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

Typical achievable part accuracy [1] [2]	±100 µm	
Smallest wall thickness [1] [3]	approx. 0.3 – 0.4 mm approx. 0.012 – 0.016 inch	
Surface roughness [1] [4]	**as built, cleaned**	Ra 6 - 10 µm, Rz 30 - 40 µm Ra 0.24 - 0.39 x 10^{-3} inch Rz 1.18 - 1.57 x 10^{-3} inch
	after micro shot-peening	Ra 7 - 10 µm, Rz 50 - 60 µm Ra 0.28 - 0.39 x 10^{-3} inch Rz 1.97 - 2.36 x 10^{-3} inch
Volume rate [5]	7.4 mm³/s (26.6 cm³/h) 1.6 in³/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

Material composition	Al (balance) Si (9.0 - 11.0 wt-%) Fe (≤ 0.55 wt-%) Cu (≤ 0.05 wt-%) Mn (≤ 0.45 wt-%) Mg (0.2 - 0.45 wt-%) Ni (≤ 0.05 wt-%) Zn (≤ 0.10 wt-%) Pb (≤ 0.05 wt-%) Sn (≤. 0.05 wt-%) Ti (≤ 0.15 wt-%)
Relative density	approx. 99.85 %
Density	2.67 g/cm³ 0.096 lb/in³

MECHANICAL PROPERTIES OF THE PARTS

		As built	**Heat treated [9]**
Tensile strength [6]	**in horizontal direction (XY)**	460 ± 20 MPa 66.7 ± 2.9 ksi	345 ± 10 MPA 50.0 ± 1.5 ksi
	in vertical direction (Z)	460 ± 20 MPa 66.7 ± 2.9 ksi	350 ± 10 MPa 50.8 ± 1.5 ksi
Yield strength (Rp 0.2 %) [6]	**in horizontal direction (XY)**	270 ± 10 MPa 39.2 ± 1.5 ksi	230 ± 15 MPa 33.4 ± 2.2 ksi
	in vertical direction (Z)	240 ± 10 MPa 34.8 ± 1.5 ksi	230 ± 15 MPa 33.4 ± 2.2 ksi
Modulus of elasticity	**in horizontal direction (XY)**	75 ± 10 GPa 10.9 ± 0.7 Msi	70 ± 10 GPa 10.2 ± 0.7 Msi
	in vertical direction (Z)	70 ± 10 GPa 10.2 ± 0.7 Msi	60 ± 10 GPa 8.7 ± 0.7 Msi
Elongation at break [6]	**in horizontal direction (XY)**	(9 ± 2) %	12 ± 2%
	in vertical direction (Z)	(6 ± 2) %	11 ± 2%
Hardness [7]		approx.119 ± 5 HBW	
Fatigue strength [1] [8]	**in vertical direction (Z)**	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]
Thermal conductivity (at 20 °C) in horizontal direction (XY)	approx. 103 ± 5 W/m°C	approx. 173 ± 10 W/m°C
Thermal conductivity (at 20 °C) in vertical direction (Z)	approx. 119 ± 5 W/m°C	approx. 173 ± 10 W/m°C
Specific heat capacity in horizontal direction (XY)	approx. 920 ± 50 J/kg°C	approx. 890 ± 50 J/kg°C
Specific heat capacity in vertical direction (Z)	approx. 910 ± 50 J/kg°C	approx. 890 ± 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

Typical achievable part accuracy [1]	**small parts (< 80 x 80 mm)**	approx. ± 20 µm approx. ± 0.8 x 10^{-3} inch
	large parts	approx. ± 50 µm approx. ± 0.002 inch
Age hardening shrinkage [2]	approx. 0.08 %	
Min. wall thickness [3]	approx. 0.3 - 0.4 mm approx. 0.012 - 0.016 inch	
Surface roughness (approx.) [4] - as manufactured	**MS1 Surface (20 µm)**	Ra 4 µm; Rz 20 µm Ra 0.16 x 10^{-3} inch, Rz 0.78 x 10^{-3} inch
	MS1 Performance (40 µm)	Ra 5 µm; Rz 28 µm Ra 0.19 x 10^{-3} inch, Rz 1.10 x 10^{-3} inch
	MS1 Speed (50 µm)	Ra 9 µm; Rz 50 µm Ra 0.47 x 10^{-3} inch, Rz 2.36 x 10^{-3} inch
	after shot-peening	Ra 4 - 6.5 µm; Rz 20 - 50 µm Ra 0.16 – 0.26 x 10^{-3} inch Rz 0.78 – 1.97 x 10^{-3} inch
	after polishing	Rz up to < 0.5 µm Rz up to < 0.02 x 10^{-3} inch (can be very finely polished)
Volume rate [5]	**Parameter set MS1_ Surface 1.0 / default job MS1_020_default.job (20 µm layer thickness)**	1.6 mm³/s (5.8 cm³/h) 0.35 in³/h
	Parameter set MS1_ Performance 2.0 / default job MS1_040_default.job (40 µm layer thickness)	3 mm³/s (10.8 cm³/h) 0.66 in³/h
	Parameter set MS1_ Performance 1.0 / for M 280 / 400 W (40 µm layer thickness)	4.2 mm³/s (15.1 cm³/h) 0.92 in³/h
	Parameter set MS1_ Speed 1.0 / for M 280 / 400 W (50 µm layer thickness)	5.5 mm³/s (19.8 cm³/h) 1.21 in³/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

Material Composition	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 ≤ 0.5 wt-%) C (≤ 0.03 wt-%) Mn, Si (each ≤ 0.1 wt-%) P, S (each ≤ 0.01 wt-%)
Relative Density	approx. 100%
Density	8.0 - 8.1 g/cm³ 0.289 - 0.293 lb/in³

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

		As-built	After age-hardening [2]
Tensile strength [6]			min. 1930 MPa min. 280 ksi
	in horizontal direction (XY)	typ. 1100 ± 100 MPa typ. 160 ± 15 ksi	typ. 2050 ± 100 MPa typ. 297 ± 15 ksi
	in vertical direction (Z)	typ. 1100 ± 100 MPa typ. 160 ± 15 ksi	
Yield strength (Rp 0.2 %) [6]			min. 1862 MPa min. 270 ksi
	in horizontal direction (XY)	typ. 1050 ± 100 MPa typ. 152 ± 15 ksi	typ. 1990 ± 100 MPa typ. 289 ± 15 ksi
	in vertical direction (Z)	typ. 1000 ± 100 MPa typ. 145 ± 15 ksi	
Elongation at break [6]			min. 2 %
	in horizontal direction (XY)	typ. (10 ± 4) %	typ. (4 ± 2) %
	in vertical direction (Z)	typ. (10 ± 4) %	
Modulus of elasticity [6]			
	in horizontal direction (XY)	typ. 160 ± 25 GPa typ. 23 ± 4 Msi	typ. 180 ± 20 GPa typ. 26 ± 3 Msi
	in vertical direction (Z)	typ. 150 ± 20 GPa typ. 22 ± 3 Msi	
Hardness [7]		typ. 33 - 37 HRC	typ. 50 - 56 HRC
Ductility (Notched Charpy impact test)		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]
Thermal conductivity	typ. 15 ± 0.8 W/m°C typ. 104 ± 6 Btu in/(h ft² °F)	typ. 20 ± 1 W/m°C typ. 139 ± 7 Btu in/(h ft² °F)
Specific heat capacity	typ. 450 ± 20 J/kg°C typ. 0.108 ± 0.005 Btu/(lb °F)	typ. 450 ± 20 J/kg°C typ. 0.108 ± 0.005 Btu/(lb °F)
Maximum operating temperature		approx. 400 °C approx. 750 °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_Performace 1.0
- EOS M290 400W System with EOSPRINT 1.0 and Parameter Set IN718_Performace 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

Typical achievable part accuracy [1], [11]	**small parts**	approx. ± 40 – 60 µm approx. ± 1.6 – 2.4 x 10^{-3} inch
	large parts	± 0.2 %
Min. wall thickness [2], [11]	typ. 0.3 - 0.4 mm typ. 0.012 – 0.016 inch	
Surface roughness [3], [11]	**after shot-peening**	Ra 4 – 6.5 µm, Rz 20 - 50 µm Ra 0.16 – 0.25 x 10^{-3} inch, Rz 0.78 – 1.97 x 10^{-3} inch
	after polishing	Rz up to < 0.5 µm Rz up to < 0.02 x 10^{-3} inch (can be very finely polished)
Volume rate [4]	**Parameter Set IN718_ Performance (40 µm)**	4 mm³/s (14.4 cm³/h) 0.88 in³/h

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g. ± 40 µm (1.6 x 10^{-3} inch) when parameters can be optimized for a certain class of parts or ± 60 µm (2.4 x 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

Material composition	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 (± 1.0 wt-%) Cu (± 0.3 wt-%) C (± 0.08 wt-%) Si, Mn (each ± 0.35 wt-%) P, S (each ± 0.015 wt-%) B (± 0.006 wt-%) Fe (balance)
Relative density	approx. 100%
Density	min. 8.15 g/cm³ min. 0.294 lb/in³

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

		As-built	Heat-treated per AMS 5662 [5]	Heat-treated per AMS 5664 [6]
Tensile strength [7]	**in horizontal direction (XY)**	typ. 1060 ± 50 MPa (154 ± 7 ksi)		
	in vertical direction (Z)	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)
Yield strength (Rp 0.2 %) [7]	**in horizontal direction (XY)**	typ. 780 ± 50 MPa (113 ± 7 ksi)		
	in vertical direction (Z)	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)
Elongation at break [7]	**in horizontal direction (XY)**	typ. (27 ± 5) %		
	in vertical direction (Z)	typ. (31 ± 5) %	min. 12 % typ. (15 ± 3) %	min. 12 % typ. (18 ± 5) %
Modulus of elasticity [7]	**in horizontal direction (XY)**	typ. 160 ± 20 GPa (23 ± 3 Msi)		
	in vertical direction (Z)		170 ± 20 GPa 24.7 ± 3 Msi	170 ± 20 GPa 24.7 ± 3 Msi
Hardness [8]		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]
Tensile Strength (Rm) [9] - in vertical direction (Z)	min. 965 MPa (140 ksi) typ. 1170 ± 50 MPa (170 ± 7 ksi)	typ. 1210 ± 50 MPa (175 ± 7 ksi)
Yield strength (Rp 0.2 %) [9] - in vertical direction (Z)	min. 862 MPa (125 ksi) typ. 970 ± 50 MPa (141 ± 7 ksi)	typ. 1010 ± 50 MPa (146 ± 7 ksi)
Elongation at break [9] - in vertical direction (Z)	min. 6 % typ. (16 ± 3) %	typ. (20 ± 3) %
Stress-Rupture Properties [10] - in vertical direction (Z)	min. 23 hours at stress level 689 MPa (100 ksi)	
Stress-Rupture Properties [10]	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]
Coefficient of thermal expansion	**over 25 - 200 °C (36 - 390 °F)**	approx. 12.5 - 13.0 x 10-6 m/m°C approx. 6.9 - 7.2 x 10-6 in/in°F
	over 25 - 750 °C (36 - 930 °F)	approx. 16.6 - 17.2 x 10-6 m/m°C approx. 9.2 - 9.6 x 10-6 in/in°F
Maximum operating temperature for parts under load	approx. 650 °C approx. 1200 °F	
Oxidation resistance up to [11]	approx. 980 °C approx. 1800 °F	

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

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

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

Material composition	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-%)
Relative density with standard parameters	approx. 100%
Density with standard parameters	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

Coefficient of thermal expansion	**over 20 - 600 °C (68 - 1080 °F)**	14 x 10-6 m/m °C 7.8 x 10-6 in/in °F
Thermal conductivity	**at 20 °C (68 °F)**	13 W/m °C 90 Btu/(h ft² °F/in)
	at 100 °C (212 °F)	14 W/m °C 97 Btu/(h ft² °F/in)
	at 200 °C (392 °F)	15 W/m °C 104 Btu/(h ft² °F/in)
	at 300 °C (572 °F)	16 W/m °C 111 Btu/(h ft² °F/in)
Maximum operating temperature	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.

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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^{-3} inch, Rz 1.6 – 3.2 x 10^{-3} inch
	Ti64 Speed 1.0 (60 µm)	Ra 6 - 10 µm, Rz 35 - 40 µm Ra 0.23 – 0.39 x 10^{-3} inch, Rz 1.37 –1.57 x 10^{-3} inch
Volume rate [4]	Ti64_30_030_default.job Ti64 Performance (30 µm)	3.75 mm^3/s (13.5 cm^3/h) 0.82 in^3/h
	Ti64 Speed 1.0 (60 µm)	9 mm^3/s (32.4 cm^3/h) 1.98 in^3/h

[1] Based on users' experience of dimensional accuracy for typical geometries. Part accuracy is subject to appropriate data preparation and post-processing, in accordance with EOS training.
[2] Mechanical stability is dependent on geometry (wall height etc.) and application
[3] Due to the layerwise building, the surface structure depends strongly on the orientation of the surface. For example sloping and curved surfaces exhibit a stair-step effect. The values also depend on the measurement method used. The values quoted here given an indication of what can be expected for horizontal (up-facing) or vertical surfaces.
[4] Volume rate is a measure of build speed during laser exposure. The total build speed depends on the average volume rate, the recoating time (related to the number of layers) and other factors such as DMLS-Start settings.

PHYSICAL AND CHEMICAL PROPERTIES OF PARTS

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

MECHANICAL PROPERTIES OF PARTS

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

[5] Tensile testing according to ISO 6892-1:2009 (B) Annex D, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), original gauge length 25 mm (1 inch).
[6] Specimens were treated at 800 °C (1470 °F) for 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 measuredhardness can vary significantly depending on how the specimen has been prepared.

MECHANICAL PROPERTIES OF PARTS

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

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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

Typical achievable part accuracy [1]	**small parts**	approx. ±20-50 µm (±0.0008 – 0.002 inch)
	large parts	approx. ± 0.2 %
Min. wall thickness [2]	approx. 0.3 - 0.4 mm (0.012 – 0.016 inch)	
Layer thickness	20 µm (0,8 x 10-3 inch)	
Surface roughness [3]	**as-manufactured**	Ra 13 ±5 µm; Rz 80 ±20 µm Ra 0.5 ±0.2 x 10^{-3} inch; Rz 3.1 ±0.8 x 10^{-3} inch
	after shot-peening	Ra 5 ±2 µm; Rz 30 ±10µm Ra 0.2 ±0.08 x 10^{-3} inch; Rz 1.2 ±0.4 x 10^{-3} inch
	after polishing	Rz up to < 1 µm Rz up to < 0.04 x 10 $^{-3}$ inch (can be very finely polished)
Volume rate [4]	2 mm³/s (7.2 cm³/h) 0.44 in³/h	

[1] Based on users' experience of dimensional accuracy for typical geometries, e.g. ± 40 µm when parameters can be optimized for a certain class of parts or ± 60 µm 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.
Material composition	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
Relative density with standard parameters	approx. 100 %		
Density with standard parameters	min. 7.9 g/cm3 min. 0.285 lb/in3		

MECHANICAL PROPERTIES OF PARTS (AT ROOM TEMPERATURE)

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

		As-built
Ultimate tensile strength [5]	**in horizontal direction (XY)**	640 ± 50 MPa
	in vertical direction (Z)	540 ± 55 MPa
Yield strength, Rp0.2% [5]	**in horizontal direction (XY)**	530 ± 60 MPa
	in vertical direction (Z)	470 ± 90 MPa
Young's modulus [5]	**in horizontal direction (XY)**	typ. 185 GPa
	in vertical direction (Z)	typ. 180 GPa
Elongation at break [5]	**in horizontal direction (XY)**	40 ± 15%
	in vertical direction (Z)	50 ± 20%
Hardness [6]	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, individualizedproducts or spare parts.
- Parts requiring high corrosion resistance, sterilisability, etc.
- Parts requiring particularly high hardness and strength.

TECHNICAL DATA

GENERAL PROCESS DATA

Typical achievable part accuracy [1]	**small parts**	± 20 – 50 µm 0.8 – 2.0 mil
	large parts	± 0.2 %
Min. wall thickness [2]	approx. 0.3 - 0.4 mm (0.012 – 0.016 inch)	
Minimum recommended layer thickness	20 µm 0.8 mil	
Surface roughness [3]	**after shot-peening**	Ra 5 ±2 µm; Rz 30 ±10µm Ra 0.2 ±0.08 x 10^{-3} inch; Rz 1.2 ±0.4 x 10^{-3} inch
	after polishing	Rz up to < 1 µm Rz up to < 0.04 x 10^{-3} inch (can be very finely polished)
Volume rate [4]	**standard parameters (20µm layers, full density)**	1.8 mm³/s 0.40 in³/h
	40µm layer parameters (full density)	3.2 mm³/s 0.70 in³/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

Material composition	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-%)
Relative density with standard parameters	approx. 100 %
Density with standard parameters	7.8 g/cm³ 0.28 lb/in³

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

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