

## EOS // ALUMINIUM ALSI10MG

EOS Aluminum AlSi10Mg is an aluminum alloy in fine powder form which has been specially optimized for processing on EOSINT M systems

This document provides information and data for parts built using EOS Aluminum AlSi10Mg powder (EOS art.-no. 9011-0024) on the following system specifications:

- EOSINT M 280 with PSW 3.6 and Original EOS Parameterset AlSi10Mg\_Speed 1.0
- EOS M 290 400Watt with EOSPRINT 1.0 and Original EOS Parameterset AlSi10Mg\_Speed 1.0

## DESCRIPTION

AlSi10Mg is a typical casting alloy with good casting properties and is typically used for cast parts with thin walls and complex geometry. It offers good strength, hardness, and dynamic properties and is therefore also used for parts subject to high loads. Parts in EOS Aluminum AlSi10Mg are ideal for applications which require a combination of good thermal properties and low weight. They can be machined, spark-eroded, welded, micro shotpeened, polished, and coated if required.

Conventionally cast components in this type of aluminum alloy are often heat-treated to improve the mechanical properties, e.g., using the T6 cycle of solution annealing, quenching, and age-hardening. The laser-sintering process is characterized by extremely rapid melting and re-solidification. This produces a metallurgy and corresponding mechanical properties in the as-built condition which is similar to T6 heat-treated cast parts. Therefore, such hardening heat treatments are not recommended for laser-sintered parts, but rather a stress-relieving cycle of two hours at 300 °C (572 °F). Due to the layerwise building method, the parts have a certain anisotropy, which can be reduced or removed by appropriate heat treatment — see Technical Data for examples.

## TECHNICAL DATA

### GENERAL PROCESS AND GEOMETRICAL DATA

<b>Typical achievable part accuracy [1] [2]</b>	±100 µm	
<b>Smallest wall thickness [1] [3]</b>	approx. 0.3 – 0.4 mm approx. 0.012 – 0.016 inch	
<b>Surface roughness [1] [4]</b>	<b>as built, cleaned</b>	Ra 6 - 10 µm, Rz 30 - 40 µm Ra 0.24 - 0.39 x 10 <sup>-3</sup> inch Rz 1.18 - 1.57 x 10 <sup>-3</sup> inch
	<b>after micro shot-peening</b>	Ra 7 - 10 µm, Rz 50 - 60 µm Ra 0.28 - 0.39 x 10 <sup>-3</sup> inch Rz 1.97 - 2.36 x 10 <sup>-3</sup> inch
<b>Volume rate [5]</b>	7.4 mm <sup>3</sup> /s (26.6 cm <sup>3</sup> /h) 1.6 in <sup>3</sup> /h	

[1] These properties were determined on an EOSINT M 270.

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

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

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

[5] The volume rate is a measure of the building speed during laser exposure. The overall building speed is dependent on the average volume rate, the time required for coating (depends on the number of layers) and other factors, e.g., DMLS settings.

## PHYSICAL AND CHEMICAL PROPERTIES OF THE PARTS

<b>Material composition</b>	Al (balance) Si (9.0 - 11.0 wt-%) Fe ( $\leq$ 0.55 wt-%) Cu ( $\leq$ 0.05 wt-%) Mn ( $\leq$ 0.45 wt-%) Mg (0.2 - 0.45 wt-%) Ni ( $\leq$ 0.05 wt-%) Zn ( $\leq$ 0.10 wt-%) Pb ( $\leq$ 0.05 wt-%) Sn ( $\leq$ 0.05 wt-%) Ti ( $\leq$ 0.15 wt-%)
<b>Relative density</b>	approx. 99.85 %
<b>Density</b>	2.67 g/cm <sup>3</sup> 0.096 lb/in <sup>3</sup>

## MECHANICAL PROPERTIES OF THE PARTS

		As built	Heat treated [9]
<b>Tensile strength [6]</b>	<b>in horizontal direction (XY)</b>	460 ± 20 MPa 66.7 ± 2.9 ksi	345 ± 10 MPa 50.0 ± 1.5 ksi
	<b>in vertical direction (Z)</b>	460 ± 20 MPa 66.7 ± 2.9 ksi	350 ± 10 MPa 50.8 ± 1.5 ksi
<b>Yield strength (Rp 0.2 %) [6]</b>	<b>in horizontal direction (XY)</b>	270 ± 10 MPa 39.2 ± 1.5 ksi	230 ± 15 MPa 33.4 ± 2.2 ksi
	<b>in vertical direction (Z)</b>	240 ± 10 MPa 34.8 ± 1.5 ksi	230 ± 15 MPa 33.4 ± 2.2 ksi
<b>Modulus of elasticity</b>	<b>in horizontal direction (XY)</b>	75 ± 10 GPa 10.9 ± 0.7 Msi	70 ± 10 GPa 10.2 ± 0.7 Msi
	<b>in vertical direction (Z)</b>	70 ± 10 GPa 10.2 ± 0.7 Msi	60 ± 10 GPa 8.7 ± 0.7 Msi
<b>Elongation at break [6]</b>	<b>in horizontal direction (XY)</b>	(9 ± 2) %	12 ± 2%
	<b>in vertical direction (Z)</b>	(6 ± 2) %	11 ± 2%
<b>Hardness [7]</b>		approx. 119 ± 5 HBW	
<b>Fatigue strength [1] [8]</b>	<b>in vertical direction (Z)</b>	approx. 97 ± 7 MPa approx. 14.1 ± 1.0 ksi	

[6] Mechanical strength tested as per ISO 6892-1:2009 (B) annex D, proportional specimens, specimen diameter 5 mm, original gauge length 25 mm (1 inch).  
 [7] Hardness test in accordance with Brinell (HBW 2.5/62.5) as per DIN EN ISO 6506-1. Note that measured hardness can vary significantly depending on how the specimen has been prepared.

[8] Fatigue test with test frequency of 50 Hz, R = -1, measurement stopped on reaching 5 million cycles without fracture.

[9] Stress relieve: anneal for 2 h at 300 °C (572 °F).

[10] These properties were determined on an EOSINT M 280-400W. Test parts from following machine type EOS M 290-400W correspond with these data.

## THERMAL PROPERTIES OF PARTS

	As-built [1]	Heat-treated [1] [9]
<b>Thermal conductivity (at 20 °C) in horizontal direction (XY)</b>	approx. $103 \pm 5$ W/m°C	approx. $173 \pm 10$ W/m°C
<b>Thermal conductivity (at 20 °C) in vertical direction (Z)</b>	approx. $119 \pm 5$ W/m°C	approx. $173 \pm 10$ W/m°C
<b>Specific heat capacity in horizontal direction (XY)</b>	approx. $920 \pm 50$ J/kg°C	approx. $890 \pm 50$ J/kg°C
<b>Specific heat capacity in vertical direction (Z)</b>	approx. $910 \pm 50$ J/kg°C	approx. $890 \pm 50$ J/kg°C

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

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

## EOS // MARAGING STEEL MS1

EOS Maraging Steel MS1 is a steel powder which has been optimized especially for processing on EOSINT M systems.

This document provides information and data for parts built using EOS Maraging Steel MS1 powder (EOS art.-no. 9011-0016) on the following system specifications:

- EOSINT M 270 Installation Mode Standard with PSW 3.3 or 3.4 and default job MS1\_020\_default.job or MS1\_040\_default.job
- EOSINT M 270 Dual Mode with PSW 3.5 and EOS Original Parameter Set MS1\_Surface 1.0 or MS1\_Performance 2.0
- EOSINT M 280 with PSW 3.5 and EOS Original Parameter Set MS1\_Performance 1.0 or MS1\_Speed 1.0

## DESCRIPTION

Parts built in EOS Maraging Steel MS1 have a chemical composition corresponding to US classification 18% Ni Maraging 300, European 1.2709 and German X3NiCoMoTi 18-9-5. This kind of steel is characterized by having very good mechanical properties, and being easily heat-treatable using a simple thermal age-hardening process to obtain excellent hardness and strength.

Parts built from EOS MaragingSteel MS1 are easily machinable after the building process and can be easily post-hardened to more than 50 HRC by age-hardening at 490 °C (914 °F) for six hours. In both as-built and age-hardened states, the parts can be machined, sparkeroded, welded, micro shot-peened, polished, and coated if required. Due to the layerwise building method, the parts have a certain anisotropy, which can be reduced or removed by appropriate heat treatment — see Technical Data for examples.

# TECHNICAL DATA

## GENERAL PROCESS AND GEOMETRICAL DATA

<b>Typical achievable part accuracy [1]</b>	<b>small parts (&lt; 80 x 80 mm)</b>	approx. ± 20 µm approx. ± 0.8 x 10 <sup>-3</sup> inch
	<b>large parts</b>	approx. ± 50 µm approx. ± 0.002 inch
<b>Age hardening shrinkage [2]</b>	approx. 0.08 %	
<b>Min. wall thickness [3]</b>	approx. 0.3 - 0.4 mm approx. 0.012 - 0.016 inch	
<b>Surface roughness (approx.) [4] - as manufactured</b>	<b>MS1 Surface (20 µm)</b>	Ra 4 µm; Rz 20 µm Ra 0.16 x 10 <sup>-3</sup> inch, Rz 0.78 x 10 <sup>-3</sup> inch
	<b>MS1 Performance (40 µm)</b>	Ra 5 µm; Rz 28 µm Ra 0.19 x 10 <sup>-3</sup> inch, Rz 1.10 x 10 <sup>-3</sup> inch
	<b>MS1 Speed (50 µm)</b>	Ra 9 µm; Rz 50 µm Ra 0.47 x 10 <sup>-3</sup> inch, Rz 2.36 x 10 <sup>-3</sup> inch
	<b>after shot-peening</b>	Ra 4 - 6.5 µm; Rz 20 - 50 µm Ra 0.16 - 0.26 x 10 <sup>-3</sup> inch Rz 0.78 - 1.97 x 10 <sup>-3</sup> inch
	<b>after polishing</b>	Rz up to < 0.5 µm Rz up to < 0.02 x 10 <sup>-3</sup> inch (can be very finely polished)
<b>Volume rate [5]</b>	<b>Parameter set MS1_Surface 1.0 / default job MS1_020_default.job (20 µm layer thickness)</b>	1.6 mm <sup>3</sup> /s (5.8 cm <sup>3</sup> /h) 0.35 in <sup>3</sup> /h
	<b>Parameter set MS1_Performance 2.0 / default job MS1_040_default.job (40 µm layer thickness)</b>	3 mm <sup>3</sup> /s (10.8 cm <sup>3</sup> /h) 0.66 in <sup>3</sup> /h
	<b>Parameter set MS1_Performance 1.0 / for M 280 / 400 W (40 µm layer thickness)</b>	4.2 mm <sup>3</sup> /s (15.1 cm <sup>3</sup> /h) 0.92 in <sup>3</sup> /h
	<b>Parameter set MS1_Speed 1.0 / for M 280 / 400 W (50 µm layer thickness)</b>	5.5 mm <sup>3</sup> /s (19.8 cm <sup>3</sup> /h) 1.21 in <sup>3</sup> /h

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

[2] Aging temperature 490 °C (914 °F), 6 hours, air cooling

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

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

[5] Volume rate is a measure of build speed during laser exposure of hatched areas. The total build speed depends on the average volume rate, the recoating time (related to the number of layers) and other geometry- and machine setting-related factors.

## PHYSICAL AND CHEMICAL PROPERTIES OF THE PARTS

<b>Material Composition</b>	Fe (balance) Ni (17 - 19 wt-%) Co (8.5 - 9.5 wt-%) Mo (4.5 - 5.2 wt-%) Ti (0.6 - 0.8 wt-%) Al (0.05 - 0.15 wt-%) Cr, Cu (each $\leq$ 0.5 wt-%) C ( $\leq$ 0.03 wt-%) Mn, Si (each $\leq$ 0.1 wt-%) P, S (each $\leq$ 0.01 wt-%)
<b>Relative Density</b>	approx. 100%
<b>Density</b>	8.0 - 8.1 g/cm <sup>3</sup> 0.289 - 0.293 lb/in <sup>3</sup>

MECHANICAL PROPERTIES OF PARTS AT 20 °C ( 68°F )

		As-built	After age-hardening [2]
<b>Tensile strength [6]</b>			min. 1930 MPa min. 280 ksi
	<b>in horizontal direction (XY)</b>	typ. 1100 ± 100 MPa typ. 160 ± 15 ksi	typ. 2050 ± 100 MPa typ. 297 ± 15 ksi
	<b>in vertical direction (Z)</b>	typ. 1100 ± 100 MPa typ. 160 ± 15 ksi	
<b>Yield strength (Rp 0.2 %) [6]</b>			min. 1862 MPa min. 270 ksi
	<b>in horizontal direction (XY)</b>	typ. 1050 ± 100 MPa typ. 152 ± 15 ksi	typ. 1990 ± 100 MPa typ. 289 ± 15 ksi
	<b>in vertical direction (Z)</b>	typ. 1000 ± 100 MPa typ. 145 ± 15 ksi	
<b>Elongation at break [6]</b>			min. 2 %
	<b>in horizontal direction (XY)</b>	typ. (10 ± 4) %	typ. (4 ± 2) %
	<b>in vertical direction (Z)</b>	typ. (10 ± 4) %	
<b>Modulus of elasticity [6]</b>			
	<b>in horizontal direction (XY)</b>	typ. 160 ± 25 GPa typ. 23 ± 4 Msi	typ. 180 ± 20 GPa typ. 26 ± 3 Msi
	<b>in vertical direction (Z)</b>	typ. 150 ± 20 GPa typ. 22 ± 3 Msi	
<b>Hardness [7]</b>		typ. 33 - 37 HRC	typ. 50 - 56 HRC
<b>Ductility (Notched Charpy impact test)</b>		typ. 45 ± 10 J	typ. 11 ± 4 J

[6] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5mm (0.2 inch), original gauge length 25mm (1 inch).

[7] Rockwell C (HRC) hardness measurement according to EN ISO 6508-1 on polished surface. Note that measured hardness can vary significantly depending on how the specimen has been prepared.

## THERMAL PROPERTIES OF PARTS

	As-built [1]	After age-hardening [2]
<b>Thermal conductivity</b>	typ. $15 \pm 0.8 \text{ W/m}^\circ\text{C}$ typ. $104 \pm 6 \text{ Btu in/(h ft}^2 \text{ }^\circ\text{F)}$	typ. $20 \pm 1 \text{ W/m}^\circ\text{C}$ typ. $139 \pm 7 \text{ Btu in/(h ft}^2 \text{ }^\circ\text{F)}$
<b>Specific heat capacity</b>	typ. $450 \pm 20 \text{ J/kg}^\circ\text{C}$ typ. $0.108 \pm 0.005 \text{ Btu/(lb }^\circ\text{F)}$	typ. $450 \pm 20 \text{ J/kg}^\circ\text{C}$ typ. $0.108 \pm 0.005 \text{ Btu/(lb }^\circ\text{F)}$
<b>Maximum operating temperature</b>		approx. $400 \text{ }^\circ\text{C}$ approx. $750 \text{ }^\circ\text{F}$

The data are valid for the combinations of powder material, machine and parameter sets referred to on page 1, when used in accordance with the relevant Operating Instructions (including Installation Requirements and Maintenance) and Parameter Sheet. Part properties are measured using defined test procedures. Further details of the test procedures used by EOS are available on request. Unless otherwise specified, the data refer to the default job MS1\_040\_default.job or the equivalent parameter set MS1\_Performance 2.0. The corresponding data for the default job MS1\_020\_default.job or the equivalent parameter set MS1\_Surface 1.0 are approximately the same except where otherwise specified.

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



## EOS // EOS NICKEL ALLOY IN718

EOS Nickel Alloy IN718 is a heat- and corrosion- resistant nickel alloy powder which has been specially optimized for processing on EOS M systems.

This document provides information and data for parts built using EOS Nickel Alloy IN718 powder (EOS art.-no. 9011-0020) on the following system specifications:

- EOSINT M280 400W System with PSW3.6 and Parameter Set IN718\_Performance 1.0
- EOS M290 400W System with EOSPRINT 1.0 and Parameter Set IN718\_Performance 1.0

## DESCRIPTION

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

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

Parts built from EOS Nickel Alloy IN718 can be easily post-hardened by precipitationhardening heat treatments. In both as-built and age-hardened states, the parts can be machined, spark-eroded, welded, micro shot-peened, polished and coated if required. Due to the layerwise building method, the parts have a certain anisotropy — see Technical Data for examples.

## TECHNICAL DATA

### GENERAL PROCESS DATA

<b>Typical achievable part accuracy [1], [11]</b>	<b>small parts</b>	approx. $\pm 40 - 60 \mu\text{m}$ approx. $\pm 1.6 - 2.4 \times 10^{-3}$ inch
	<b>large parts</b>	$\pm 0.2 \%$
<b>Min. wall thickness [2], [11]</b>	typ. 0.3 - 0.4 mm typ. 0.012 - 0.016 inch	
<b>Surface roughness [3], [11]</b>	<b>after shot-peening</b>	Ra 4 - 6.5 $\mu\text{m}$ , Rz 20 - 50 $\mu\text{m}$ Ra 0.16 - 0.25 $\times 10^{-3}$ inch, Rz 0.78 - 1.97 $\times 10^{-3}$ inch
	<b>after polishing</b>	Rz up to < 0.5 $\mu\text{m}$ Rz up to < 0.02 $\times 10^{-3}$ inch (can be very finely polished)
<b>Volume rate [4]</b>	<b>Parameter Set IN718_ Performance (40 <math>\mu\text{m}</math>)</b>	4 mm <sup>3</sup> /s (14.4 cm <sup>3</sup> /h) 0.88 in <sup>3</sup> /h

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g.  $\pm 40 \mu\text{m}$  ( $1.6 \times 10^{-3}$  inch) when parameters can be optimized for a certain class of parts or  $\pm 60 \mu\text{m}$  ( $2.4 \times 10^{-3}$  inch) when building a new kind of geometry for the first time. Part accuracy is subject to appropriate data preparation and postprocessing, in accordance with EOS training.

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

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

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

### PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

<b>Material composition</b>	Ni (50 - 55 wt-%) Cr (17.0 - 21.0 wt-%) Nb (4.75 - 5.5 wt-%) Mo (2.8 - 3.3 wt-%) Ti (0.65 - 1.15 wt-%) Al (0.20 - 0.80 wt-%) Co ( $\pm 1.0$ wt-%) Cu ( $\pm 0.3$ wt-%) C ( $\pm 0.08$ wt-%) Si, Mn (each $\pm 0.35$ wt-%) P, S (each $\pm 0.015$ wt-%) B ( $\pm 0.006$ wt-%) Fe (balance)
<b>Relative density</b>	approx. 100%
<b>Density</b>	min. 8.15 g/cm <sup>3</sup> min. 0.294 lb/in <sup>3</sup>

MECHANICAL PROPERTIES OF PARTS AT 20 °C (68 °F)

		As-built	Heat-treated per AMS 5662 [5]	Heat-treated per AMS 5664 [6]
<b>Tensile strength [7]</b>	<b>in horizontal direction (XY)</b>	typ. 1060 ± 50 MPa (154 ± 7 ksi)		
	<b>in vertical direction (Z)</b>	typ. 980 ± 50 MPa (142 ± 7 ksi)	min. 1241 MPa (180 ksi) typ. 1400 ± 100 MPa (203 ± 15 ksi)	min. 1241 MPa (180 ksi) typ. 1380 ± 100 MPa (200 ± 15 ksi)
<b>Yield strength (Rp 0.2 %) [7]</b>	<b>in horizontal direction (XY)</b>	typ. 780 ± 50 MPa (113 ± 7 ksi)		
	<b>in vertical direction (Z)</b>	typ. 634 ± 50 MPa (92 ± 7 ksi)	min. 1034 MPa (150 ksi) typ. 1150 ± 100 MPa (167 ± 15 ksi)	min. 1034 MPa (150 ksi) typ. 1240 ± 100 MPa (180 ± 15 ksi)
<b>Elongation at break [7]</b>	<b>in horizontal direction (XY)</b>	typ. (27 ± 5) %		
	<b>in vertical direction (Z)</b>	typ. (31 ± 5) %	min. 12 % typ. (15 ± 3) %	min. 12 % typ. (18 ± 5) %
<b>Modulus of elasticity [7]</b>	<b>in horizontal direction (XY)</b>	typ. 160 ± 20 GPa (23 ± 3 Msi)		
	<b>in vertical direction (Z)</b>		170 ± 20 GPa 24.7 ± 3 Msi	170 ± 20 GPa 24.7 ± 3 Msi
<b>Hardness [8]</b>		approx. 30 HRC approx. 287 HB	approx. 47 HRC approx. 446 HB	approx. 43 HRC approx. 400 HB

[5] Heat treatment procedure per AMS 5662:

1. Solution Anneal at 980 °C (1800 °F) for one hour, air (/argon) cool.
2. Aging treatment; hold at 720 °C (1330 °F) eight hours, furnace cool to 620 °C (1150 °F) in two hours, hold at 620 °C (1150 °F) 8 hours, air (/argon) cool.

[6] Heat treatment procedure per AMS 5664:

1. Solution Anneal at 1065 °C (1950 °F) for 1 hour, air (/argon) cool.
2. Aging treatment; hold at 760 °C (1400 °F) 10 hours, furnace cool to 650 °C (1200 °F) in two hours, hold at 650 °C (1200 °F) 8 hours, air (/argon) cool

[7] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5 mm (0.2 inch) , original gauge length 25 mm (1 inch).

[8] Rockwell C (HRC) hardness measurement according to EN ISO 6508-1 on polished surface. Note that measured hardness can vary significantly depending on how the specimen has been prepared.

## MECHANICAL PROPERTIES OF PARTS AT HIGH TEMPERATURES (649 °C, 1200 °F) [11]

	Heat-treated per AMS 5662 [5]	Heat-treated per AMS 5664 [6]
<b>Tensile Strength (Rm) [9] - in vertical direction (Z)</b>	min. 965 MPa (140 ksi) typ. 1170 ± 50 MPa (170 ± 7 ksi)	typ. 1210 ± 50 MPa (175 ± 7 ksi)
<b>Yield strength (Rp 0.2 %) [9] - in vertical direction (Z)</b>	min. 862 MPa (125 ksi) typ. 970 ± 50 MPa (141 ± 7 ksi)	typ. 1010 ± 50 MPa (146 ± 7 ksi)
<b>Elongation at break [9] - in vertical direction (Z)</b>	min. 6 % typ. (16 ± 3) %	typ. (20 ± 3) %
<b>Stress-Rupture Properties [10] - in vertical direction (Z)</b>	min. 23 hours at stress level 689 MPa (100 ksi)	
<b>Stress-Rupture Properties [10]</b>	51 ± 5 hours (final applied stress to rupture 792.5 MPa / 115 ksi)	81 ± 10 hours (final applied stress to rupture 861.5 MPa / 125 ksi)

[9] Elevated temperature tensile testing at 649 °C (1200 °F) in accordance with EN 10002-5 (92)

[10] Testing at 649 °C (1200 °F) in accordance with ASTM E139 (2006), smooth specimens. Test method as described in AMS 5662 (3.5.1.2.3.3): "The load required to produce an initial axial stress of 689 MPa (100 ksi) shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 hours minimum, thereafter, the stress shall be increased in increments of 34.5 MPa (5 ksi)."

[11] These properties were determined on an EOSINT M 270 IM Xtended and EOSINT M 280-400W. Test parts from following machine types EOSINT M 270 Dual Mode, EOSINT M 280-200W and EOS M 290-400W correspond with these data.

## THERMAL PROPERTIES OF PARTS

	Heat treated per AMS 5662 [4]	
<b>Coefficient of thermal expansion</b>	<b>over 25 - 200 °C (36 - 390 °F)</b>	approx. 12.5 - 13.0 x 10 <sup>-6</sup> m/m°C approx. 6.9 - 7.2 x 10 <sup>-6</sup> in/in°F
	<b>over 25 - 750 °C (36 - 930 °F)</b>	approx. 16.6 - 17.2 x 10 <sup>-6</sup> m/m°C approx. 9.2 - 9.6 x 10 <sup>-6</sup> in/in°F
<b>Maximum operating temperature for parts under load</b>		approx. 650 °C approx. 1200 °F
<b>Oxidation resistance up to [11]</b>		approx. 980 °C approx. 1800 °F

[12] Based on literature of conventional Ni-alloy with identical chemistry

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

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

## EOS // STAINLESS STEEL GP1 FOR EOSINT M 270

A number of different materials are available for use with EOSINT M systems, offering a broad range of e-Manufacturing applications. EOS Stainless Steel GP1 is a stainless steel powder which has been optimized especially for EOSINT M 270 systems. Other materials are also available for EOSINT M systems, and further materials are continuously being developed — please refer to the relevant material data sheets for details.

This document provides a brief description of the principle applications and a table of technical data. For details of the system requirements please refer to the relevant information quote.

### DESCRIPTION, APPLICATION

EOS Stainless Steel GP1 is a pre-alloyed stainless steel in fine powder form. Its composition corresponds to US classification 17-4 and European 1.4542. This kind of steel is characterized by having good corrosion resistance and mechanical properties, especially excellent ductility in laser processed state, and is widely used in a variety of engineering applications.

This material is ideal for many part-building applications (DirectPart) such as functional metal prototypes, small series products, individualized products or spare parts. Standard processing parameters use full melting of the entire geometry with 20 µm layer thickness, but it is also possible to use Skin & Core building style to increase the build speed. Using standard parameters, the mechanical properties are fairly uniform in all directions. Parts made from EOS Stainless Steel GP1 can be machined, spark-eroded, welded, micro shotpeened, polished and coated if required. Unexposed powder can be reused.

Typical applications:

- Engineering applications including functional prototypes, small series products, individualized products or spare parts.
- Parts requiring high corrosion resistance, sterilizability, etc.
- Parts requiring particularly high toughness and ductility.

## TECHNICAL DATA

### GENERAL PROCESS AND GEOMETRIC DATA

<b>Minimum recommended layer thickness</b>	20 µm 0.8 mil	
<b>Typical achievable part accuracy [1]</b>	<b>Small parts</b>	± 20 – 50 µm 0.8 – 2.0 mil
	<b>Large Parts [2]</b>	± 0.2 %
<b>Min. wall thickness [3]</b>	0.3 - 0.4 mm 0.012 - 0.016 in	
<b>Surface roughness</b>	<b>after shot-peening</b>	Ra 2.5 - 4.5 µm, Ry 15 - 40 µm Ra 0.1 - 0.2 , Ry 0.6 - 1.6 mil
	<b>after polishing</b>	Rz up to < 0.5 µm (can be very finely polished)
<b>Volume rate [4]</b>	standard parameters (20 µm layers, full density)	

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g. ± 20 µm when parameters can be optimized for a certain class of parts or ± 50 µm when building a new kind of geometry for the first time.

[2] For larger parts, the accuracy can be improved by post-process stress-relieving at 650 °C for one hour.

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

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

### PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

<b>Material composition</b>	Steel including alloying elements Cr (15 – 17.5 wt-%) Ni (3 - 5 wt-%) Cu (3 - 5 wt-%) Mn (max. 1 wt-%) Si (max. 1 wt-%) Mo (max. 0.5 wt-%) Nb (0.15 - 0.45 wt-%) C (max. 0.07 wt-%)
<b>Relative density with standard parameters</b>	approx. 100%
<b>Density with standard parameters</b>	7.8 g/cm³ 0.28 lb/in³

MECHANICAL PROPERTIES OF PARTS [5]

		As-manufactured	Stress-relieved (One hour at 650 °C)
Ultimate tensile strength	in horizontal direction (XY)	min 850 MPa (123 ksi) typical 930 ± 50 MPa (135 ± 7 ksi)	typical 1100 MPa (160 ksi)
	in vertical direction (Z)	min 850 MPa (123 ksi) typical 960 ± 50 MPa (139 ± 7 ksi)	typical 980 MPa (142 ksi)
Yield strength	(ReL, Lower yield strength) in horizontal direction (XY)	min 530 MPa (77 ksi) typical 586 ± 50 MPa (85 ± 7 ksi)	typical 590 Mpa (86 ksi)
	(ReL, Lower yield strength) in vertical direction (Z)	min 530 MPa (77 ksi) typical 570 ± 50 MPa (83 ± 7 ksi)	typical 550 MPa (80 ksi)
	(ReH, Upper yield strength) in horizontal direction (XY)	min 595 MPa (86 ksi) typical 645 ± 50 MPa (94 ± 7 ksi)	typical 634 MPa (92 ksi)
	(ReH, Upper yield strength) in vertical direction (Z)	min 580 MPa (84 ksi) typical 630 ± 50 MPa (91 ± 7 ksi)	typical 595 MPa (86 ksi)
Young's modulus		170 ± 30 GPa (25 ± 4 msi)	typical 180 GPa (26 msi)
Elongation at break	in horizontal direction (XY)	min 25 % typical 31 ± 5 %	typical 29 %
	in vertical direction (Z)	min 25 % typical 35 ± 5 %	typical 31 %
Hardness [6]	as built		approx. 230 ± 20 HV1
	ground & polished [7]		approx. 250 - 400 HV1

[5] Mechanical testing according to ISO 6892:1998(E) Annex C, proportional test pieces, diameter of the neck area 5 mm, original gauge length 25 mm

[6] Vickers hardness measurement (HV) according to DIN EN ISO 6507-1. Note that, depending on the measurement method used, the measured hardness value can be dependent on the surface roughness and can be lower than the real hardness. To avoid inaccurate results, hardness should be measured on a polished surface.

[7] Due to work-hardening effect

## THERMAL PROPERTIES OF PARTS

<b>Coefficient of thermal expansion</b>	<b>over 20 - 600 °C (68 - 1080 °F)</b>	14 x 10 <sup>-6</sup> m/m °C 7.8 x 10 <sup>-6</sup> in/in °F
<b>Thermal conductivity</b>	<b>at 20 °C (68 °F)</b>	13 W/m °C 90 Btu/(h ft <sup>2</sup> °F/in)
	<b>at 100 °C (212 °F)</b>	14 W/m °C 97 Btu/(h ft <sup>2</sup> °F/in)
	<b>at 200 °C (392 °F)</b>	15 W/m °C 104 Btu/(h ft <sup>2</sup> °F/in)
	<b>at 300 °C (572 °F)</b>	16 W/m °C 111 Btu/(h ft <sup>2</sup> °F/in)
<b>Maximum operating temperature</b>	550 °C 1022 °F	

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

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



## EOS // TITANIUM Ti64

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

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

- EOSINT M 270 Installation Mode Xtended with PSW 3.4 and default job Ti64\_30\_030\_default.job
- EOSINT M 270 Dual Mode with PSW 3.5 and Original EOS Parameter Set Ti64\_Performance 2.0
- EOSINT M 280 with PSW 3.5 and Original EOS Parameter Set Ti64\_Speed 1.0

## DESCRIPTION

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

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

This material is ideal for many high-performance engineering applications, e.g., in aero-space and motor racing, and as well as the production of biomedical implants. (Note: subject to fulfilment of statutory validation requirements where appropriate.)

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

## TECHNICAL DATA

### GENERAL PROCESS AND GEOMETRIC DATA

Typical achievable part accuracy [1]	± 50 µm	
Min. wall thickness [2]	approx. 99.85 %	approx. 0.3 – 0.4 mm approx. 0.012 – 0.016 inch
Surface roughness, as-built [3]	Ti64_30_030_default.job Ti64 Performance (30 µm)	Ra 9 - 12 µm, Rz 40 - 80 µm Ra 0.36 – 0.47 x 10 <sup>-3</sup> inch, Rz 1.6 – 3.2 x 10 <sup>-3</sup> inch
	Ti64 Speed 1.0 (60 µm)	Ra 6 - 10 µm, Rz 35 - 40 µm Ra 0.23 – 0.39 x 10 <sup>-3</sup> inch, Rz 1.37 – 1.57 x 10 <sup>-3</sup> inch
Volume rate [4]	Ti64_30_030_default.job Ti64 Performance (30 µm)	3.75 mm <sup>3</sup> /s (13.5 cm <sup>3</sup> /h) 0.82 in <sup>3</sup> /h
	Ti64 Speed 1.0 (60 µm)	9 mm <sup>3</sup> /s (32.4 cm <sup>3</sup> /h) 1.98 in <sup>3</sup> /h

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

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

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

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

## PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

<b>Material composition</b>	Ti (balance) Al (5.5 – 6.75 wt.-%) V (3.5 – 4.5 wt.-%) O (< 2000 ppm) N (< 500 ppm) C (< 800 ppm) H (< 150 ppm) Fe (< 3000 ppm)
<b>Relative density</b>	approx. 100 %
<b>Density</b>	4.41 g/cm <sup>3</sup> 0.159 lb/in <sup>3</sup>

## MECHANICAL PROPERTIES OF PARTS

	As-built		Heat-treated [6]
<b>Tensile strength [5]</b>	<b>in horizontal direction (XY)</b>	typ. 1230 ± 50 MPa typ. 178 ± 7 ksi	min. 930 MPa (134.8 ksi) typ. 1050 ± 20 MPa (152 ± 3 ksi)
	<b>in vertical direction (Z)</b>	typ. 1200 ± 50 MPa typ. 174 ± 7 ksi	min. 930 MPa (134.8 ksi) typ. 1060 ± 20 MPa (154 ± 3 ksi)
<b>Yield strength (Rp0.2) [5]</b>	<b>in horizontal direction (XY)</b>	typ. 1060 ± 50 MPa typ. 154 ± 7 ksi	min. 860 MPa (124.7 ksi) typ. 1000 ± 20 MPa (145 ± 3 ksi)
	<b>in vertical direction (Z)</b>	typ. 1070 ± 50 MPa typ. 155 ± 7 ksi	min. 860 MPa (124.7 ksi) typ. 1000 ± 20 MPa (145 ± 3 ksi)
<b>Elongation at break [5]</b>	<b>in horizontal direction (XY)</b>	typ. (10 ± 2) %	min. 10 % typ. (14 ± 1) %
	<b>in vertical direction (Z)</b>	typ. (11 ± 3) %	min. 10 % typ. (15 ± 1) %
<b>Modulus of elasticity [5]</b>	<b>in horizontal direction (XY)</b>	typ. 110 ± 10 GPa typ. 16 ± 1.5 Msi	typ. 116 ± 10 GPa typ. 17 ± 1.5 Msi
	<b>in vertical direction (Z)</b>	typ. 110 ± 10 GPa typ. 16 ± 1.5 Msi	typ. 114 ± 10 GPa typ. 17 ± 1.5 Msi
<b>Hardness [7]</b>	typ. 320 ± 12 HV5		

[5] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), original gauge length 25 mm (1 inch).

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

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

## MECHANICAL PROPERTIES OF PARTS

<b>Maximum long-term operating temperature</b>	approx. 350 °C approx. 660 °F
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The data are valid for the combinations of powder material, machine, and parameter sets referred to on page 1 when used in accordance with the relevant Operating Instructions (including Installation Requirements and Maintenance) and Parameter Sheet. Part properties are measured using defined test procedures. Further details of the test procedures used by EOS are available on request.

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

## EOS // STAINLESS STEEL 316L

EOS Stainless Steel 316L is a corrosion-resistant iron based alloy which has been specially optimized for processing on EOSINT M280 systems.

This document provides information and data for parts built using EOS Stainless Steel 316L powder (EOS art.-no. 9011-0032) on the following system specifications:

- EOSINT M280 400W System with PSW3.6 and Parameter Set 316L\_Surface 1.0
- EOSINT M280 200W System with PSW3.6 and Parameter Set 316L\_Surface 1.0

## DESCRIPTION

The parts built from EOS Stainless Steel 316L have chemical compositions corresponding to ASTM F138 "Standard Specification for Wrought 18Cr-14Ni-2.5Mo Stainless Steel Bar and Wire for Surgical Implants (UNS S31673)". This kind of stainless steel is characterized having a good corrosion resistance and evidence that there are no leachable substances in cytotoxic concentrations.

This material is ideal in:

- Lifestyle/Consumer – watches, other jewelry, glasses frames, decorations, functional elements in electronic housing, and accessories
- Automotive/Industrial – non-corroding common material, food, and chemical plants
- Aerospace/Turbine industry – entry-level material for Laser Sintering Technology, mounting parts, brackets, heat exchangers

Parts built from EOS Stainless Steel 316L can be machined, shot-peened and polished in as-built or stress-relieved (AMS2759) states if required. Solution annealing is not necessary because the mechanical properties of as-built state are showing desired values (ASTM A403). Parts are not ideal in temperature range 427°C - 816°C where precipitation of chromium carbides occurs. Due to layerwise building method, the parts have a certain anisotropy which could be seen from mechanical properties.

# TECHNICAL DATA

## GENERAL PROCESS DATA

<b>Typical achievable part accuracy [1]</b>	<b>small parts</b>	approx. $\pm 20\text{-}50\ \mu\text{m}$ ( $\pm 0.0008 - 0.002$ inch)
	<b>large parts</b>	approx. $\pm 0.2\ \%$
<b>Min. wall thickness [2]</b>	approx. $0.3 - 0.4\ \text{mm}$ ( $0.012 - 0.016$ inch)	
<b>Layer thickness</b>	$20\ \mu\text{m}$ ( $0.8 \times 10^{-3}$ inch)	
<b>Surface roughness [3]</b>	<b>as-manufactured</b>	Ra $13 \pm 5\ \mu\text{m}$ ; Rz $80 \pm 20\ \mu\text{m}$ Ra $0.5 \pm 0.2 \times 10^{-3}$ inch; Rz $3.1 \pm 0.8 \times 10^{-3}$ inch
	<b>after shot-peening</b>	Ra $5 \pm 2\ \mu\text{m}$ ; Rz $30 \pm 10\ \mu\text{m}$ Ra $0.2 \pm 0.08 \times 10^{-3}$ inch; Rz $1.2 \pm 0.4 \times 10^{-3}$ inch
	<b>after polishing</b>	Rz up to $< 1\ \mu\text{m}$ Rz up to $< 0.04 \times 10^{-3}$ inch (can be very finely polished)
<b>Volume rate [4]</b>	$2\ \text{mm}^3/\text{s}$ ( $7.2\ \text{cm}^3/\text{h}$ ) $0.44\ \text{in}^3/\text{h}$	

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g.  $\pm 40\ \mu\text{m}$  when parameters can be optimized for a certain class of parts or  $\pm 60\ \mu\text{m}$  when building a new kind of geometry for the first time. Part accuracy is subject to appropriate data preparation and post-processing.

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

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

[4] Volume rate is a measure of build speed during laser exposure. The total build speed depends on the average volume rate, the recoating time (related to the number of layers), and other factors such as contour and Up/Down Skin parameters.

## PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

	Element	Min.	Max.
<b>Material composition</b>	Fe	Balance	
	Cr	17.00	19.00
	Ni	13.00	15.00
	Mo	2.25	3.00
	C		0.030
	Mn		2.00
	Cu		0.50
	P		0.025
	S		0.010
	Si		0.75
	N		0.10
	<b>Relative density with standard parameters</b>	approx. 100 %	
<b>Density with standard parameters</b>	min. 7.9 g/cm <sup>3</sup> min. 0.285 lb/in <sup>3</sup>		

## MECHANICAL PROPERTIES OF PARTS (AT ROOM TEMPERATURE)

		As-built
<b>Ultimate tensile strength [5]</b>	<b>in horizontal direction (XY)</b>	640 ± 50 MPa
	<b>in vertical direction (Z)</b>	540 ± 55 MPa
<b>Yield strength, Rp0.2% [5]</b>	<b>in horizontal direction (XY)</b>	530 ± 60 MPa
	<b>in vertical direction (Z)</b>	470 ± 90 MPa
<b>Young's modulus [5]</b>	<b>in horizontal direction (XY)</b>	typ. 185 GPa
	<b>in vertical direction (Z)</b>	typ. 180 GPa
<b>Elongation at break [5]</b>	<b>in horizontal direction (XY)</b>	40 ± 15%
	<b>in vertical direction (Z)</b>	50 ± 20%
<b>Hardness [6]</b>	typ. 85 HRB	

[5] Machining and testing of the test bars according to ISO 6892 / ASTM E8M, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), gauge length 4D = 20.0mm (0.79 inch), stress rate 10MPa/s, strain speed in plastic region 0.375 1/min.

[6] Rockwell hardness (HRB) measurement according to EN ISO 6508-1 on polished surface.

## MECHANICAL PROPERTIES OF PARTS (AT ROOM TEMPERATURE)

		<b>As-built</b>
<b>Ultimate tensile strength [5]</b>	<b>in horizontal direction (XY)</b>	640 ± 50 MPa
	<b>in vertical direction (Z)</b>	540 ± 55 MPa
<b>Yield strength, Rp0.2% [5]</b>	<b>in horizontal direction (XY)</b>	530 ± 60 MPa
	<b>in vertical direction (Z)</b>	470 ± 90 MPa
<b>Young's modulus [5]</b>	<b>in horizontal direction (XY)</b>	typ. 185 GPa
	<b>in vertical direction (Z)</b>	typ. 180 GPa
<b>Elongation at break [5]</b>	<b>in horizontal direction (XY)</b>	40 ± 15%
	<b>in vertical direction (Z)</b>	50 ± 20%
<b>Hardness [6]</b>	typ. 85 HRB	

[5] Machining and testing of the test bars according to ISO 6892 / ASTM E8M, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), gauge length 4D = 20.0mm (0.79 inch), stress rate 10MPa/s, strain speed in plastic region 0.375 1/min.

[6] Rockwell hardness (HRB) measurement according to EN ISO 6508-1 on polished surface.

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

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## EOS // STAINLESS STEEL PH1 FOR EOSINT M 270

Several different materials are available for use with EOSINT M systems, offering a broad range of e-Manufacturing applications. EOS Stainless Steel PH1 is a stainless steel powder which has been specially optimized for EOSINT M 270 systems. Other materials are also available for EOSINT M systems, and further materials are continuously being developed — please refer to the relevant material data sheets for details.

This document provides a brief description of the principle applications and a table of technical data. For details of the system requirements, please refer to the relevant information quote.

### DESCRIPTION

EOS Stainless Steel PH1 is a pre-alloyed stainless steel in fine powder form. The chemistry of EOS Stainless Steel PH1 conforms to the compositions of DIN 1.4540 and UNS S15500.

This kind of steel is characterized by having good corrosion resistance and excellent mechanical properties, especially in the precipitation hardened state. This type of steel is widely used in va-riety of medical, aerospace, and other engineering applications requiring high hardness, strength, and corrosion resistance.

This material is ideal for many part-building applications (DirectPart) such as functional metal prototypes, small series products, individualized products or spare parts. Standard processing parameters use full melting of the entire geometry with 20 µm layer thickness, but it is also possible to use 40µm layer thickness to increase the build speed. Using standard parameters the mechanical properties are fairly uniform in all directions. Parts made from EOS Stainless Steel PH1 can be machined, spark-eroded, welded, micro shot-peened, polished, and coated if required. Unexposed powder can be reused.

Typical applications:

- Engineering applications including functional prototypes, small series products, individualized products or spare parts.
- Parts requiring high corrosion resistance, sterilisability, etc.
- Parts requiring particularly high hardness and strength.



## TECHNICAL DATA

### GENERAL PROCESS DATA

<b>Typical achievable part accuracy [1]</b>	<b>small parts</b>	± 20 – 50 µm 0.8 – 2.0 mil
	<b>large parts</b>	± 0.2 %
<b>Min. wall thickness [2]</b>	approx. 0.3 - 0.4 mm (0.012 – 0.016 inch)	
<b>Minimum recommended layer thickness</b>	20 µm 0.8 mil	
<b>Surface roughness [3]</b>	<b>after shot-peening</b>	Ra 5 ±2 µm; Rz 30 ±10µm Ra 0.2 ±0.08 x 10 <sup>-3</sup> inch; Rz 1.2 ±0.4 x 10 <sup>-3</sup> inch
	<b>after polishing</b>	Rz up to < 1 µm Rz up to < 0.04 x 10 <sup>-3</sup> inch (can be very finely polished)
<b>Volume rate [4]</b>	<b>standard parameters (20µm layers, full density)</b>	1.8 mm <sup>3</sup> /s 0.40 in <sup>3</sup> /h
	<b>40µm layer parameters (full density)</b>	3.2 mm <sup>3</sup> /s 0.70 in <sup>3</sup> /h

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g. ± 20 µm when parameters can be optimized for a certain class of parts or ± 50 µm when building a new kind of geometry for the first time.

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

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

### PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

<b>Material composition</b>	Fe (balance) Cr (14 – 15.5 wt-%) Ni (3.5 – 5.5 wt-%) Cu (2.5 – 4.5 wt-%) Mn (max. 1 wt-%) Si (max. 1 wt-%) Mo (max. 0.5 wt-%) Nb (0.15 - 0.45 wt-%) C (max. 0.07 wt-%)
<b>Relative density with standard parameters</b>	approx. 100 %
<b>Density with standard parameters</b>	7.8 g/cm <sup>3</sup> 0.28 lb/in <sup>3</sup>

## MECHANICAL PROPERTIES OF PARTS [4]

		As-manufactured	Hardened [6] (mod H900 heat treatment)
Ultimate tensile strength [5]	in horizontal direction (XY)	1150 ± 50 MPa	min 1310 MPa (typical 1450 ± 100 MPa)
	in vertical direction (Z)	1050 ± 50 MPa	min 1310 MPa (typical 1450 ± 100 MPa)
Yield strength, Rp0.2% [5]	in horizontal direction (XY)	1050 ± 50 MPa	min 1170 MPa (typical 1300 ± 100 MPa)
	in vertical direction (Z)	1050 ± 50 MPa	min 1170 MPa (typical 1300 ± 100 MPa)
Elongation at break [5]	in horizontal direction (XY)	16 % ± 4 %	min 10 % (typical 12 % ± 2 %)
	in vertical direction (Z)	17 % ± 4 %	min 10 % (typical 12 % ± 2 %)
Hardness [5]		30 - 35 HRC	min 40 HRC

[4] Mechanical testing according to ISO 6892:1998(E) Annex C, proportional test pieces, Diameter of the neck area 5mm, original gauge length 25mm, test pieces built in 20µm layer-thickness.

[5] Rockwell C (HRC) hardness measurement according to DIN EN ISO 6508-1. Note that depending on the measurement method used, the measured hardness value can be dependent on the surface roughness and can be lower than the real hardness. To avoid inaccurate results, hardness should be measured on a polished surface.

[6] Mechanical properties are expressed as minimum values to indicate that mechanical properties exceed the min. requirements of material specification standards such as ASTM A564-04 (XM12), ASTM A693-06 (XM12). Hardening of EOS Stainless Steel PH1 done using modified H900 heat treatment (soaking time at precipitation hardening temperature 482°C elongated from one hour to four hours).

## THERMAL PROPERTIES OF PARTS (ROOM TEMPERATURE)

		As-manufactured	Hardened [6] (mod H900 heat treatment)
Thermal conductivity	in horizontal direction (XY)	13.8 ± 0.8 W/m°C	15.7 ± 0.8 W/m°C
	in vertical direction (Z)	13.7 ± 0.8 W/m°C	15.8 ± 0.8 W/m°C
Specific heat capacity		460 ± 20 J/kg °C	470 ± 20 J/kg °C

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

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