grade 5 titanium alloy according to ASTM B348. The chemical composition is in compliance with standards ISO5832-3, ASTM F1472, ASTM F2924, and ASTM F3302.

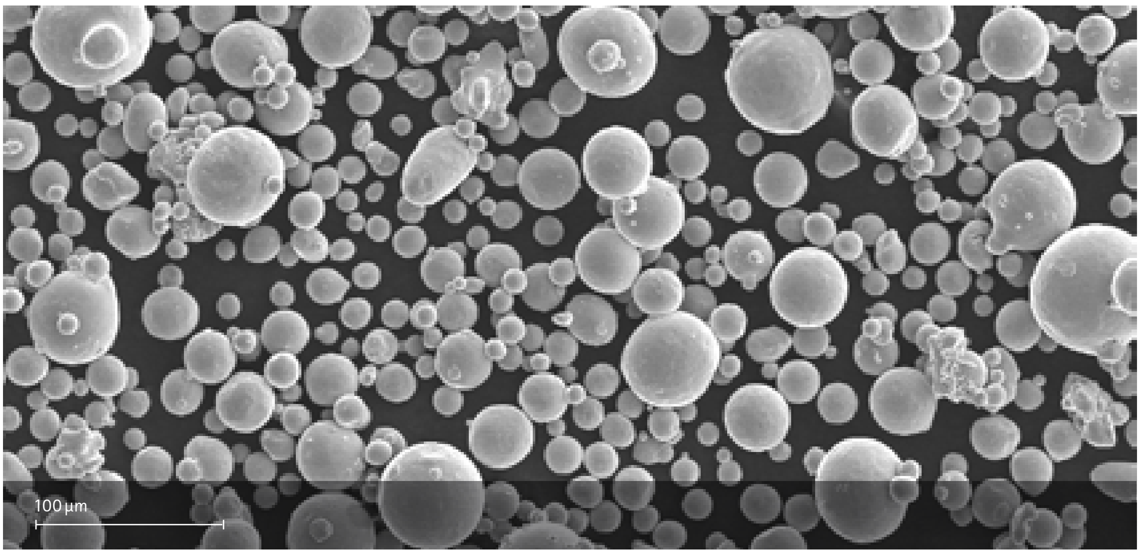
Powder chemical composition (wt.–%)

Element	Min.	Max.
Ti	Balance	
Al	5.50	6.75
V	3.50	4.50
O	-	0.20
N	-	0.05
C	-	0.08
H	-	0.015
Fe	-	0.30
Y	-	0.005
Other elements, each	-	0.10
Other elements, total	-	0.40

Powder particle size

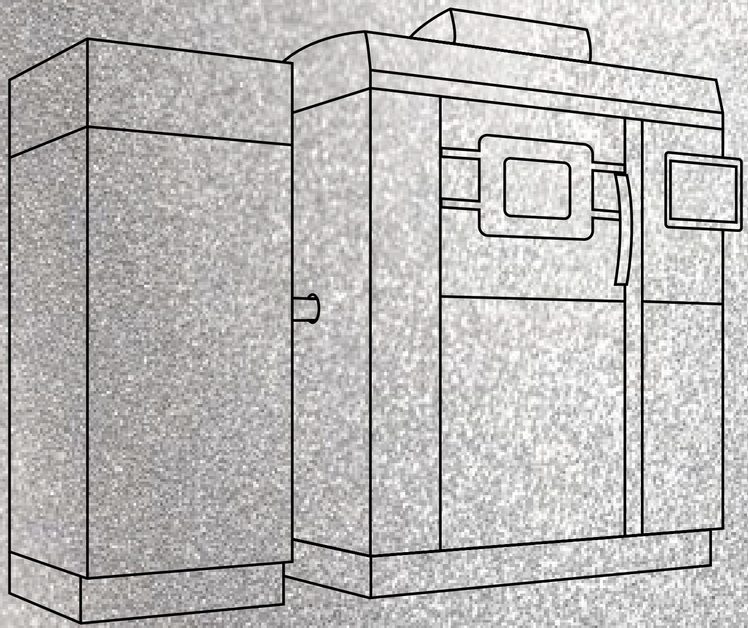
Generic particle size distribution	20 – 80 µm

SEM picture of EOS Titanium Ti64 Grade 5 powder.



TRL 7

Premium



EOS Titanium Ti64 Grade 5
for EOS M 290 | 40 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

V1.0, CR617, 2019-02

EOS Titanium Ti64 Grade 5 for EOS M 290 | 40 µm

High Fatigue Strength without HIP

This process product was developed specifically for the production of parts with high fatigue strength without the need for Hot Isostatic Pressing (HIP).

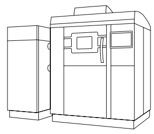
Main characteristics:

- Robust production of parts in small series and series production
- Improved fatigue strength compared to previous generation EOS Titanium Ti64 products
- Possibility for shortened overall production time by avoiding HIP as post-process treatment step

Process Information

System set-up	EOS M 290
EOS ParameterSet	M 290 Ti64 Grade 5 040 V1
EOSPAR name	Ti64Grade5_040_HiPerM291_100
Software requirements	EOSPRINT 2.5 or newer EOSYSTEM 2.8 or newer
Powder part no.	9011-0045
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	40 µm
Min. wall thickness	Approx. 0.4 mm
Volume rate	6.2 mm^3/s



Chemical and Physical Properties of Parts

The chemical composition of parts is in compliance with standards ISO5832-3, ASTM F1472, ASTM F2924, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 5 powder.

Heat treated microstructure. Etched according to ASTM E407 modified recipe #190.

The areal defect percentage was determined from cross-cuts of the built parts using optical microscope fitted with a camera and analysis software. The analysis was carried out for a sample area of 15 x 15 mm. The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images. The density of the built specimen was measured according to ISO3369.

Defects	Result	Number of samples
Average defect percentage	0.01 %	30
Density, ISO3369	**Result**	**Number of samples**
Average density	$\geq 4.4\ g/cm^3$	10

Heat Treatment

As manufactured microstructure for additively manufactured Ti64 consists of fully acicular alpha prime (α′) phase. Standard heat treatments for titanium do not necessarily produce desired microstructures due to this different starting microstructure.

Heat treatment is recommended to relieve stresses and to increase ductility. Use of vacuum furnace is highly recommended to avoid the formation of alpha case on the surface of the parts.

Heat Treatment Description:
120 min (± 30 min) at 800 °C (± 10 °C) measured from the part in vacuum (1.3×10^{-3} - 1.3×10^{-5} mbar) followed by cooling under vacuum or argon quenching. Material mechanical properties are relatively insensitive to changes in heating and cooling rates, but longer treatment times may result in decreased strength and increased elongation.

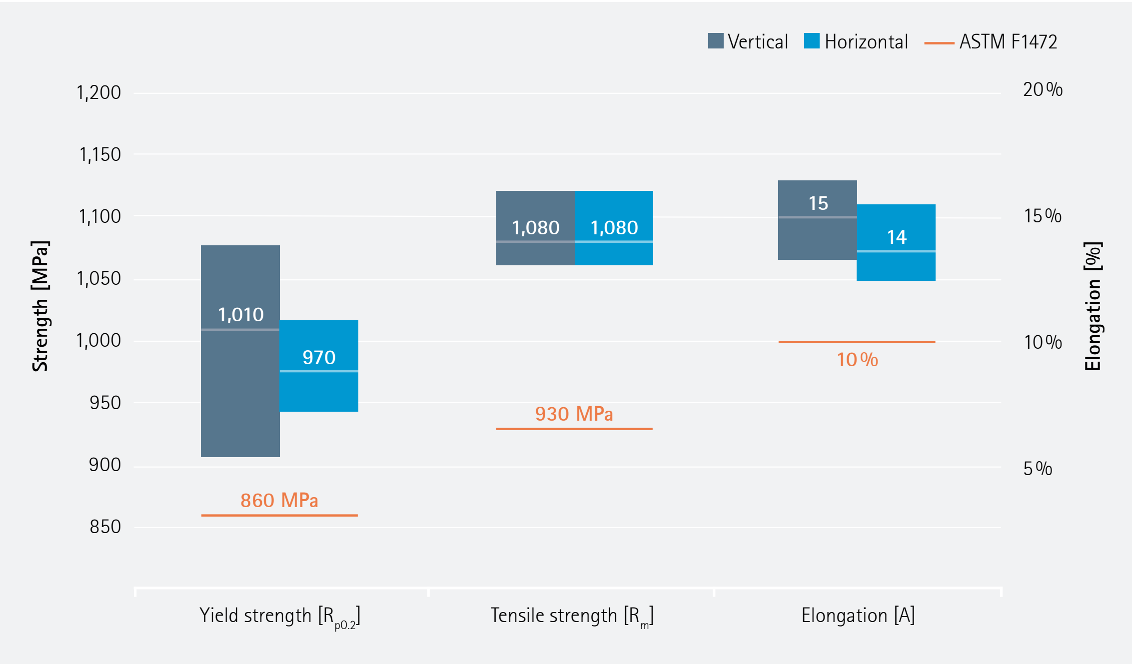
Parts heat treated according to the recommended heat treatment have a microstructure consisting of fine alpha + beta (α + β) phase.

EOS Titanium Ti64 Grade 5 for EOS M 290 | 40 µm

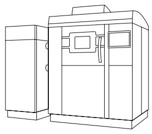
Mechanical Properties in Heat Treated State

Mechanical properties ISO6892-1

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Reduction of area Z [%]	Number of samples
Vertical	1,010	1,080	15	≥ 25	84
Horizontal	970	1,080	14	≥ 25	72



Additional Data

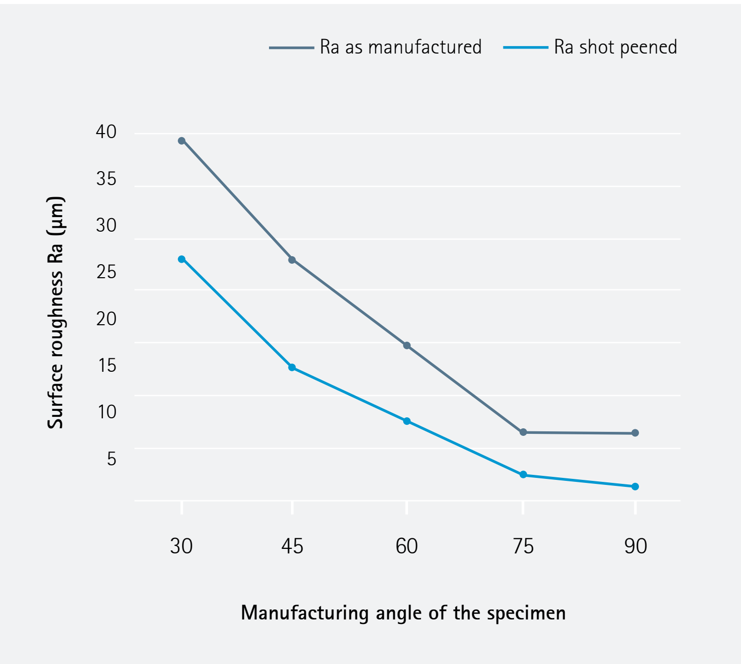


Fatigue Strength

Fatigue strength determines a stress level where specimen fails at a defined number of stress cycles [ISO 12107]. Fatigue strength was estimated statistically according to ISO 12107. Testing was done according to ASTM E466. Fatigue results typically show large deviations due to the nature of the fatigue process [ISO 12107].

Fatigue strength at 1 x 10^7 cycles in heat treated state	
Fatigue strength, MPa	595 MPa

Surface Roughness

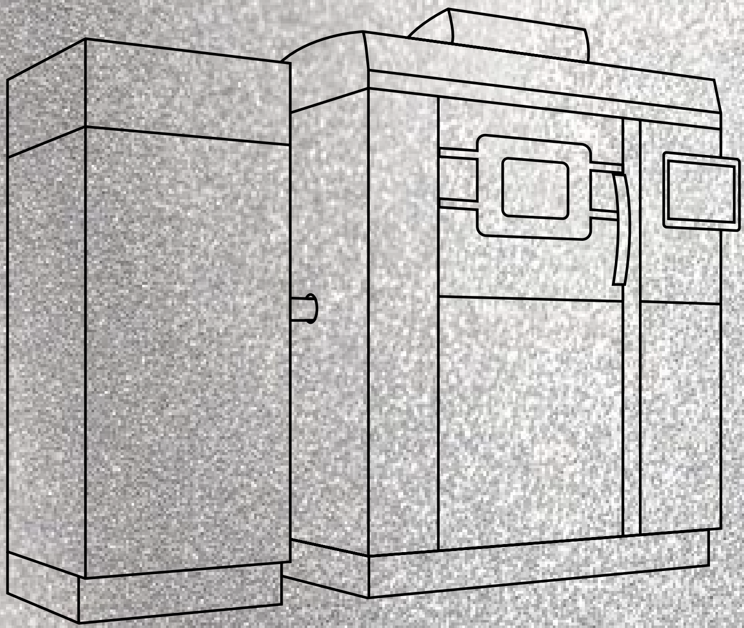


The surface quality was characterized by optical measurement method from down-facing surfaces according to internal procedure. The 90 degree angle corresponds to vertical surface.

Coefficient of Thermal Expansion ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25 – 300 °C
CTE	9.0 $*10^{-6}$/K	9.4 $*10^{-6}$/K	9.7 $*10^{-6}$/K

TRL 3
Core



EOS Titanium Ti64 Grade 5
for EOS M 290 | 80 µm

Process Information
Physical Part Properties

V1.0, preCR09, 2020-04

EOS Titanium Ti64 Grade 5 for EOS M 290 | 80 µm

Process Information

This process product is optimized for faster production of parts with properties according to ASTM F1472. For most demanding applications, Hot Isostatic Pressing (HIP) is recommended to optimize high cycle fatigue properties

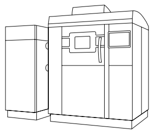
Main Characteristics:

- → Parameter set for fast and cost efficient production of Ti64 parts in small series or serial production
- → 15 - 30 % faster than EOS Ti64 Speed (60 µm) parameter set
- → 50 % faster than EOS Ti64 Grade 5 HiPer (40 µm) parameter set
- → Material fulfills ASTM F2924 mechanical requirements in heat treated state. For fatigue critical applications, HIP is recommended as post-treatment.

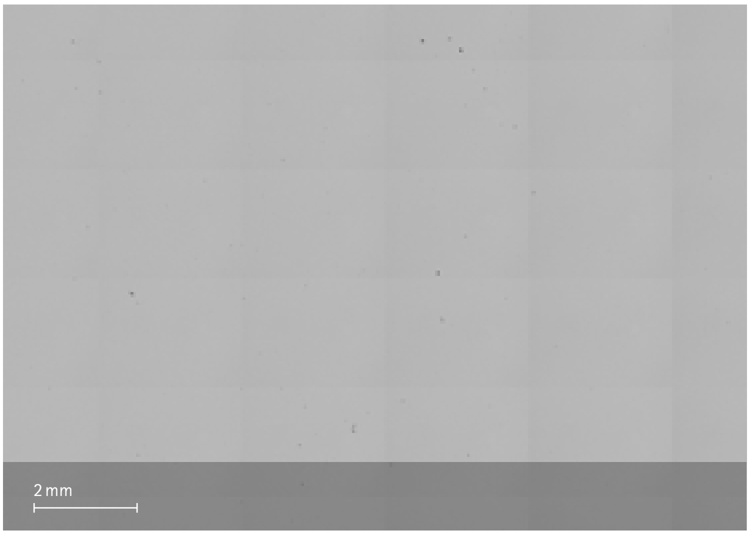
System set-up	EOS M 290
EOS ParameterSet	M 290 Ti64 Grade 5 080 V1
EOSPAR name	Ti64Grade5_080_CoreM291_100
Software requirements	EOSPRINT 2.5 or newer EOSYSTEM 2.8 or newer
Powder part no.	9011-0045
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	80 µm
Volume rate	12.0 mm^3/s

Chemical and Physical Properties of Parts



The chemical composition of parts is in compliance with standards ISO5832-3, ASTM F1472, ASTM F2924, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 5 powder.



Defects	**Result**
Average defect percentage	<0.1 %*
Surface roughness Ra	**Result**
Vertical	9 µm

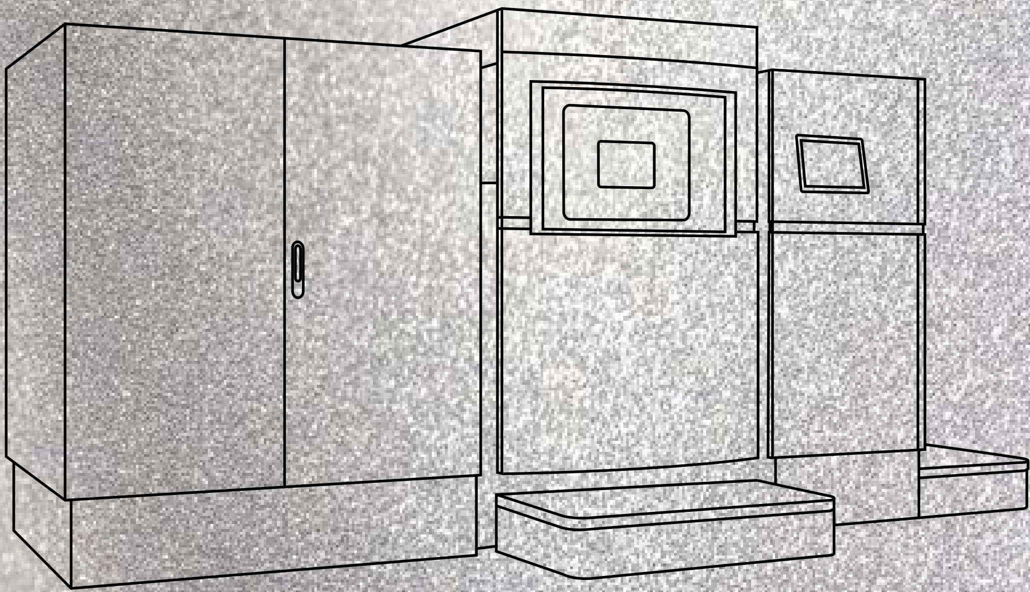
** Defect% varies with platform position.*

Typical properties

	Yield strength $R_{p0.2}$ [MPa]	**Tensile strength** R_m [MPa]	**Elongation at break** A [%]	**Reduction of area** Z [%]	**Fatigue strength N = 9**
Heat treated horizontal	1,000	1,100	15	> 25	-
Heat treated vertical	1,020	1,110	15**	> 25**	
HIP horizontal	900	1,010	16	> 25	675 MPa
HIP vertical	920	1,020	16	> 25	

High cycle fatigue strength was estimated statistically according to ISO 12107.
Testing was done according to ASTM E466 with run-out limit 10^7 cycles.
*** Mean values above the standard limit, some outliers below the limit.*

TRL 3
Core



EOS Titanium Ti64 Grade 5
for EOS M 400-4 | 80 µm

Process Information
Physical Part Properties

V1.0, preCR09, 2020-04

EOS Titanium Ti64 Grade 5 for EOS M 400-4 | 80 µm

Process Information

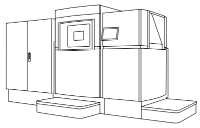
This process product is optimized for faster production of parts with properties according to ASTM F1472. For most demanding applications, Hot Isostatic Pressing (HIP) is recommended to optimize high cycle fatigue properties

Main Characteristics:

- Parameter set for fast and cost efficient production of Ti64 parts in small series or serial production
- 15 - 30 % faster than EOS Ti64 Speed (60 µm) parameter set
- Material fulfills ASTM F2924 mechanical requirements in heat treated state. For fatigue critical applications, HIP is recommended as post-treatment.

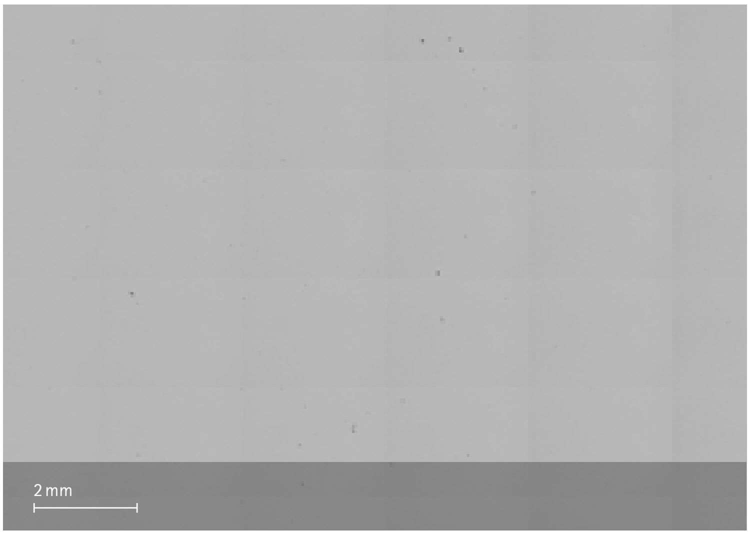
System set-up	EOS M 400-4
EOS ParameterSet	M 400-4 Ti64 Grade 5 080 V1
EOSPAR name	Ti64Grade5_040_080_CoreM404 1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0045
Recoater blade	EOS HSS blade
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	80 µm
Volume rate	4 x 12.0 mm^3/s



Chemical and Physical Properties of Parts

The chemical composition of parts is in compliance with standards ISO5832-3, ASTM F1472, ASTM F2924, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 5 powder.



Defects	Result
Average defect percentage	<0.1 %*
Surface roughness Ra	**Result**
Vertical	9 µm

** Defect% varies with platform position.*

Typical properties

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Reduction of area Z [%]	Fatigue strength N = 9
Heat treated horizontal	990	1,090	15	> 25	-
Heat treated vertical	1,010	1,090	14**	> 25**	
HIP horizontal	890	1,000	16	> 25	563 MPa
HIP vertical	910	1,010	16	> 25	

High cycle fatigue strength was estimated statistically according to ISO 12107.
Testing was done according to ASTM E466 with run-out limit 10^7 cycles.
*** Mean values above the standard limit, some outliers below the limit.*

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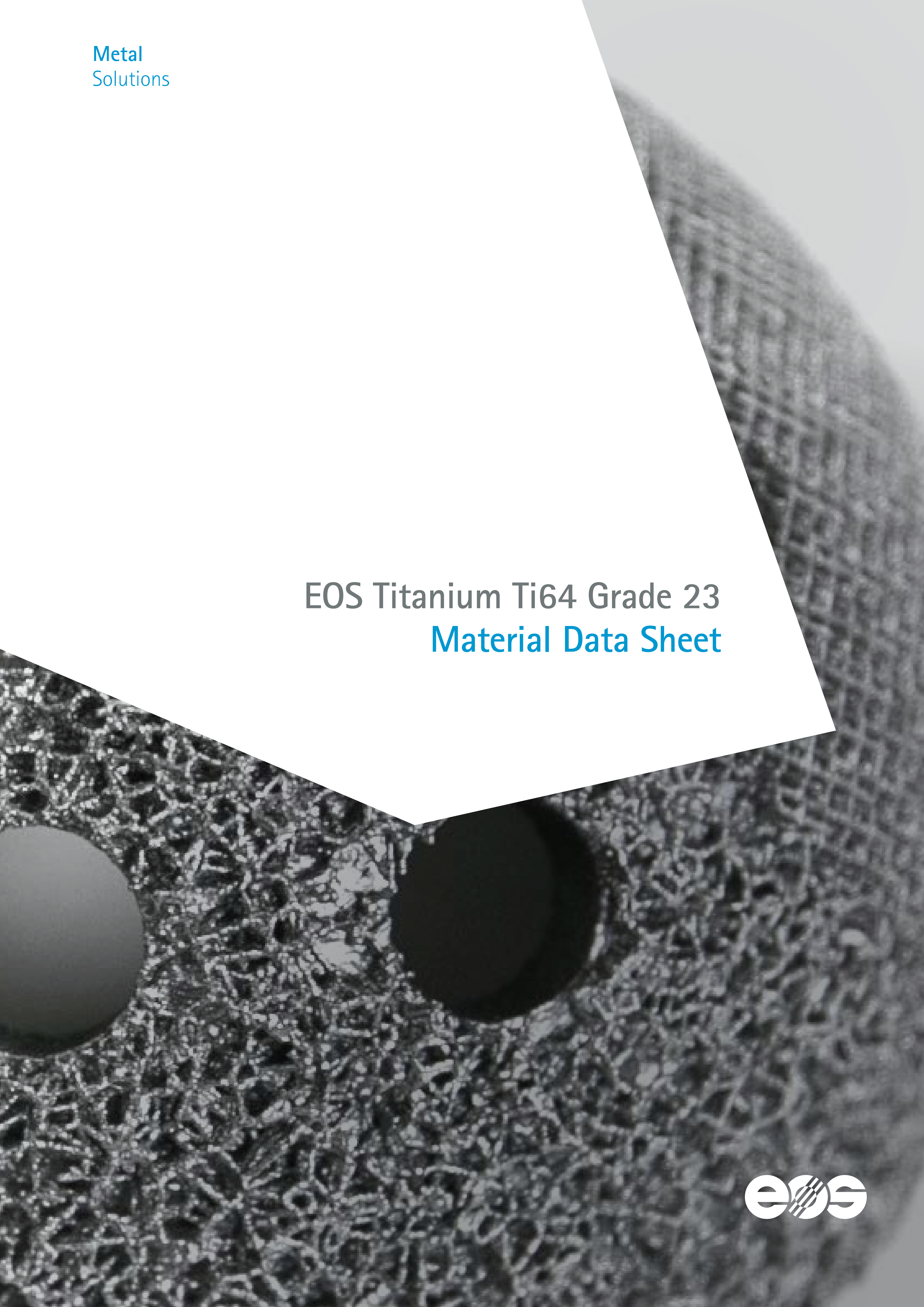
Status 07/2020

Cover: This image shows a possible application.

The quoted values refer to the use of this material with above specified type of EOS DMLS system, EOSYSTEM and EOSPRINT 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. EOS does not warrant any properties or fitness for a specific purpose, unless explicitly agreed upon. This also applies regarding any rights of protection as well as laws and regulations.

Metal
Solutions

EOS Titanium Ti64 Grade 23
Material Data Sheet



EOS Titanium Ti64 Grade 23

EOS Titanium Ti64 Grade 23 is a Ti6Al4V alloy with lower amount of oxygen and iron compared to the standard Ti64 alloy. The material is well-known for having excellent mechanical properties: low density with high strength and excellent corrosion resistance.
Compared to Ti64, Ti64ELI has better elongation and toughness, but lower strength. Generally, Ti64ELI alloys are considered to be biocompatible and have low specific weight compared to CoCr alloys.

Parts built with EOS Titanium Ti64 Grade 23 powder can be machined, shot peened and polished in as manufactured and heat treated states.
Due to the layerwise building method, the parts have a certain anisotropy. Heat treatment is recommended to reduce internal stresses and increase ductility.

EOS Titanium Ti64 Grade 23 powder can be used on the EOS M 290 with a 40 µm and 80 µm process and on the EOS M 400-4 with an 80 µm process.

Main Characteristics:

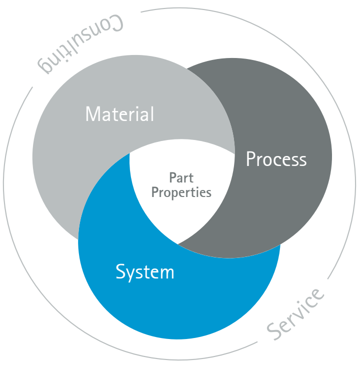
- Low weight combined with high strength
- Excellent corrosion resistance
- High fatigue resistance compared to other lightweight alloys
- The parts fulfill chemical requirements for Grade 23 alloy

Typical Applications:

- Medical components
- Implants
- Other industrial applications where low weight in combination with high strength are required

The EOS Quality Triangle

EOS uses an approach that is unique in the AM industry, taking each of the three central technical elements of the production process into account: the system, the material and the process – together simply described as the Quality Triangle. EOS focuses on delivering reproducible part properties for the customer.



All of the data stated in this material data sheet is produced according to EOS Quality Management System and international standards.

Powder Properties

EOS Titanium Ti64 Grade 23 powder is classified as Grade 23 titanium alloy according to ASTM B348. The chemical composition is in compliance with standards ASTM F136, ASTM F3001, and ASTM F3302.

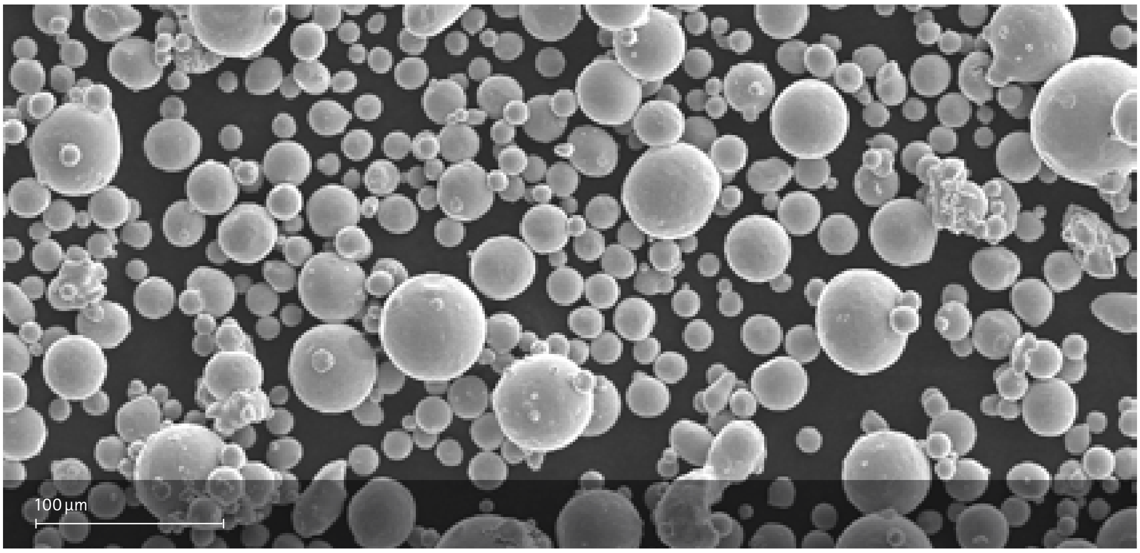
Powder chemical composition (wt.-%)

Element	Min.	Max.
Ti	Balance	
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

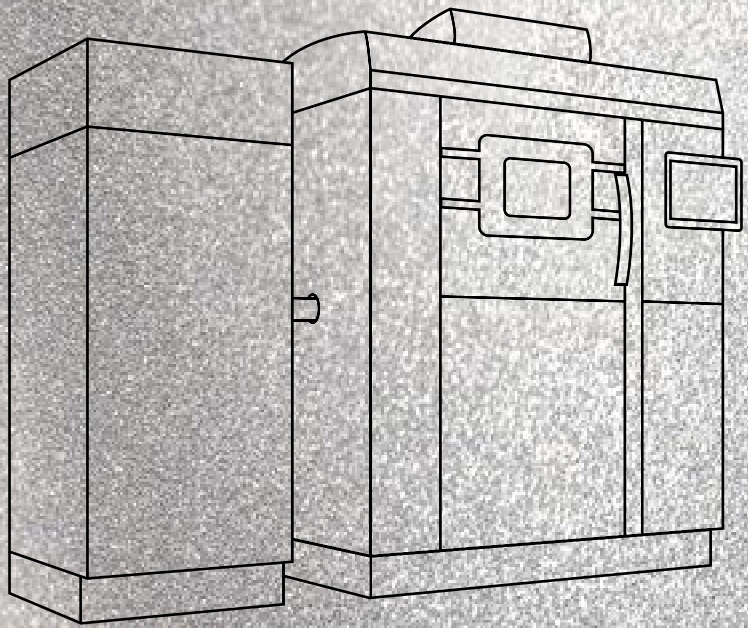
Powder particle size

Generic particle size distribution	20 – 80 µm

SEM picture of EOS Titanium Ti64 Grade 23 powder.



TRL 7
Premium



EOS Titanium Ti64 Grade 23
for EOS M 290 | 40 µm

Process Information
Heat Treatment
Physical Part Properties
Mechanical Properties
Additional Data

V1.0, CR617, 2019-02

EOS Titanium Ti64 Grade 23 for EOS M 290 | 40 µm

High Fatigue Strength without HIP

This process product was developed specifically for the production of parts with high fatigue strength without the need for Hot Isostatic Pressing (HIP).

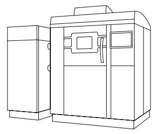
Main Characteristics:

- → Robust production of parts in small series and series production
- → Improved fatigue strength compared to previous generation EOS Titanium Ti64ELI products
- → Possibility for shortened overall production time by avoiding HIP as post-process treatment step

Process Information

System set-up	EOS M 290
EOS ParameterSet	M 290 Ti64 Grade23 040 V1
EOSPAR name	Ti64_Grade23_040_HiPerM291_100
Software requirements	EOSPRINT 2.5 or newer EOSYSTEM 2.8 or newer
Powder part no.	9011-0046
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	40 µm
Volume rate	6.2 mm^3/s
Min. wall thickness	Approx. 0.4 mm



Chemical and Physical Properties of Parts

The chemical composition of parts is in compliance with standards ASTM F136, ASTMF3001, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 23 powder.

Heat treated microstructure. Etched according to ASTM E407 modified recipe #190.

The areal defect percentage was determined from cross-cuts of the built parts using optical microscope fitted with a camera and analysis software. The analysis was carried out for a sample area of 15 x 15 mm. The defects were detected and analyzed with an image capture/analysis software with an automatic histogram based filtering procedure on monochrome images. The density of the built specimen was measured according to ISO3369.

Defects	**Result**	**Number of samples**
Average defect percentage	0.01 %	30
Density, ISO3369	**Result**	**Number of samples**
Average density	≥ 4.4 g/cm^3	10

Heat Treatment

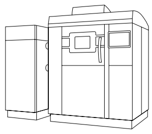
As manufactured microstructure for additively manufactured Ti64ELI consists of fully acicular alpha prime (α') phase. Standard heat treatments for titanium do not necessarily produce desired microstructures due to this different starting microstructure.

Heat treatment is recommended to relieve stresses and to increase ductility. Use of vacuum furnace is highly recommended to avoid the formation of alpha case on the surface of the parts.

Heat Treatment Description:
120 min (± 30 min) at 800 °C (± 10 °C) measured from the part in vacuum (1.3×10^{-3}–1.3×10^{-5} mbar) followed by cooling under vacuum or argon quenching. Material mechanical properties are relatively insensitive to changes in heating and cooling rates, but longer treatment times may result in decreased strength and increased elongation.

Parts heat treated according to the recommended heat treatment have a microstructure consisting of fine alpha + beta ($\alpha + \beta$) phase.

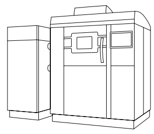
Mechanical Properties in Heat Treated State



Mechanical properties ISO6892-1

	Yield strength Rp0.2 [MPa]	Tensile strength Rm [MPa]	Elongation at break A [%]	Reduction of area Z [%]	Number of samples
Vertical	980	1050	15	≥ 25	84
Horizontal	940	1050	14	≥ 25	72

Additional Data

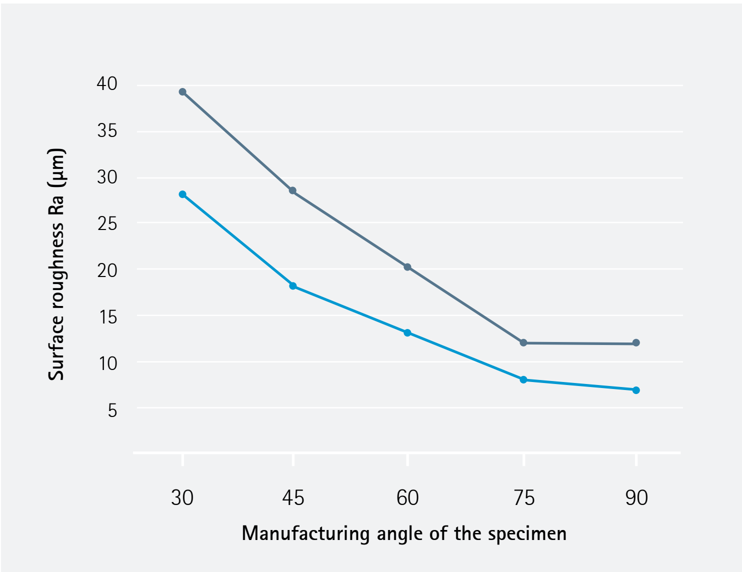


Fatigue Strength

Fatigue strength determines a stress level where specimen fails at a defined number of stress cycles [ISO 12107]. Fatigue strength was estimated statistically according to ISO 12107. Testing was done according to ASTM E466. Fatigue results typically show large deviations due to the nature of the fatigue process [ISO 12107].

Fatigue strength at 1 x 10^7 cycles in heat treated state	
Fatigue strength, MPa	589 MPa

Surface Roughness



The surface quality was characterized by optical measurement method from down-facing surfaces according to internal procedure. The 90 degree angle corresponds to vertical surface.

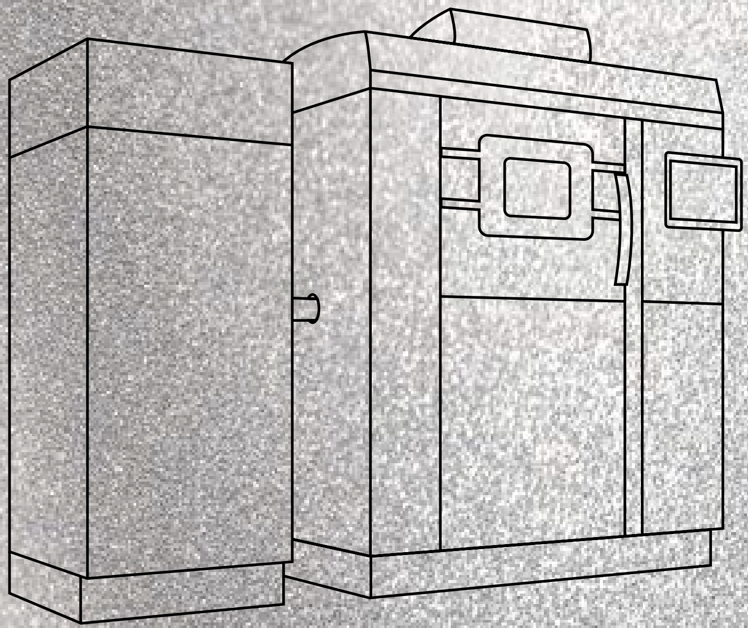
Coefficient of Thermal Expansion ASTM E228

Temperature	25 – 100 °C	25 – 200 °C	25 – 300 °C
CTE	9.0 $*10^{-6}$/K	9.4 $*10^{-6}$/K	9.7 $*10^{-6}$/K

Cytotoxicity

The cytotoxicity of EOS Titanium Ti64 Grade 23 plate samples was evaluated using an in vitro method according to ISO 10993-1: 2009, ISO 10993-5: 2009 and ISO 10993-12: 2012. In this study under the given conditions no leachable substances were released in cytotoxic concentrations from the test item as confirmed by two different endpoints (XTT, BCA). It is the responsibility of the producer of a part to validate biocompatibility as well as its suitability for a particular purpose. EOS has not FDA cleared this product for medical device manufacturers to use this material in FDA sensitive applications.

TRL 3
Core



EOS Titanium Ti64 Grade 23
for EOS M 290 | 80 µm

Process Information
Physical Part Properties

V3.0, preCR09, 2020-05

EOS Titanium Ti64 Grade 23 for EOS M 290 | 80 µm

Process Information

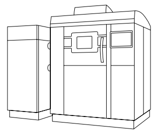
This process product is optimized for faster production of parts with properties according to ASTM F136. For most demanding applications, Hot Isostatic Pressing (HIP) is recommended to optimize high cycle fatigue properties

Main Characteristics:

- Parameter set for fast and cost efficient production of Ti64ELI parts in small series or serial production
- 15 - 30 % faster than EOS Ti64 Speed (60 µm) parameter set
- 50 % faster than EOS Ti64 Grade 23 HiPer (40 µm) parameter set
- Industries that require hot isostatic pressing (HIP) as standard post-treatment, the parameter set enables faster production.

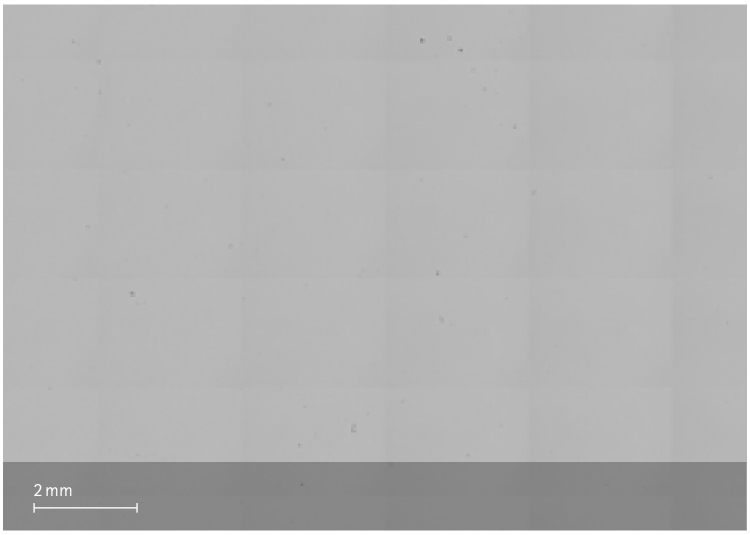
System set-up	EOS M 290
EOS ParameterSet	M 290 Ti64 Grade 23 080 V1
EOSPAR name	Ti64Grade23_080_CoreM291_100
Software requirements	EOSPRINT 2.5 or newer EOSYSTEM 2.8 or newer
Powder part no.	9011-0046
Recoater blade	EOS HSS blade
Nozzle	EOS grid nozzle
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	80 µm
Volume rate	12.0 mm^3/s



Chemical and Physical Properties of Parts

The chemical composition of parts is in compliance with standards ASTM F136, ASTM F3001, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 23 powder.



Defects	Result
Average defect percentage	<0.1 %*
Surface roughness Ra	**Result**
Vertical	9 µm

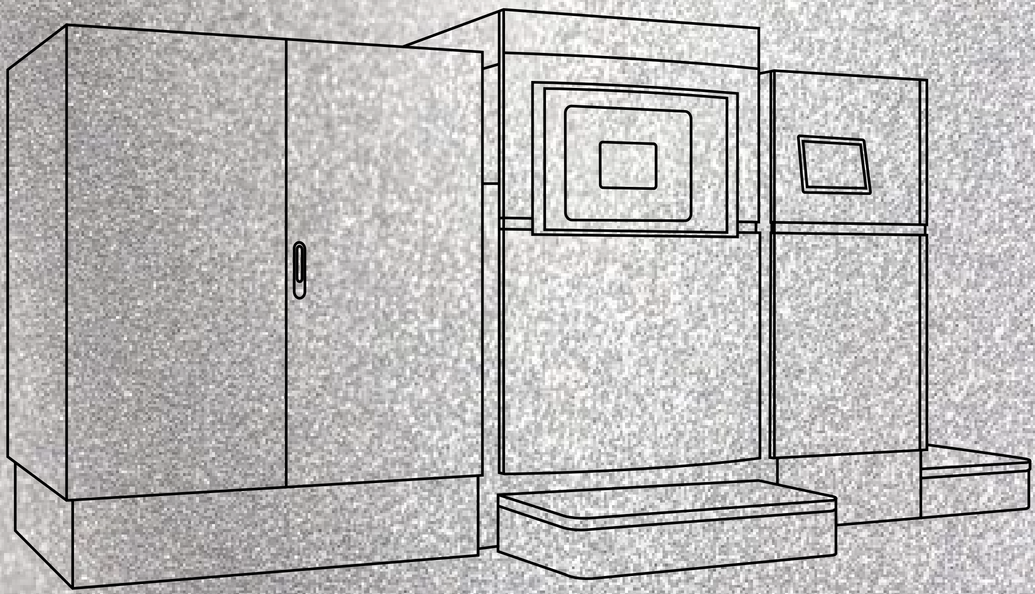
** Defect% varies with platform position.*

Typical properties

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Reduction of area Z [%]	Fatigue strength N = 9
Heat treated horizontal	1,000	1,100	15	> 25	-
Heat treated vertical	1,020	1,110	15**	> 25**	
HIP horizontal	900	1,010	16	> 25	675 MPa
HIP vertical	920	1,020	16	> 25	

High cycle fatigue strength was estimated statistically according to ISO 12107.
Testing was done according to ASTM E466 with run-out limit 10^7 cycles.
*** Mean values above the standard limit, some outliers below the limit.*

TRL 3
Core



EOS Titanium Ti64 Grade 23
for EOS M 400-4 | 80 µm

Process Information
Physical Part Properties

V3.0, preCR09, 2020-05

EOS Titanium Ti64 Grade 23 for EOS M 400-4 | 80 µm

Process Information

This process product is optimized for faster production of parts with properties according to ASTM F136. For most demanding applications, Hot Isostatic Pressing (HIP) is recommended to optimize high cycle fatigue properties

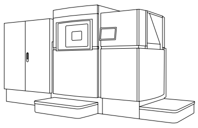
Main Characteristics:

- Parameter set for fast and cost efficient production of Ti64ELI parts in small series or serial production
- 15 - 30 % faster than EOS Ti64 Speed (60 µm) parameter set
- Industries that require hot isostatic pressing (HIP) as standard post-treatment, the parameter set enables faster production.

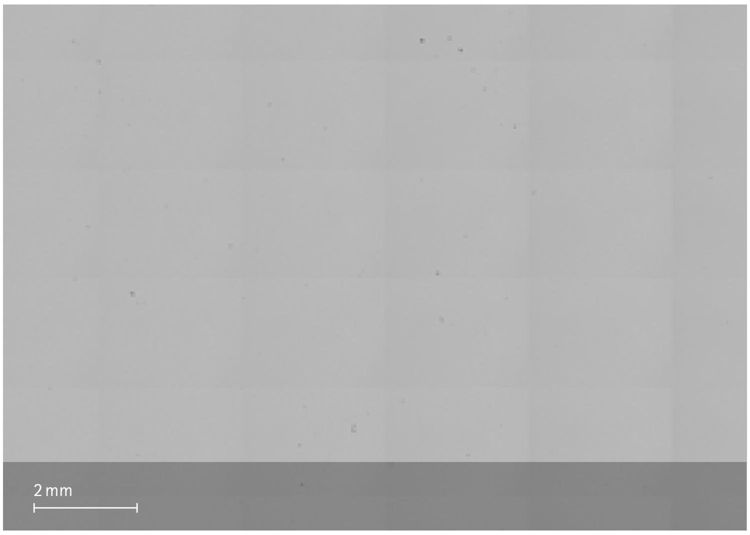
System set-up	EOS M 400-4
EOS ParameterSet	M 400-4 Ti64 Grade 23 080 V1
EOSPAR name	Ti64Grade23_040_080_CoreM404 1.X
Software requirements	EOSPRINT 2.7 or newer EOSYSTEM 2.11 or newer
Powder part no.	9011-0046
Recoater blade	EOS HSS blade
Inert gas	Argon
Sieve	90 µm

Additional information	
Layer thickness	80 µm
Volume rate	4 x 12.0 mm^3/s

Chemical and Physical Properties of Parts



The chemical composition of parts is in compliance with standards ASTM F136, ASTM F3001, and ASTM F3302. Composition complies with EOS Titanium Ti64 Grade 23 powder.



Defects	Result
Average defect percentage	<0.1 %*
Surface roughness Ra	**Result**
Vertical	9 µm

** Defect% varies with platform position.*

Typical properties

	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]	Reduction of area Z [%]	Fatigue strength N = 9
Heat treated horizontal	990	1,090	15	> 25	-
Heat treated vertical	1,010	1,090	14**	> 25**	
HIP horizontal	890	1,000	16	> 25	563 MPa
HIP vertical	910	1,010	16	> 25	

High cycle fatigue strength was estimated statistically according to ISO 12107.
Testing was done according to ASTM E466 with run-out limit 10^7 cycles.
*** Mean values above the standard limit, some outliers below the limit.*

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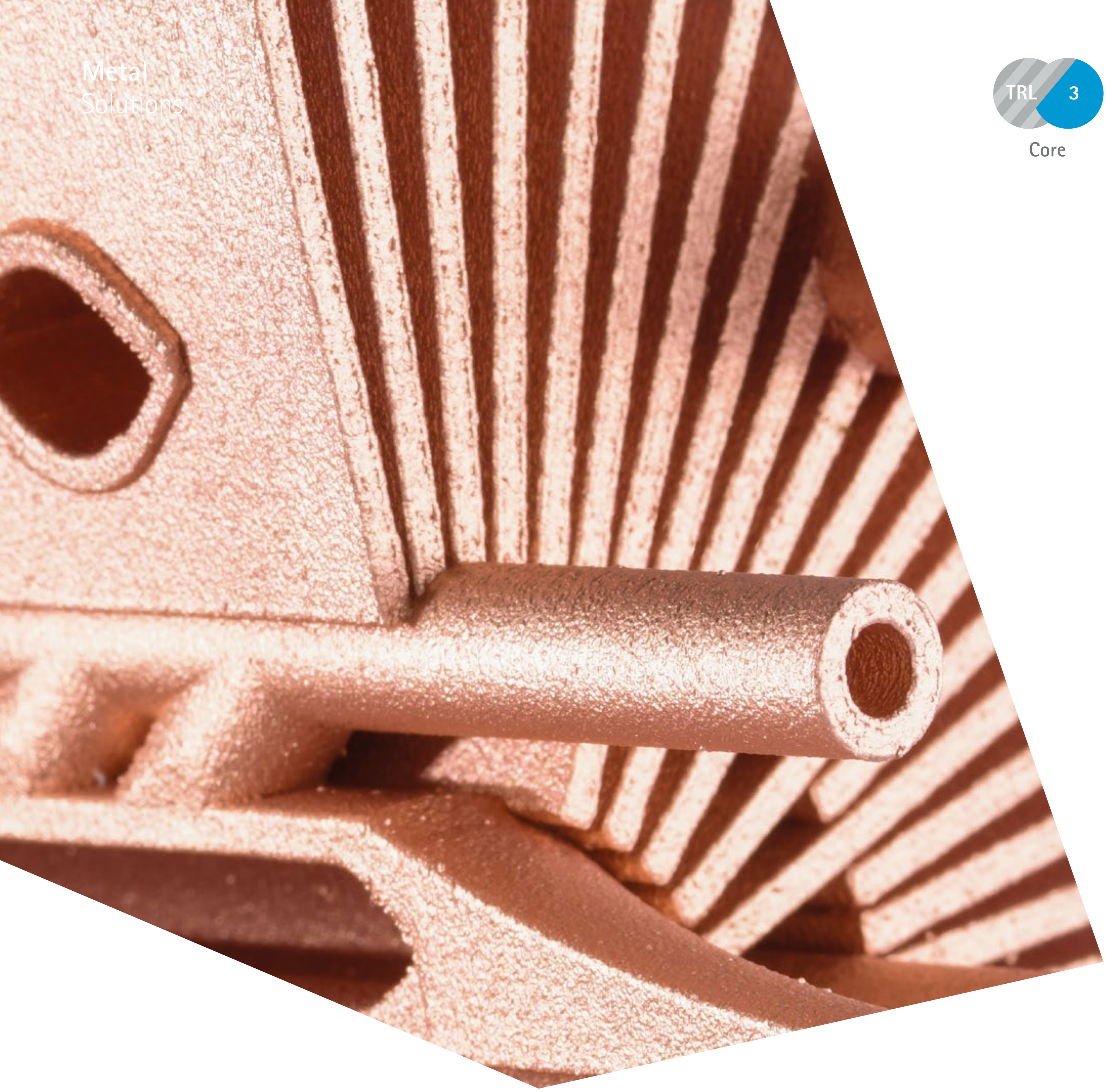
Status 07/2020

Cover: This image shows a possible application.

Metal
Solutions

TRL 3
Core

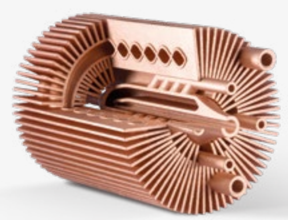


EOS Copper CuCP
for AMCM M 290 1kW

EOS Copper CuCP

EOS M 290 with 1 kW laser | 40 µm

Commercially pure copper for the EOS M 290 with 1 kW – customized by AMCM – designed to reach excellent conductivity properties. Suitable for a wide variety of applications.



Project Partner Delva Oy

Main Characteristics

- Commercially pure copper (> 99.95 % purity)
- Excellent electrical and heat conductivity
- Designed for an EOS M 290 with a 1 kW laser which is the AMCM M 290 1kW sold by AMCM GmbH

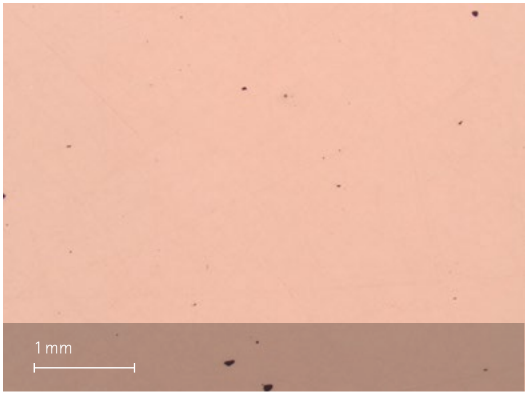
Typical Applications

- Electrical motors
- Inductors
- Variety of industry applications requiring excellent conductivity properties

Product Information

DMLS System	EOS M 290 with 1 kW laser
Recoater type	HSS blade or brush
Protective gas	Argon
Material	EOS Copper CuCP
Process	CuCP_040_CoreM291_1kW_100

Layer thickness 40 µm
Volume rate 5.4 mm³/s **Porosity < 0.5 %**



Typical part properties	Yield strength $R_{p0.2}$ [MPa]	Tensile strength R_m [MPa]	Elongation at break A [%]
Mechanical properties as manufactured	~ 165	~ 235	~ 45
Mechanical properties heat treated	~ 110	~ 220	~ 50
Conductivity as manufactured & heat treated	up to 100 % IACS (ASTM E1004-17)		

CuCP parts can be heat treated to reach more homogenous properties. Properties in the table have been achieved with the following heat-treatment: Hold 1 h at ~ 1 000 °C, slow cooling by taking the samples out of the furnace and cooling with continued Argon input.

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IndustryLine

EOS StainlessSteel
17-4PH

e-Manufacturing Solutions

EOS StainlessSteel 17-4PH

EOS StainlessSteel 17-4PH is an iron based metal alloy powder intended for processing on EOS DMLS® systems.

This document provides information and data for parts built using EOS StainlessSteel 17-4PH powder EOS art.-no. 9011-0041 on the following system specifications:

DMLS® System: EOS M 290
→ Ceramic blade (2200-3013)
→ Grid nozzle (2200-5501)
→ IPCM M extra Sieving Module with 75µm mesh size (200000315) recommended

Manual sieve with 75µm mesh size (200000321) recommended; standard manual sieve with 80µm mesh possible
→ Argon atmosphere

Software: EOSYSTEM 2.5 or newer / EOSPRINT 1.5 or newer EOS Parameter Set: 17-4PH 40µm Stainless
→ (Default Job: 17-4PH_040_StainlessM291_100)

Description

Precipitation hardening steels are widely used in engineering applications, which require corrosion resistance and strength. Parts built from EOS StainlessSteel 17-4PH can be machined, shot-peened and polished in as-built or heat treated states. Solution annealing together with ageing treatment are necessary in order to achieve proper hardness and mechanical properties (ASTM A564 – 13). Due to the layerwise building method, the parts have a certain anisotropy which can be eased by solution annealing.

Heat treatment

Vacuum H900 heat treatment procedure:
→ Solution annealing: Hold at 1040°C (1904°F) ±15°C (± 59°F) for 30 minutes, air cooling under 32°C (89°F).
→ Ageing: Hold at 480°C (896°F) for one hour, air cooling under 32°C (89°F).

Atmospheric HT procedure (preferred atmosphere: Argon):
→ Solution annealing: Hold at 1040°C (1904°F) ±15°C (± 59°F) for 30 minutes, air cooling under 32°C (89°F).
→ Ageing: Hold at 460°C (860°F) for one hour, air cooling under 32°C (89°F).

Quality Assurance of EOS StainlessSteel 17-4PH powder material

The quality of the delivered EOS StainlessSteel 17-4PH powder lots is ensured by the Quality Assurance procedures which are part of EOS Quality Management System. The procedures include quality assurance of both the powder and process.

Quality assurance of the powder product includes:
→ sampling (ASTM B215)
→ sieving (ASTM B214)
→ particle size analysis (ASTM B822)
→ chemistry analyses (ASTM E2823/E1479/E1019)
→ apparent density (ASTM B212/B329/B417)

The quality of the process is assured with each delivered powder lots by building a quality assurance job with a qualified EOS M 290 system.

Process quality is assured by:
→ tensile tests (ISO6892, ASTM E8M)
→ density measurement (ISO3369)
→ hardness measurement (ISO 6508)
→ chemistry analysis of the solid part (ASTM 2823/E1479/E1019).

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

Technical Data

Powder properties

The chemical composition of the powder is in compliance with standards "F899 – 12b Standard Specification for Wrought Stainless Steels for Surgical Instruments" and "A564M – 13 Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes".

Material composition	Acc. to standard	
Element	**Min.**	**Max.**
Cr	15.00	17.50
Ni	3.00	5.00
Cu	3.00	5.00
Si	–	1.00
Mn	–	1.00
C	–	0.07
P	–	0.040
S	–	0.030
Nb + Ta	0.15	0.45

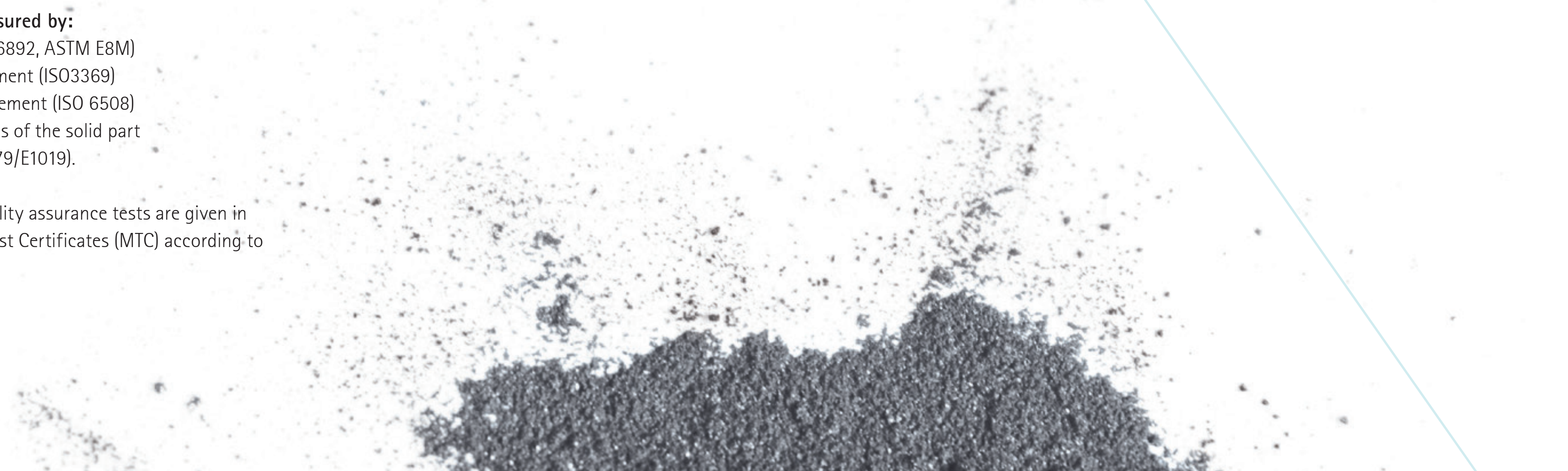
Particle size	
D50 [1]	36-44 µm approx. 1.4-1.7 · 10-3 inch
Particles >53µm [2]	Max 6.0 wt.-%
Particles >63µm [2]	Max 1.0 wt.-%
Powder density	
Apparent density [3]	Mean 3.83 g/cm^3 Mean 13.84 lbs/in^3
Tap density [4]	Mean 4.7 g/cm^3 Mean 1.7 lbs/in^3

[1] According to ASTM B822 [2] According to ASTM B214.
[3] According to ASTM B212, ASTM B329 & ASTM B417. [4] According to ASTM B527.

General process data

Layer thickness	40 µm 1.6 · 10-3 inch
Volume rate [5]	3.32 mm^3/s (11.95 cm^3/h) 0.73 in^3/h

[5] 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.



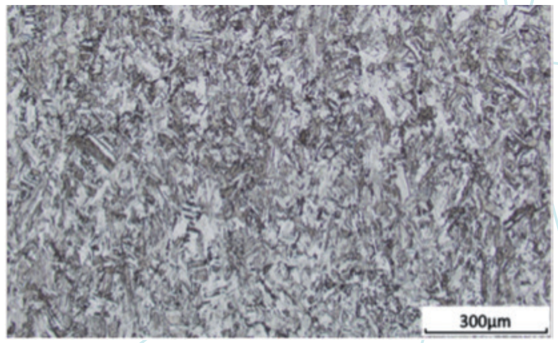
Physical and chemical properties of parts

The chemical composition of parts is in compliance with standards "F899 – 12b Standard Specification for Wrought Stainless Steels for Surgical Instruments" and "A564M – 13 Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes". Composition complies the material composition in "powder properties" section. Part accuracy is adjustable by changing the "Beam Offset, X-, Y- and Z-Shrinkage"-parameters.

Part density [6]	Mean 7.79 g/cm^3 Mean 28.14 lbs/in^3
Part accuracy [7]	
Small parts	approx. ± 50 µm approx. ± 1.1 · 10-3 inch
Min. wall thickness [8]	approx. 0.4 mm approx. 0.016 inch
Typical shrinkage after HT (for parts 50mm)	0.2%

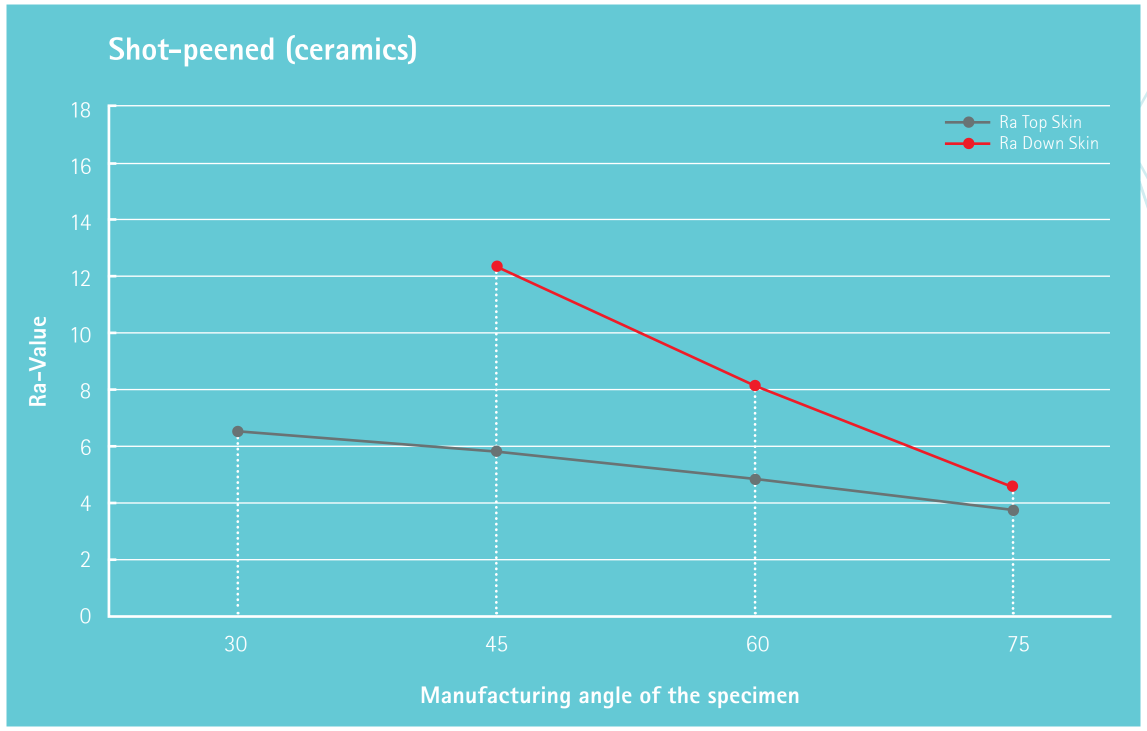
Thermal expansion after atmospheric HT [9]	
25 – 100°C	10.4 10^{-6}/K
25 – 200°C	11.0 10^{-6}/K
25 – 300°C	11.4 10^{-6}/K
25 – 400°C	11.8 10^{-6}/K
25 – 500°C	12.0 10^{-6}/K

Microstructure of heat treated parts	
Average porosity [10]	0.030%
Average pore size [10]	7.2 µm
N (number of samples)	70



Atmospheric furnace (Atmospheric HT) was used to heat treat etched part.
Etchant: Marble's reagent.
10 X magnification

Surface roughness after shot-peening (approx.) [11]	
Horizontal	**Ra** 3.5 – 5.9 µm; **Rz** 17.3 – 27.7 µm **Ra** 0.12 – 0.20 · 10-3 inch; **Rz** 0.67 – 1.06 · 10-3 inch
Vertical	**Ra** 3.4 – 5.5 µm; **Rz** 15.9 – 28.5 µm **Ra** 0.12 – 0,20 · 10-3 inch; **Rz** 0.59 – 1.12 · 10-3 inch
Angled surfaces	Surface roughness measured in a function of manufacturing angle



[6] Weighing in air and water according to ISO 3369. [7] Based on users' experience of dimensional accuracy for typical geometries, e.g. ± 50 µm when parameters can be optimized for a certain class of parts or ± 70 µm when building a new kind of geometry for the first time. Part accuracy is subject to appropriate data preparation and postprocessing. [8] Mechanical stability is dependent on geometry (wall height etc.) and application. [9] According ASTM E228. [10] Porosities were measured from 15x15mm cross cuts using optical microscope according to internal procedure. Average porosity and pore size value depends on the job load. [11] Measurement according to ISO 4287. The numbers were measured at the horizontal (up-facing) and 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. Angles under 45° should be supported.

Statistical analysis of part properties

Process and powder validation was performed using several powder lots and EOS M 290 systems. Number of samples used in process and powder validation are shown in tables below. All heat treated mechanical properties showed over 3 sigma performance against ASTM A564M H900 requirement. Vacuum H900 validation data includes two EOS M 290 systems and four powder lots. Atmospheric HT validation data includes one EOS M 290 system and two powder lots.

Mechanical properties at room temperature [12]

	As built	Vacuum H900	Atmospheric HT	ASTM A564 (H900)
Ultimate tensile strength, Rm		4 Sigma		
In horizontal direction (XY)	Mean 886.0 MPa	Mean 1335.8 MPa	Mean 1340.0 MPa	min. 1310 MPa
	StDev. 70.4 MPa	StDev. 5.2 MPa	StDev. 5.9 MPa	
N (number of samples)	72	144	36	
In vertical direction (Z)	Mean 924.2 MPa	Mean 1342.6 MPa	Mean 1345.5 MPa	min. 1310 MPa
	StDev. 65.9 MPa	StDev. 7.7 MPa	StDev. 2.8 MPa	
N (number of samples)	84	168	42	
Yield strength, Rp 0.2		6 Sigma		
In horizontal direction (XY)	Mean 860.6 MPa	Mean 1235.2 MPa	Mean 1235.5 MPa	
	StDev. 75.7 MPa	StDev. 9.8 MPa	StDev. 8.7 MPa	
N (number of samples)	72	144	36	
In vertical direction (Z)	Mean 861.3 MPa	Mean 1250.7 MPa	Mean 1242.6 MPa	min. 1170 MPa
	StDev. 44.7 MPa	StDev. 13.5 MPa	StDev. 10.1 MPa	
N (number of samples)	84	168	41	
Elongation at break A		Almost 4 Sigma		
In horizontal direction (XY)	Mean 19.9%	Mean 14.0%	Mean 13.5%	min. 10%
	StDev. 1.2%	StDev. 0.8%	StDev. 0.9%	
N (number of samples)	72	144	36	
In vertical direction (Z)	Mean 20.1%	Mean 13.5%	Mean 12.6%	min. 10%
	StDev. 1.5%	StDev. 0.7%	StDev. 0.9%	
N (number of samples)	84		42	
Hardness HRC		Almost 4 Sigma		
IHardness [13]	Mean 23.9 HRC	Mean 42.1 HRC	Mean 42.1 HRC	min. 40 HRC
	StDev. 3.6 HRC	StDev. 0.5 HRC	StDev. 0.5 HRC	
N (number of samples)	20	40	10	

[12] Tensile testing according to ISO 6892 & ASTM E8M. [13] Rockwell Hardness, HRC, according to ISO 6508.

Additional information

Modified Heat treatment

Modified heat treatment may improve properties further. Lower aging temperature 460°C (860°F) has proven to be more suitable for DMLS® manufactured 17-4PH. Tensile data with vacuum furnace – Solution anneal as [14] following by ageing in 460°C.

	Vacuum 460°C [14]
Ultimate tensile strength, Rm	
Both directions	Mean 1358.1 MPa
	StDev. 6.7 MPa
N (number of samples)	39
Yield strength, Rp0.2	
Both directions	Mean 1262.4 MPa
	StDev. 12.9 MPa
N (number of samples)	39
Elongation at break, A	
In horizontal direction (XY)	Mean 13.8%
	StDev. 0.6%
N (number of samples)	39
Hardness, HRC	
Hardness	Mean 42.8 HRC
	StDev. 0.3 HRC
N (number of samples)	5

Cytotoxicity

Cytotoxicity tests were done according to ISO 10993-5. It included growth inhibition tests evaluated from two endpoints (XTT & BCA). Tests were done with as-manufactured cubes. EOS StainlessSteel 17-4PH cubes were extracted under agitation for 24±2h with DMEM 10% FBS. L929 cells were then incubated for 68 – 72h with the following concentrations of the test extract: 13.2%, 19.8%, 29.6%, 44.4%, 66.7% and 100%. Surface/volume ratio used was 3cm2/mL.

Cytotoxicity results

In this study under the given conditions no leachable substances were released in cytotoxic concentrations from the test item as confirmed by two different endpoints (XTT, BCA).

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→ Save time and costs as qualification effort by the customer is less, easier and faster
→ More efficient development and manufacturing process
→ Shorter time-to-market

Abbreviations

Min.	Minimum
Max.	Maximum
StDev.	Standard deviation
Wt.	Weight
HT	Heat Treatment
XTT	Tetrazolium salt
BCA	Bicinchoninic acid
DMEM	Dulbecco's Modified Eagle Medium
FBS	Fetal Bovine Serum

The quoted values refer to the use of this material with above specified type of EOS DMLS® system, EOSYSTEM and EOSPRINT 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.
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Cover: This image shows a possible application. It is not a device cleared by the FDA or any other local authority for distribution in the United States.

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