EOSINT M Materials
for Direct Metal Laser-Sintering (DMLS)

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EOS metal powder materials for EOSINT M systems

Material name	Material type	Typical applications
EOS MaragingSteel MS1	18 Mar 300 / 1.2709	Injection moulding series tooling; engineering parts
EOS StainlessSteel GP1	Stainless steel 17-4 / 1.4542	Functional prototypes and series parts; engineering and medical
EOS StainlessSteel PH1	Hardenable stainless 15-5 / 1.4540	Functional prototypes and series parts; engineering and medical
EOS NickelAlloy IN718	Inconel™ 718, UNS N07718, AMS 5662, W.Nr 2.4668 etc.	Functional prototypes and series parts; high temperature turbine parts etc.
EOS CobaltChrome MP1	CoCrMo superalloy	Functional prototypes and series parts; engineering, medical, dental
EOS CobaltChrome SP2	CoCrMo superalloy	Dental restorations (series production)
EOS Titanium Ti64	Ti6Al4V light alloy	Functional prototypes and series parts; aerospace, motor sport etc.
EOS Aluminium AlSi10Mg	AlSi10Mg light alloy	Functional prototypes and series parts; engineering, automotive etc.
DirectMetal 20	Bronze-based mixture	Injection moulding tooling; functional prototypes

Quelle: EOS

Contents

- EOS MaragingSteel MS1
- EOS StainlessSteel GP1
- EOS StainlessSteel PH1
- EOS NickelAlloy IN718
- EOS CobaltChrome MP1
- EOS CobaltChrome SP2
- EOS Titanium Ti64
- EOS Aluminium AlSi10Mg
- DirectMetal 20

Quelle: EOS

EOS MaragingSteel MS1

Various types of steels are conventionally used for injection moulds, depending on the requirements

Summary of tool steel types with examples

Material type	Examples / designations AISI / Material No. / German	Characteristics & applications
Nitriding steels	---- / 1.7735 / 14 CrMoV 6 9	Hard surface but low toughness. Used for screws and extruders
Case-hardened steels	P4 / 1.2341 / X 6 CrMo 4 P21 / 1.2764 / X 19 NiCrMo 4	Case-hardening: hard surface with tough core; warpage risk
Through-hardened steels	H11 / 1.2343 / X 38 CrMoV 5 1 D2 / 1.2379 / X 155 CrVMo 12 1	Typ. precipitation hardening. High hardness but low toughness
Maraging steels	18 Mar 300 / 1.2709 / X 3 NiCoMoTi 18 9 5	Age hardening: hard and tough, very low shrinkage (hardening)
Pre-hardened steels	P20 / 1.2311 / 40 CrMnMo 7 P20+S / 1.2312 / 40 CrMnMoS 8 6	No post-hardening needed
Corrosion-resistant steels	420SS / 1.2083 / X 42 Cr 12 ---- / 1.2316 / X 36 CrMo 17	For moulding corrosive plastics, e.g. PVC

Quelle: EOS

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Maraging steels are high performance, hardenable steels typically used for e.g. aerospace and tooling

Characteristics of standard maraging steels

- Maraging = "mar"tensite + "aging" [treatment]
- Low-carbon steels with martensitic structure
  - e.g. 18 Mar 300 / 1.2709 / X 3 NiCoMoTi 18 9 5 has 0.2% carbon
- In solution-annealed condition has high strength (~1,000 MPa) but can be easily machined
- Age-hardenable up to approx. 55 HRC hardness and much increased strength
  - e.g. 6 hours at 490°C
- Originally developed as high-strength steels for aerospace, also conventionally used for injection moulding tools with particularly complex cavities

Quelle: EOS

EOS MaragingSteel MS1 - high performance steel for series tooling and other applications

Characteristics and applications

- Key characteristics
  - 18 Maraging 300 type steel (1.2709, X3NiCoMoTi18-9-5)
  - fully melted to full density for high strength and polishability
  - easily machinable as-built
  - age hardenable up to approx. 55 HRC
  - good thermal conductivity
- Typical applications
  - series injection moulding, also for high volume production
  - other tooling applications, e.g. die casting
  - high performance parts, e.g. for aerospace applications

Injection mould insert with conformal cooling, built in EOS MaragingSteel MS1

Source: EOS, Oase

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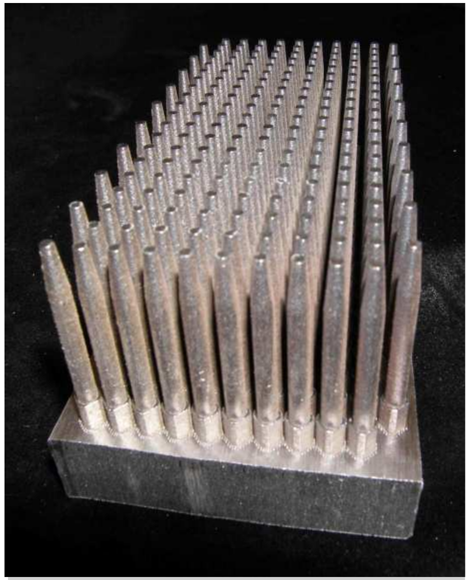
EOS MaragingSteel MS1 - high performance steel for series tooling and other applications

Key properties

Property	As built	After age hardening (6 hours at 490°C)
Ultimate tensile strength	1100 MPa ± 100 MPa 160 ksi ± 15 ksi	1950MPa ± 100 MPa 280 ksi ± 15 ksi
Yield strength (Rp 0.2 %)	1000 MPa ± 100 MPa 145 ksi ± 15 ksi	1900MPa ± 100 MPa 275 ksi ± 15 ksi
Elongation at break	8% ± 3 %	2% ± 1 %
Youngs Modulus	180 GPa ± 20 GPa 26.5 msi ± 3 msi	
Hardness	33-37 HRC	50-54 HRC
Ductility	45 J ± 10 J	11 J ± 4 J
Relative Density	approx. 100 %	



200 internally cooled pin inserts for injection moulding, built in EOS MaragingSteel MS1.

Source: EOS, LBC

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Folie 8

STGDE1 Vorschlag: als Tabelle, nicht benötigte Werte müssen noch rausgenommen werden
Denninger, Gerd; 31.07.2009

EOS StainlessSteel GP1

EOS StainlessSteel GP1 - stainless steel material for prototyping and series production

Characteristics and applications

- Key characteristics
  - raw material corresponds to 17-4 (1.4542, X5CrNiCuNb16-4)
  - excellent ductility
- Typical applications
  - engineering applications including functional prototypes, small series products, individualised products or spare parts
  - parts requiring high corrosion resistance, sterilisability, etc.
  - parts requiring particularly high toughness and ductility

Demonstration part in EOS StainlessSteel GP1, partly polished

Benchmark test geometry in EOS StainlessSteel GP1. Source: NASA/ General Pattern.

Quelle: EOS

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EOS StainlessSteel GP1 is an industrially accepted stainless steel material

Chemistry and metallurgy

- Composition corresponds to US 17-4 and European 1.4542
- Metallurgy of as-sintered material characterized by laser processing
  - very fast melting and solidification
  - microstructure and properties are not identical to cast- or wrought-type alloy

Element	Content (by weight)
Iron	balance
Manganese	max. 1 %
Molybdenum	max. 0.5 %
Nickel	3 - 5 %
Silicon	max. 1 %
Carbon	max. 0,07 %
Chromium	15 - 17.5 %
Copper	3 - 5 %

Source: EOS

EOS StainlessSteel GP1 produces parts with good mechanical properties

Mechanical properties

Property	Horizontal orientation	Vertical orientation
Ultimate tensile strength, MPa	1100 MPa 160 ksi	980 MPa 142 ksi
Yield strength (ReL), MPa	590 MPa 86 ksi	550 MPa 80 ksi
Young's Modulus (GPa)	180 GPa 26 msi	n/a
Remaining elongation	25 ±5 %	
Surface hardness		
- as laser-sintered	230 ±20 HV1	
- (ground & polished)	(250-400 HV1) *	

* Work hardening effect

Quelle: EOS

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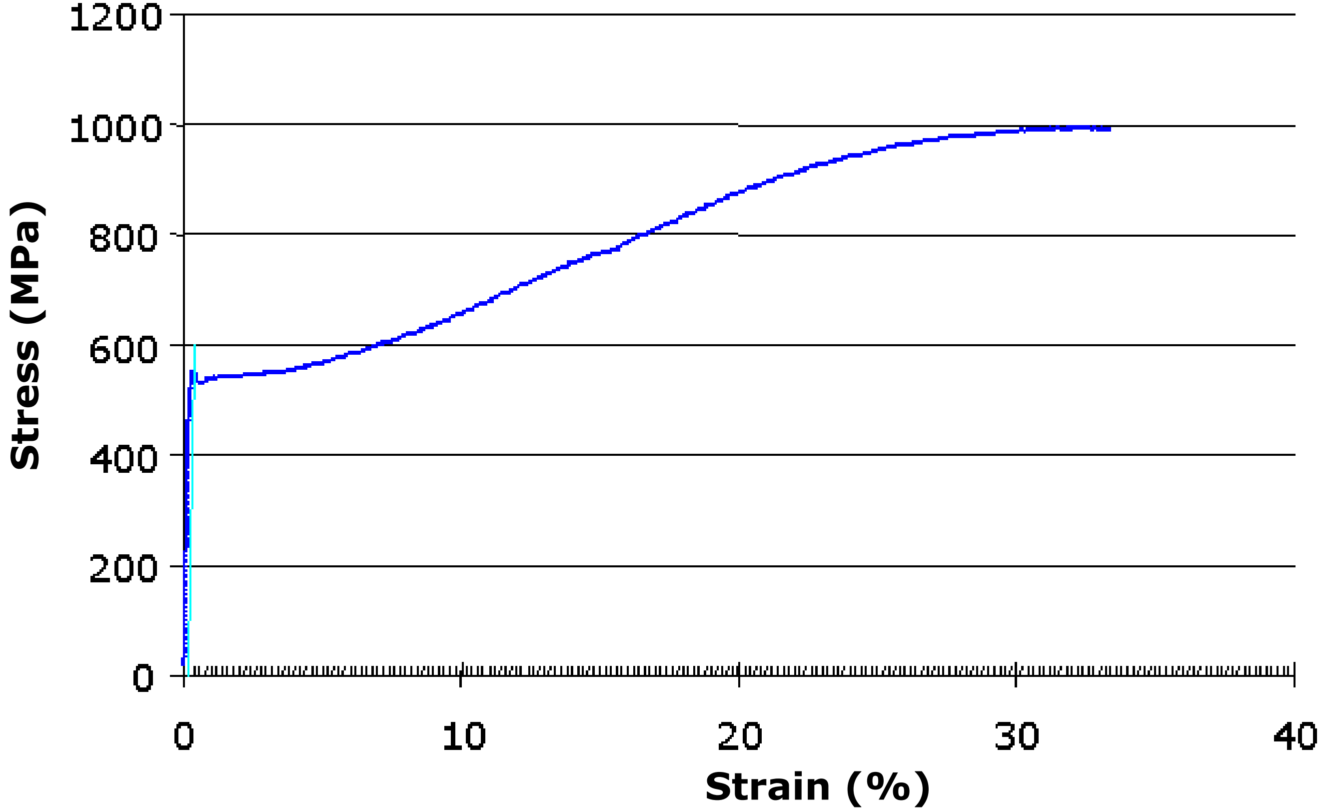
EOS StainlessSteel GP1 produces parts with good mechanical properties and excellent ductility

Typical tensile testing behaviour of EOS StainlessSteel GP1

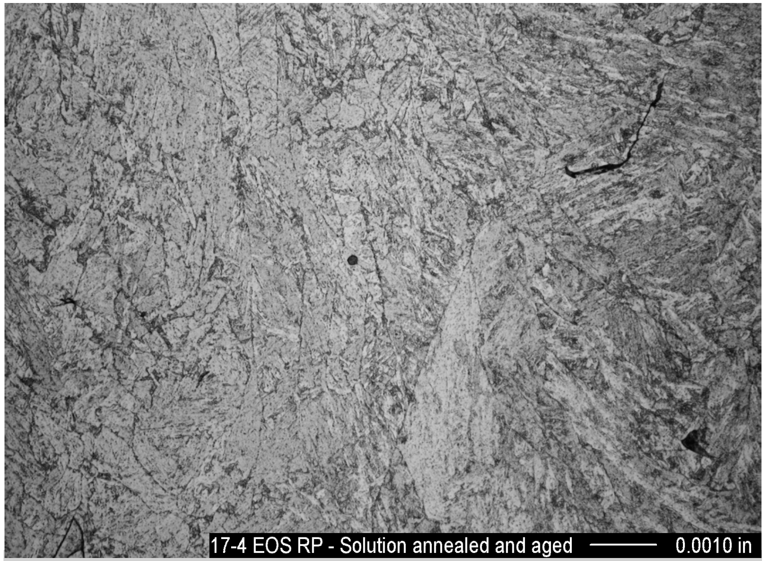


Source: EOS

EOS StainlessSteel GP1 produces fully dense parts

Physical & thermal properties

Property	Value
Relative density	approx. 100 %
Density	7.8 g/cm³
Max. operating temperature	550 °C
Melting range	1350-1430 °C
Thermal conductivity	
at 20 °C:	13 W/m°C
at 100 °C:	14 W/m°C
at 200 °C:	15 W/m°C
at 3000 °C:	16 W/m°C
Coefficient of thermal expansion	
20 – 600 °C	14 x10^{-6} m/m°C



Micrograph of laser-sintered EOS StainlessSteel GP1 in solution-annealed and H1150 aged condition showing fully remelted, dense structure

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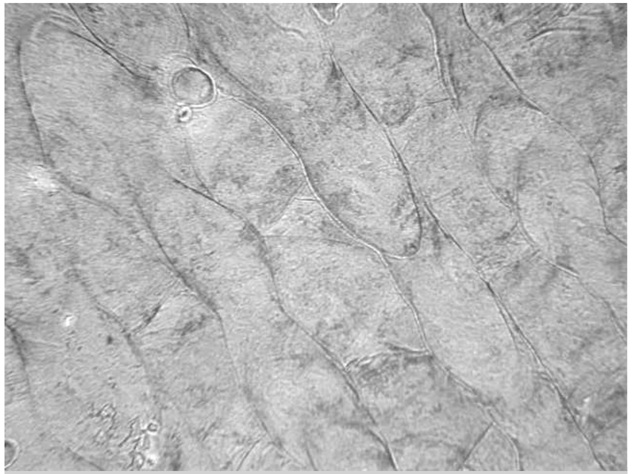
EOS StainlessSteel GP1 produces fully dense parts

Optical micrograph

Micrograph of laser-sintered EOS StainlessSteel GP1 showing fully remelted, dense structure. Side view along the layers



Optical micrograph of EOS StainlessSteel GP1.
Top view

Source: EOS, Helsinki University of Technology

EOS StainlessSteel PH1

EOS StainlessSteel PH1 – hardenable stainless steel material for prototyping and series production

Characteristics and applications

- Key characteristics
  - very high strength
  - fulfils ASTM E 8 specifications as built
  - easily hardenable up to around 43 HRC
- Typical applications
  - engineering applications including functional prototypes, small series products, individualised products or spare parts
  - parts requiring particularly high strength and hardness

Complete set of instruments for bone surgery

Source: Socinser, Prodintec

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EOS StainlessSteel PH1 produces parts with very high strength and easy hardenability

Mechanical properties

Property	As built	After age hardening (6 hours at 490°C)
Ultimate tensile strength		
- Horizontal (XY), MPa	1150 ± 50	min 1310 (typical 1450 ± 100)
- Vertical (Z), MPa	1050 ± 50	min 1310 (typical 1450 ± 100)
Yield strength (Rp 0.2 %)		
- Horizontal (XY), MPa	1050 ± 50	min 1170 (typical 1300 ± 100)
- Vertical (Z), MPa	1000 ± 50	min 1170 (typical 1300 ± 100)
Elongation at break		
- Horizontal (XY)	16 % ± 4 %	min 10 % (typical 12 % ± 2 %)
- Vertical (Z)	17 % ± 4 %	min 10 % (typical 12 % ± 2 %)
Hardness	30 - 35 HRC	min 40 HRC

Quelle: EOS

EOS StainlessSteel PH1 can easily be hardened

Chemical and physical properties

- Composition corresponds to DIN 1.4540 and UNS S15500.
- Simple heat treatment (ageing at 482 °C for 1 hour + air cool)
  - superior mechanical properties due to precipitation hardening
  - solution annealing + quenching not required before ageing treatment

Element	Content (by weight)
Iron	balance
Chromium	14 – 15.5 %
Nickel	3.5 – 5.5 %
Copper	2.5 – 4.5 %
Manganese	max. 1 %
Silicon	max. 1 %
Molybdenum	max. 0.5 %
Niobium	0.15 - 0.45 %
Carbon	max. 0.07 %

Source: EOS

EOS StainlessSteel PH1 produces fully dense parts

Physical & thermal properties

Property	Value
Relative density	approx. 100 %
Density	7.8 g/cm³
Thermal conductivity	
as manufactured	13.8 ± 0.8 W/m°C
in post-hardened state	15.7 ± 0.8 W/m°C
Specific heat capacity	
as manufactured	460 ± 20 J/kg °C
in post-hardened state	470 ± 20 J/kg °C

Optical micrograph of EOS StainlessSteel PH1.
Top view

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EOS NickelAlloy IN718

EOS NickelAlloy IN718 is a heat resistant nickel alloy powder for series production in aerospace

Characteristics and applications

- Key characteristics
  - nickel based heat resistant alloy
  - outstanding corrosion resistance
  - high performance at temperatures up to 700°C, e.g. tensile strength, fatigue, creep and rupture
- Typical applications
  - aero and land based turbine engine parts
  - rocket and space application components
  - chemical and process industry parts
  - oil wells, petroleum and natural gas industry

Left: Turbine blade (demo part)
Top: Turbine wheel in EOS NickelAlloy IN718 built on EOSINT M 270 IM Xtended.

Source: EOS

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EOS NickelAlloy IN718, Technical Data

Mechanical properties, Room temperature

- Typical tensile properties of EOS IN718 parts at room temperature
  - Tensile testing (ISO 6892:1998)
- Specifications given in standards (SAE/AMS)

Minimum requirements	AMS 5662	AMS 5664
Tensile Strength, R_m	1241 MPa (180 ksi)	1241 MPa (180 ksi)
Yield Strength, $R_{p0.2}$	1034 MPa (150 ksi)	1034 MPa (150 ksi)
Elongation in 4D	6-12%	10 %
Hardness	331 HB	341 HB

tensile properties	Heat treatment per AMS 5662[2]	Heat treatment per AMS 5664[3]
Tensile Strength, R_m	**1400** ± 100 MPa (203 ± 15ksi)	**1380** ± 100 MPa (200 ± 15ksi)
Yield Strength, $R_{p0.2}$	**1150** ± 100 MPa (167 ± 15 ksi)	**1240** ± 100 MPa (180 ± 15 ksi)
Elongation at break, A25	Typical **16** ± 3 %	Typical **16** ± 3 %
Young's Modulus	**170** ±20 GPa (26,5 ± 3 msi)	**170** ±20 GPa (26,5 ± 3 msi)
Hardness	Approx. **47 HRC** (446 HB)	Approx. **43 HRC** (400HB)

[2] Heat treatment AMS 5662, details see next slide

[3] Heat treatment AMS 5664, details see next slide

Source: EOS

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EOS NickelAlloy IN718 is a heat resistant nickel alloy powder for series production in aerospace

Heat treatment and further properties

- Heat treatment (solution anneal and age hardening)
  - AMS 5662:
    Step 1: Solution Anneal at 980°C for 1 hour, air (/argon) cool
    Step 2: Ageing treatment; hold at 720°C 8 hours, furnace cool to 620°C in 2 hours, hold at 620°C 8 hours, air (/argon) cool
  - AMS 5664:
    Step 1: Solution Anneal at 1065°C for 1 hour, air (/argon) cool.
    Step 2: Ageing treatment; hold at 760°C 10 hours, furnace cool to 650°C in 2 hours, hold at 650°C 8 hours, air (/argon) cool
- Physical properties
  - relative density as built: ~ 100 %
  - density: 8.2 g/cm^3 (0.296 lb/in^3)

Source: EOS

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EOS NickelAlloy IN718, Technical Data

Mechanical properties, High temperature (649°C, 1200°F)

- Typical tensile properties of EOS IN718 parts at high temperature
  - Tensile properties (EN 10002-5:1992)
- Specifications given in standards (SAE/AMS)

tensile testing	Heat treatment per AMS 5662	Heat treatment per AMS 5664
Tensile Strength, R_m	**1170** ± 50 MPa (170 ± 7 ksi)	**1210** ± 50 MPa (175 ± 7 ksi)
Yield Strength, $R_{p0.2}$	**970** ± 50 MPa (141 ± 7 ksi)	**1010** ± 50 MPa (146 ± 7 ksi)
Elongation at break, A25	**16** ± 3%	**20** ± 3%

Minimum requirements	AMS 5662
Tensile Strength, R_m	965-1000 MPa (140-145 ksi)
Yield Strength, $R_{p0.2}$	862 MPa (125 ksi)
Elongation in 4D	6-12%

Source: EOS

EOS NickelAlloy IN718 is a heat resistant nickel alloy powder for series production in aerospace

Chemistry

- Composition corresponds to Inconel™ 718, UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, DIN NiCr19Fe19NbMo3
- Outstanding corrosion resistance

Element	Content (by weight)
Nickel	50 - 55 %
Chromium	17.0 - 21.0 %
Niobium	4.75 - 5.5 %
Molybdenum	2.8 - 3.3 %
Titanium	0.65 - 1.15 %
Aluminium	0.20 - 0.80 %
Cobalt	≤ 1.0 %
Copper	≤ 0.3 %
Carbon	≤ 0.08 %
Silicon, Manganese	each ≤ 0.35 %
Phosphorus, Silicon	each ≤ 0.015 %
Boron	≤ 0.006 %
Iron	balance

Source: EOS

The layer structure of EOS NickelAlloy IN718 can be completely removed by thermal post-processing

Micrographs

Vertical cross-sections through EOS NickelAlloy IN718 parts, etched.

Left: as built, showing weld-lines of laser-sintering process.

Right: after thermal post-processing (solution treatment), fully homogenized.

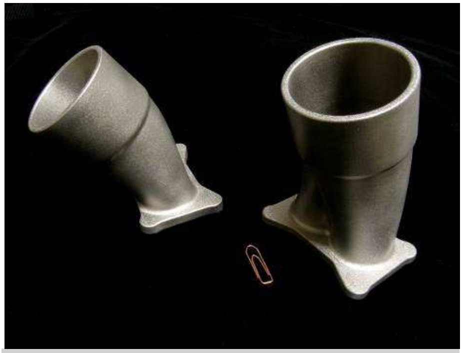
Source: EOS

EOS CobaltChrome MP1

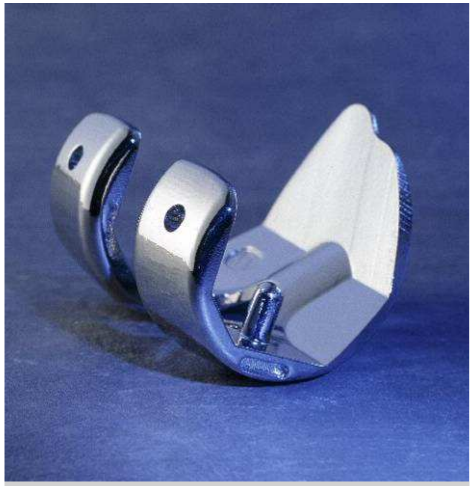
EOS CobaltChrome MP1 - CoCrMo superalloy material for prototyping and series production

Characteristics and applications

- Key characteristics
  - high strength, temperature and corrosion resistance
  - biocompatibility
  - fulfils ISO 5832-4 and ASTM F75 (cast CoCrMo implant alloys), and most of ISO 5832-12 and ASTM F1537 (wrought CoCrMo implants)
- Typical applications
  - high-temperature engineering applications, e.g. turbines
  - medical implants [1]



Engine exhausts in EOS CobaltChrome MP1



Knee implant in EOS CobaltChrome MP1

[1]: subject to fulfilment of statutory validation requirements where appropriate, e.g. for commercial use as a medical device in most countries.

Source: EOS; Knee implant: Stryker Orthopaedics

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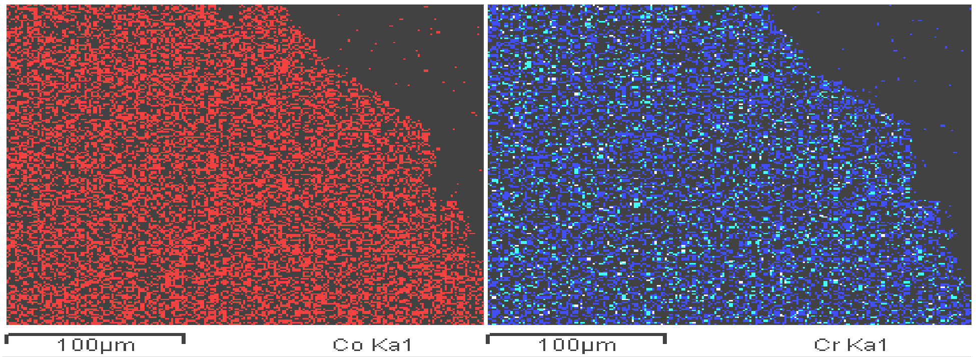
EOS CobaltChrome MP1 is a biomedical CoCrMo alloy

Chemistry and metallurgy

- Nickel free, contains < 0.10 wt-% of nickel
- Uniform, fine distribution of elements
  - see picture



Dot-mapping analysis of SEM micrographs of cross-section through laser-sintered sample.

Left: Co distribution　　Right: Cr distribution

Element	Content (by weight)
Cobalt	60 – 65 %
Chromium	26 - 30 %
Molybdenum	5 - 7 %
Silicon	max. 1.0 %
Manganese	max. 1.0 wt-%
Iron	max. 0.75 wt-%
Carbon	max. 0.16 wt-%
Nickel	max. 0.10 %

Source: EOS

EOS CobaltChrome MP1 produces parts with excellent mechanical properties

Mechanical properties at 20 °C (1)

Property	As built	High temp. stress relieved [1]
Ultimate tensile strength		
- Horizontal (XY)	1200 MPa ± 150 MPa 174 ksi ± 22 ksi	1100 MPa ± 100 MPa 160 ksi ± 15 ksi
- Vertical (Z)	1200 MPa ± 150 MPa 174 ksi ± 22 ksi	1100 MPa ± 100 MPa 160 ksi ± 15 ksi
Yield strength (Rp 0.2 %)		
- Horizontal (XY)	950 MPa ± 100 MPa 138 ksi ± 15 ksi	600 MPa ± 50 MPa 87 ksi ± 7 ksi
- Vertical (Z)	800 MPa ± 100 MPa 116 ksi ± 15 ksi	600 MPa ± 50 MPa 87 ksi ± 7 ksi
Elongation at break		
- Horizontal (XY)	min. 8 %	min. 20 %
- Vertical (Z)	min. 8 %	min. 20 %

Note: Mechanical properties improve with increased temperature up to 500-600 °C
[1]: 6 hours at 1150 °C

EOS CobaltChrome MP1 produces parts with excellent mechanical properties

Mechanical properties at 20 °C (2)

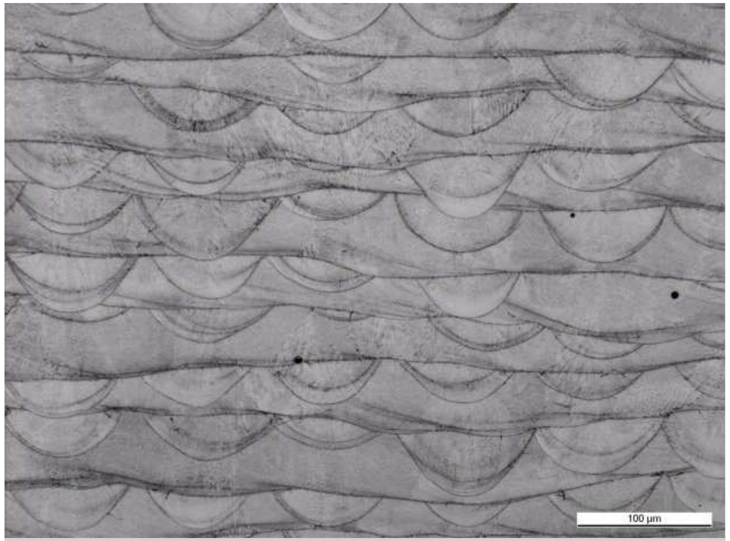
Property	As built	After age hardening (6 hours at 490°C)
Young’s Modulus		
- Horizontal (XY)	190 GPa ± 20 GPa 28 msi ± 3 msi	200 GPa ± 20 GPa 29 msi ± 3 msi
- Vertical (Z), MPa	1050 ± 50	min 1310 (typical 1450 ± 100)
Fatigue life in vertical direction (Z) at 0-440 MPa load range and 45 Hz, as built	> 10 million cycles	
Hardness	35 - 45 HRC	

Note: Mechanical properties improve with increased temperature up to 500-600 °C

EOS CobaltChrome MP1 produces fully dense parts suitable for high-temperature operation

Physical & thermal properties

Property	Value
Relative density	approx. 100 %
Density	8.29 g/cm³
Max. operating temperature	1150 °C
Melting range	1350-1430 °C
Thermal conductivity	1350-1430 °C
- at 20 °C:	13 W/m°C
- at 300 °C:	18 W/m°C
- at 500 °C:	22 W/m°C
- at 1000 °C:	33 W/m°C
Coefficient of thermal expansion	
- 20 – 500 °C	13.6 x10^{-6} m/m°C
- 500 – 1000 °C	15.1 x10^{-6} m/m°C

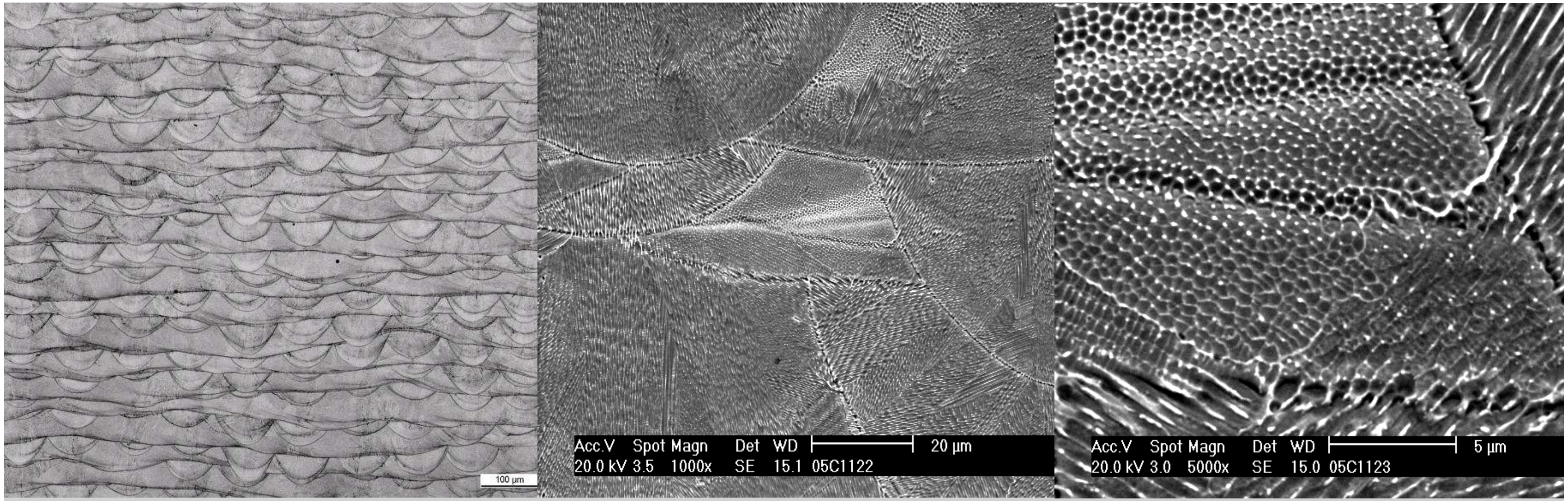


Micrograph of laser-sintered EOS CobaltChrome MP1 showing fully remelted, dense structure

Note: Mechanical properties improve with increased temperature up to 500-600 °C

EOS CobaltChrome MP1 produces parts with very fine 0.3-0.6 μm grain size

Micrographs



Micrographs of EOS CobaltChrome MP1 samples, laser-sintered on EOSINT M 270 and etched

Left: 10x optical micrograph Middle: 1000x SEM micrograph Right: 5000x SEM micrograph

Source: EOS

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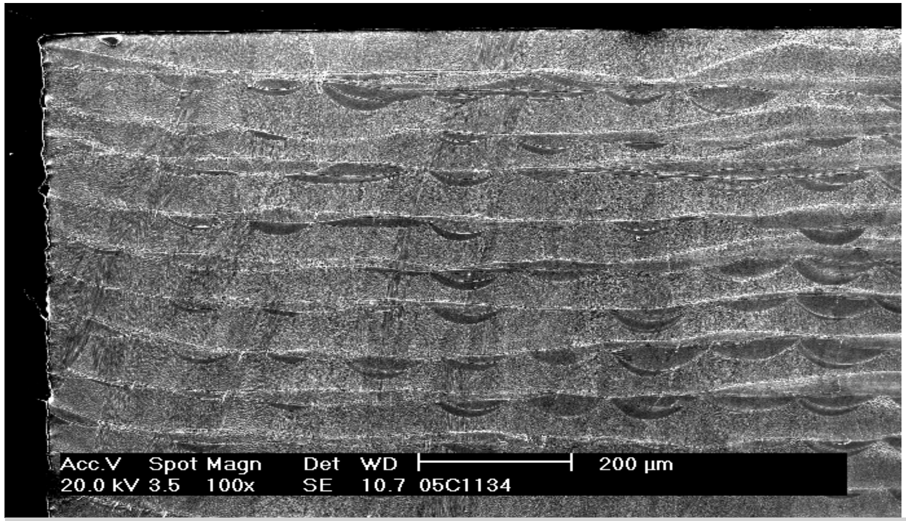
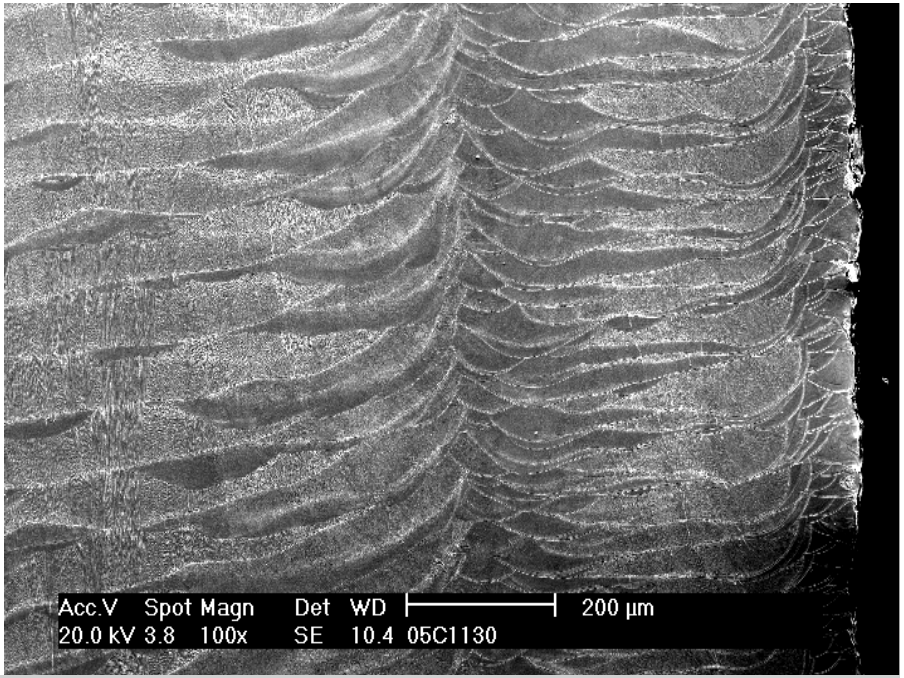
EOS CobaltChrome MP1 is fully dense with only skin or with Skin&Core parameters

Micrographs





Micrographs of EOS CobaltChrome MP1 samples, laser-sintered on EOSINT M 270 and etched

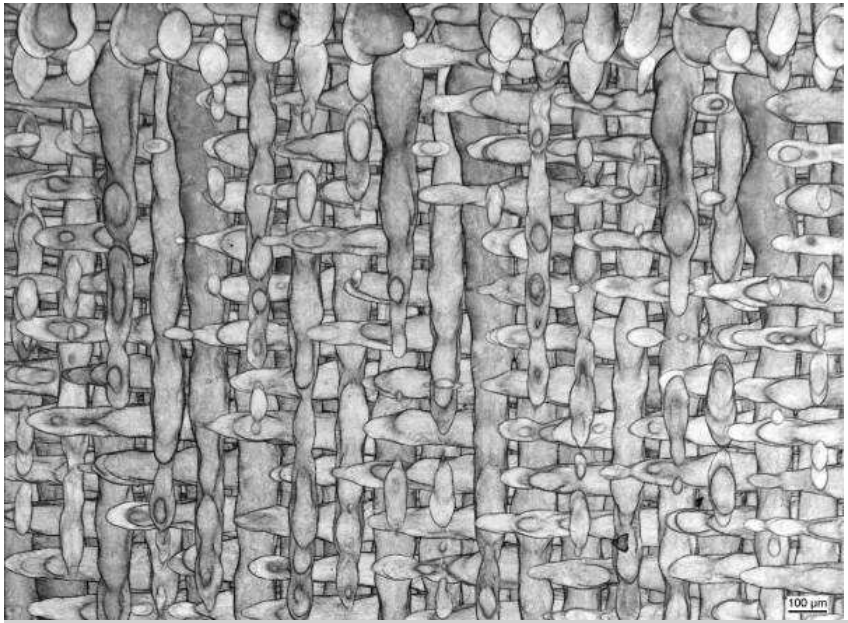
Left: 100x SEM micrograph of only skin parameters

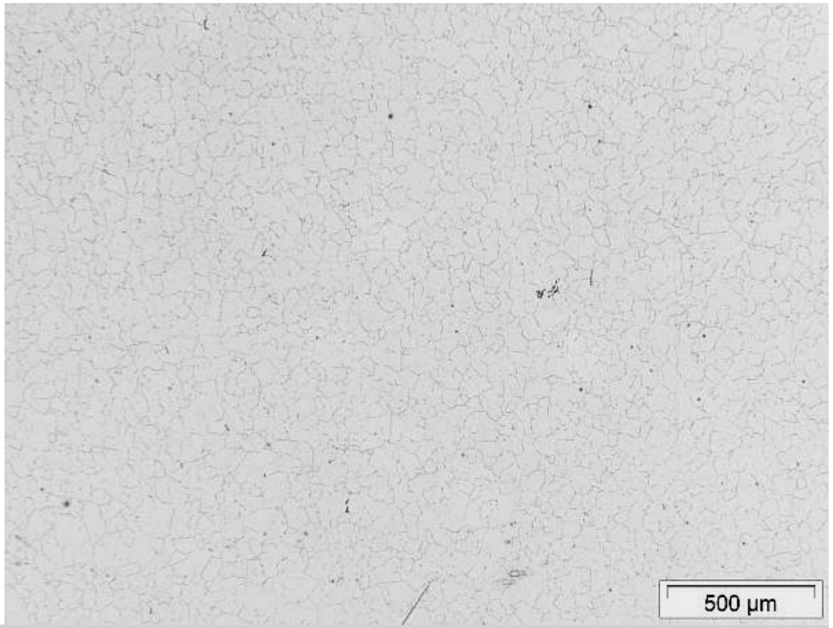
Right: 100x SEM micrograph of faster Skin&Core

Source: EOS

The layer structure of EOS CobaltChrome MP1 can be completely removed by thermal post-processing

Micrographs





Cross-sections through EOS CobaltChrome MP1 parts, electrolytically etched.

Left: as built, showing weld-lines of laser-sintering process.

Right: after thermal post-processing, fully homogenized.

Source: EOS

EOS CobaltChrome MP1 parts fulfil relevant industrial standards well

Comparison with cast and wrought material

- Properties fulfil ISO 5832-4 and ASTM F75 of cast CoCrMo implant alloys
- Properties fulfil ISO 5832-12 and ASTM F1537 of wrought CoCrMo implants alloys, except remaining elongation
  - also elongation requirement can be fulfilled by using hot isostatic pressing

Source: EOS

EOS CobaltChrome SP2

EOS CobaltChrome SP2 - special purpose CoCrMo superalloy for veneered dental restorations

Characteristics and applications

- Key characteristics
  - high strength, temperature and corrosion resistance
  - biocompatibility
  - thermal characterisitcs suitable for veneering with dental ceramic
- Application
  - dental restorations (crowns, bridges etc.)

Dental restorations in
EOS CobaltChrome SP2

Job in EOS CobaltChrome SP2 with 384 units of dental restorations. Building time 20h.

Source: EOS

EOS Titanium Ti64/ TiCP

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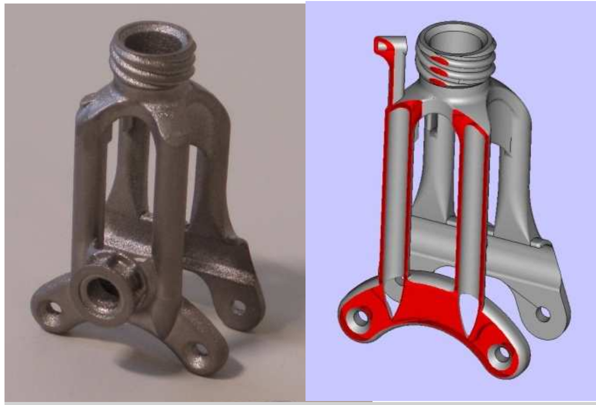
Titanium alloys offer a unique combination of properties for many applications

Key properties

- Key characteristics
  - light weight with high specific strength (strength per weight)
  - corrosion resistance
  - biocompatibility
- Typical applications
  - aerospace and engineering applications
  - biomedical implants



Thin-walled brake component built in EOS Titanium Ti64

Spinal implant built in EOS Titanium Ti64

Source: EOS

Various grades of Titanium (alloys) are commonly used in industrial applications

Summary of the most important Ti materials

Material name	Composition	Typical applications	Tensile strength (*) [MPa]	Elongation at break (*) [%]
Ti CP grade 1	Ti; O <0.18%; N <0.03%	Medical and dental	240	24
Ti CP grade 2	Ti; O <0.25%, N <0.03%	Medical and dental, chemical industry	345	20
Ti CP grade 3	Ti; O <0.35%, N < 0.05%	Medical and dental	450	18
Ti CP grade 4	Ti; O < 0.40%, N < 0.05%	Medical and dental	550	15
Ti6Al4V (grade 5)	Ti; Al 6%; V 4%; O <0.20%, N < 0.05%	Aerospace, medical, dental etc.	895	10
Ti6Al4V ELI	Ti; Al 6%; V 4%; O <0.15%, N < 0.05%	Medical and dental		

CP = commercially pure, ELI = extra-low interstitials

(*) Source: Euro-Titan Handels AG, Solingen, Germany

Source: EOS

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EOS Titanium Ti64 parts fulfil relevant industrial standards and relevant requirements

Physical and chemical properties

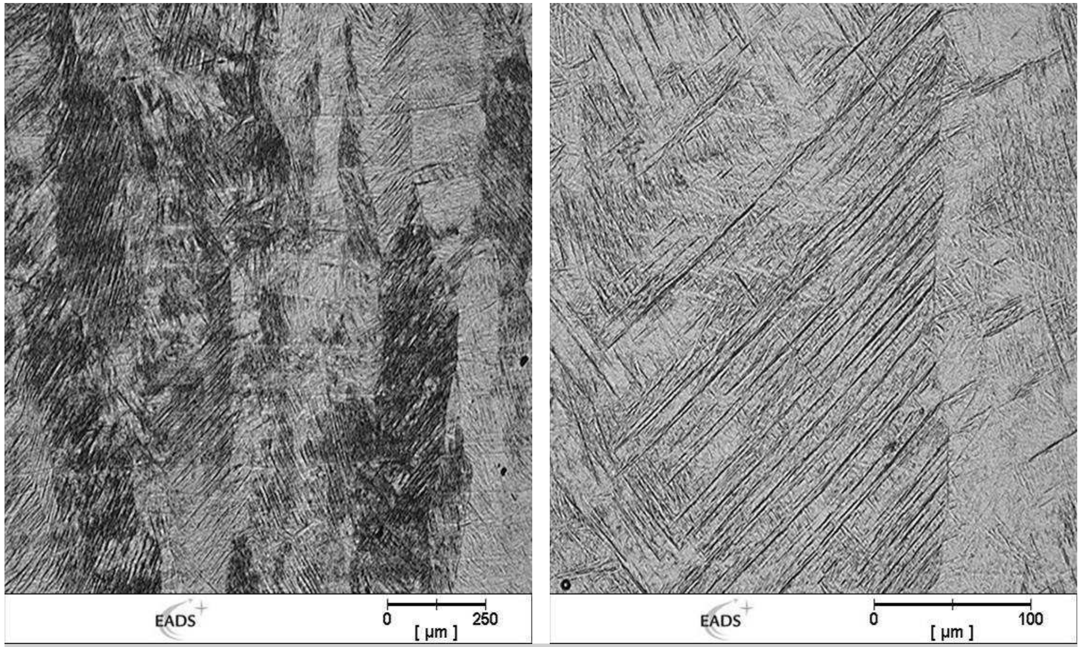
- Physical properties
  - laser-sintered relative density: approx. 100 %
  - density: 4.43 g/cm³ (0.160 lb/in³)
  - only single pores
- Chemical properties
  - laser-sintered parts fulfil requirements of ASTM F1472 (for Ti6Al4V) and ASTM F136 (for Ti6Al4V ELI) regarding maximum concentration of impurities
    - oxygen < 2000ppm or 1500ppm
    - nitrogen < 700ppm
- Bioadhesion
  - cell growth tested with good results

Source: EOS

EOS Titanium Ti64 produces fully dense parts with dendritic, martensitic grain structure

Metallurgy

- Typically martensitic structure with grains growing from layer to layer
  - preferential Z orientation
  - grain size >> layer thickness



Optical micrographs of laser-sintered EOS Titanium Ti64, showing fully dense structure (only single pores) and dendritic, martensitic structure with preferential orientation

Source: EOS, EADS

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EOS Titanium Ti64 produces parts with excellent mechanical properties

Mechanical properties

Property	Value
Ultimate tensile strength	1150 ± 60 MPa 166 ± 9 ksi
Yield strength (Rp 0.2 %)	1030 ± 70 MPa 150 ± 10 ksi
Young's Modulus	110 ± 7 GPa 16 ± 1 msi
Elongation at break	11 % ± 2 %
Hardness	approx. 400 - 430 HV (41 - 44 HRC)

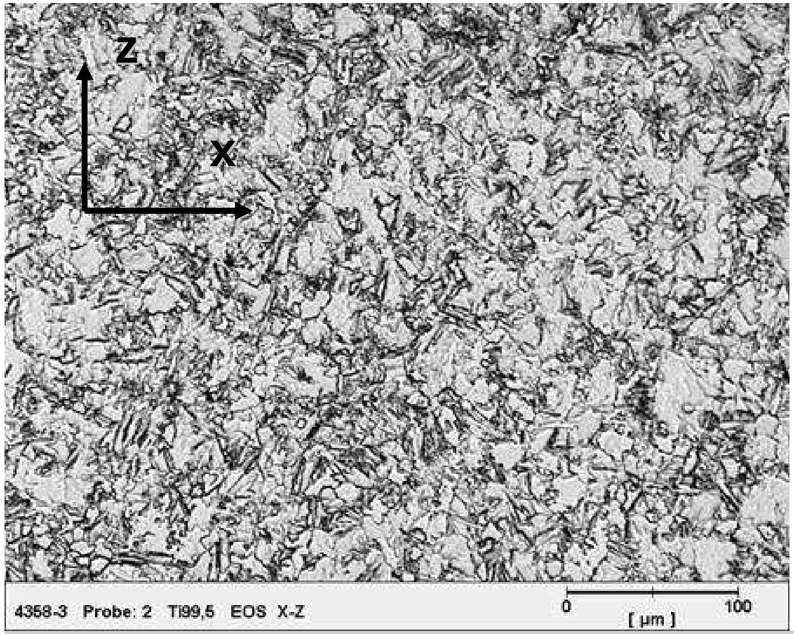
Source: EOS

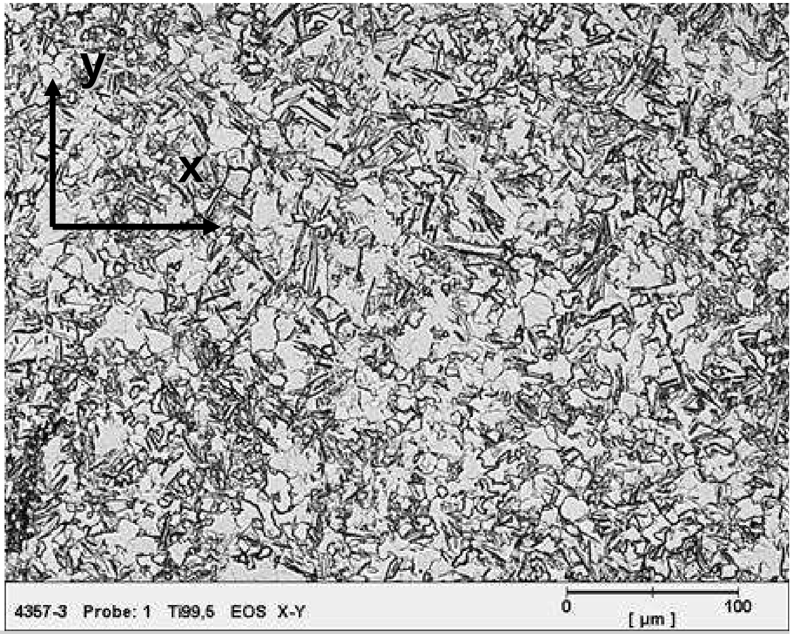
Many different kinds of parts have been built in EOS Titanium Ti64

Examples of parts built in EOS Titanium Ti64

Source: EOS, Protocast, Technikon

EOS Titanium TiCP produces fully dense parts with very fine, uniform grain structure





Optical micrographs of laser-sintered EOS Titanium TiCP (commercially pure), etched, showing fully dense structure and no sign of layer structure. Build orientation as indicated.

Source: EOS

e-Manufacturing Solutions

EOS Titanium TiCP produces parts with excellent mechanical properties

Mechanical properties (preliminary)

Property	Value
Ultimate tensile strength	455 MPa ± 10 MPa 60 ksi ± 1,5 ksi
Yield strength (Rp 0.2 %)	370 MPa ± 10 MPa 54 ksi ± 1,5 ksi
Young's Modulus	95 GPa ± 10 GPa 14 msi ± 1,5 msi
Elongation at break	19 % ± 1 %

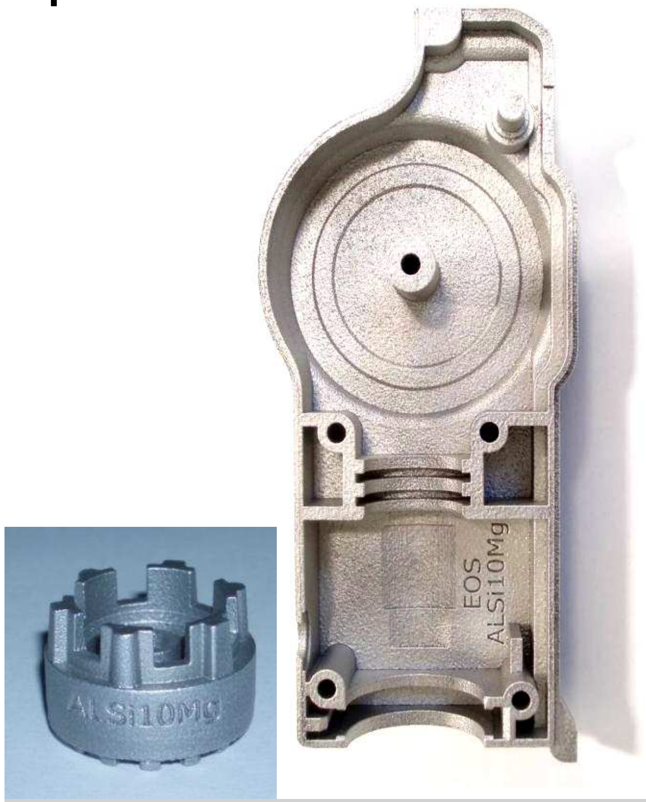
Source: EOS

EOS Aluminium AlSi10Mg

EOS Aluminium AlSi10Mg – casting Aluminium alloy material for prototyping and series production

Characteristics and applications

- Key characteristics
  - lightweight
  - high thermal conductivity
- Typical applications
  - engineering applications in aluminium, e.g. functional prototypes, small series products, individualised products or spare parts
  - automotive, engineering, motor racing, aerospace, pneumatics
  - prototype parts for AlSi10Mg die casting



Functional prototypes in
EOS Aluminium AlSi10Mg produced on
EOSINT M 270

Source: EOS

e-Manufacturing Solutions

EOS Aluminium AlSi10Mg offers good mechanical properties

Mechanical properties

Property	As built	Heat treated T6 [1]
Ultimate tensile strength in vertical direction (Z)	340 ± 40 MPa	315 ±20 MPa
Yield strength (Rp 0.2 %) in horizontal direction (XY)	250 ±15 MPa	260 ±15 MPa
Elongation at break	1.5 % ± 0.5 %	1.2 ± 0.5 %
Hardness	120 ± 5 HBW	112 ± 5 HBW
Fatigue strength in vertical direction (Z) [2]	97 ±7 MPa	93 ±3 MPa

[1] Heat treatment T6: solution annealing 5h/530°C, quenching in water bath, elevated temperature age hardening 12h/160°C
[2] Fatigue test with test frequency of 50Hz, R=-1, measurement stopped on reaching 5 million cycles without fracture

Source: EOS

e-Manufacturing Solutions

EOS Aluminium AlSi10Mg – casting Aluminium alloy material for prototyping and series production

Chemical and physical properties

- Silicon and magnesium alloying elements result in increased strength and hardness
- Good dynamic properties
- Physical properties
  - relative density as built: ~ 100 %
  - density: 2.68 g/cm^3 (0.097 lb/in^3)

Element	Content (by weight)
Silicon	(9.0 – 11.0 %)
Iron	max. 0.55 %
Copper	max. 0.05 %
Manganese	max. 0.45 %
Magnesium	(0.2 – 0.45 %)
Nickel	max. 0.05 %
Zinc	max. 0.10 %
Lead	max. 0.05 %
Tin	max. 0.05 %
Titanium	max. 0.15 %
Aluminium	balance

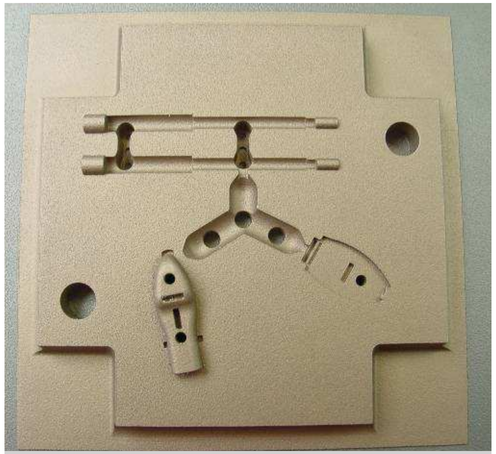
Source: EOS

DirectMetal 20

DirectMetal 20 - bronze-based material for rapid tooling and rapid functional prototypes

Characteristics and applications

- Key characteristics
  - good mechanical properties
  - very fast build rate
  - very easy to finish
- Typical applications
  - injection mould tool inserts for moulding up to hundreds of thousands of plastic parts
  - other tooling applications
  - prototype parts, e.g. for functional tests, wind tunnel testing etc.
  - fixtures, test parts etc.



injection mould insert
(Source:: EGi, EOS)

propeller prototype for
wind tunnel testing

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DirectMetal 20 quickly and easily produces functional tooling and parts

Key properties

- Mechanical properties
  - UTS: approx. 400 MPa
  - yield strength: approx. 200 MPa
  - Young's Modulus: approx. 80 GPa
  - hardness: 115 HV
- Physical properties
  - min. remaining porosity: 8 %
    - surface porosity closed by micro-shot-peening
  - massive parts typically built using Skin & Core build strategy
  - max. operating temperature 400 °C

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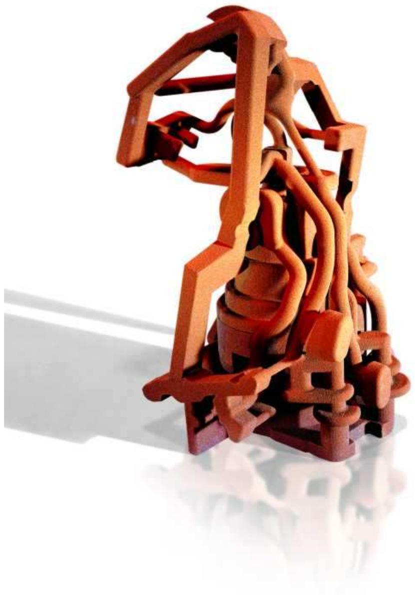

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