MATERIAL DATASHEET

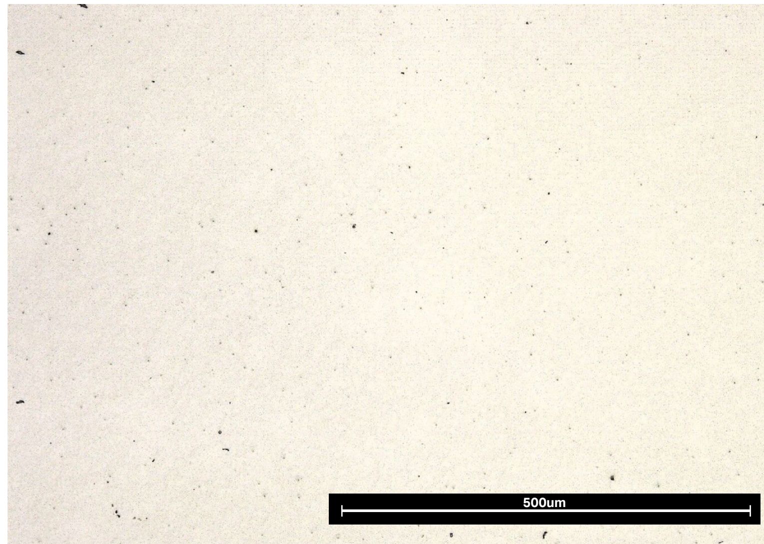
Markforged

D2 Tool Steel

Other Designations: DIN 12379, ASTM A681, UNS T30402, BD 2

D2 Tool Steel is a high carbon, high chromium air-hardening tool steel that can be heat treated to high hardness and compressive strength. D2 Tool Steel offers excellent wear resistance and is widely used in cold work applications that require sharp edges, abrasion resistance, and compressive strength. Markforged D2 Tool Steel meets chemical requirements of ASTM A681.

Composition	Amount
Chromium	11-13%
Carbon	1.4-1.6%
Molybdenum	0.7-1.2%
Vanadium	0.5-1.1%
Nickel + Copper	0.75% max
Manganese	0.1-0.6%
Silicon	0.1-0.6%
Phosphorus	0.03% max
Sulfur	0.03% max
Iron	bal



Typical Mechanical Properties	Standard	Markforged Heat-Treated[1]	Wrought Heat Treated[2]
0.2% Compressive Yield Strength	ASTM E9	1690 MPa	2200 MPa
Elastic Modulus	ASTM E9	187 GPa	210 GPa
Hardness[3,5]	ASTM E18	55 HRC	62 HRC
Relative Density[4]	ASTM B923	97%	100%

Heat Treatment

D2 Tool Steel can be heat-treated to increase hardness and durability after an optional annealing step and machining work. Markforged recommends heat-treating D2 Tool Steel to optimize material properties for target applications.

1. Slowly heat to 760°C (1400°F), hold at temperature for 30 minutes minimum.
2. Heat to 1040°C (1904°F). Hold part at temperature for 30-45 minutes.
3. Air quench part to below 65°C (150°F).
4. Temper part. For each temper, heat part to 200°C (392°F) and temper for 30 minutes. If double tempering, let part cool to room temperature between tempers. Note: Higher temperature tempers may also be used — which will increase toughness but reduce hardness.

1. Markforged heat-treated D2 Tool Steel was heated to 1040°C (1904°F) and single tempered at 200°C (392°F) for 30 minutes.
2. Wrought heat treatment data from Bohler-Uddeholm: http://cdna.terasrenki.com/ds/1.2379_X153CrMoV12_AISI-D2_SS-2310_Datasheet_2.pdf
3. Markforged hardness was measured on sample coupons that were printed with solid fill.
4. Relative density for D2 Tool Steel assumes a density of 7.7 g/cm^3.
5. As-sintered hardness can vary significantly based on furnace loading and ambient environment. Markforged recommends post-sinter heat treatment for maximum hardness and compression strength.

DIGITAL METAL®

ADDITIVE MANUFACTURING OF SMALL AND COMPLEX METAL PARTS

RAPID 3D PRINTING FOR YOU

The proprietary technology of Digital Metal® is making great strides into territories previously ruled by conventional manufacturing technologies. High productivity, excellent surface quality and great resolution have brought our 3D metal printing services out of the prototyping phase, and into large series manufacturing. This is what's in it for you.

ADVANTAGES

- High productivity
- Excellent surface quality
- High resolution
- Serial production
- Mass customisation
- Repeatability and reliability

> "So far no other metal additive manufacturing technology can match the level of resolution and surface quality provided by Digital Metal."

BATHSHEBA GROSSMAN, BATHSHEBA SCULPTURE LLC (USA)

The DM P2500 is a robust machine for both serial production and prototyping.

WHAT'S SO GOOD ABOUT IT?

For a start, the process requires no complex or costly tools and keeps waste material down to an absolute minimum. But that's not all. Here are just a few of the other advantages:

CERTIFIED FOR YOUR SECURITY

- CE-Certified in accordace with EC Machinery Directive 2006/42/EC
- UL-Certified, file nr. E496006

'IMPOSSIBLE' OBJECTS BECOME POSSIBLE

3D metal printing enables the production of complex objects that would be costly – if not impossible to produce – using conventional methods. This is music to the ears of industrial designers, who can at last unleash their full creativity and explore the new territory that 3D metal printing opens up.

FAST TRACK FROM CONCEPT TO COMPLETION

In today's fast-paced, competitive environment, producers face ever shorter product life cycles and ever greater product variety. You need new, quicker ways to innovate and get your innovations to market. 3D printing is the answer. With this technology, Digital Metal can take your product from concept to completion in a short time.

COST-EFFECTIVE PRODUCTION

Not only does 3D metal printing provide a much more cost-effective way of manufacturing complex metal parts, it is also the ideal solution.

WHERE CAN YOU USE IT?

INDUSTRIAL APPLICATIONS

3D metal printing makes it possible to quickly and cost-effectively produce complex metal components for industrial use. They can be hollow or meshed, with undercuts, ducts, cavities and internal structures. Almost any design, no matter how complicated, is achieveable using this technique.

DENTAL/MEDICAL

Dental/medical 3D metal printing also opens up the possibility of making radically new tools and components designed for optimal functionality instead of complying to the restrictions of traditional manufacturing.

AEROSPACE

By making lightweight but strong metal components, with hollow or meshed interiors, Digital Metal can also contribute to advances in aircraft design.

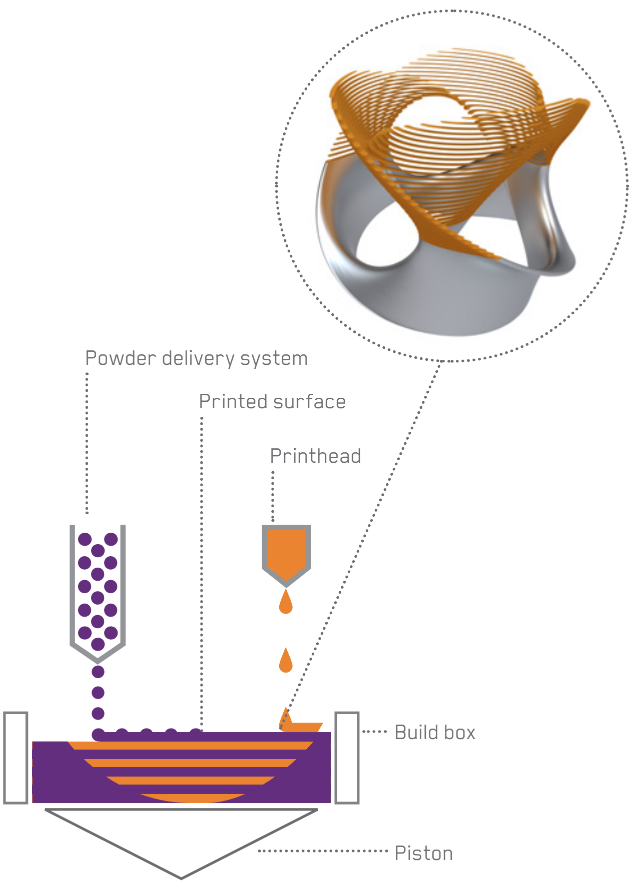
DESIGN

3D metal printing enables a whole new level of creative freedom!

Non-critical metal parts can be hollowed out, thus making them much lighter, which helps solve one of the main challenges of aircraft design.

THIS IS HOW IT WORKS

Are you looking for an additive manufacturing (AM) system that delivers fine tolerances, surface finish and resolution, while maximizing productivity for small complex components? Then high-precision binder jetting on powder bed is the solution you are looking for.



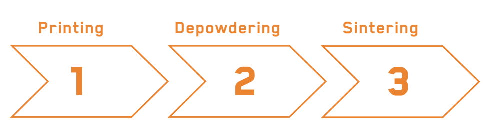
High-precision binder jetting on powder bed

LAYER BY LAYER

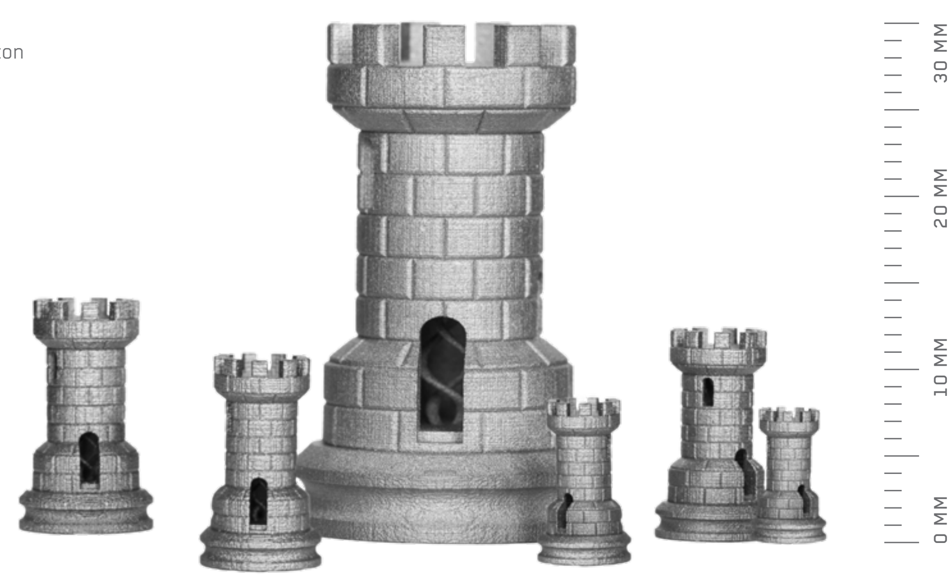
Our process begins with an object described in a CAD file. This is materialised in our 3D printer, which builds the object layer by layer, using metal powder and high-precision binder jetting. Once complete, the object is sintered for strength.

The result? A metal component with high resolution and tolerance. An additional third step can be added to refine surface quality.

Digital Metal offers a range of different materials to print with. New materials are constantly under development and will be readily available after rigorous testing.



The fine metal powder and high-precision binder jetting technology provide consistent high resolution.

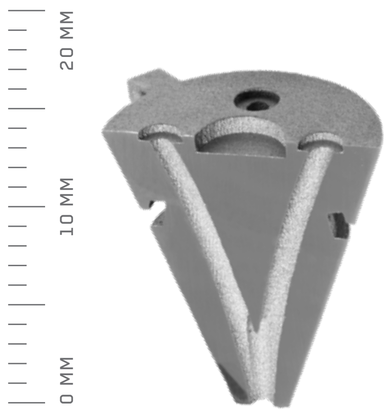


VARYING HOLE DIAMETER

Due to the very precise process, our proprietary additive manufacturing technology Digital Metal, can be used for making parts with extremely fine holes of great dimensional accuracy. This particular sieve adds yet another dimension to precision and customisation: the holes are of variable diameters.

ITSY BITSY

It may be hard to grasp the small size of this pair of happy twins. Apart from the precision required, our small friends visualise yet another advantage of Digital Metal: high productivity. In just one batch, we are able to manufacture very large numbers of similar, or – even better – dissimilar objects.



INTERNAL CHANNELS

A major advantage of Digital Metal is the free form design capability offered. Nowhere is this more evident than in the case of internal channels that easily can be utilised to provide complex, optimised internal structures. The average surface quality of merely Ra 6 µm ensures a good flow in the channels.

DETAIL ACCURACY

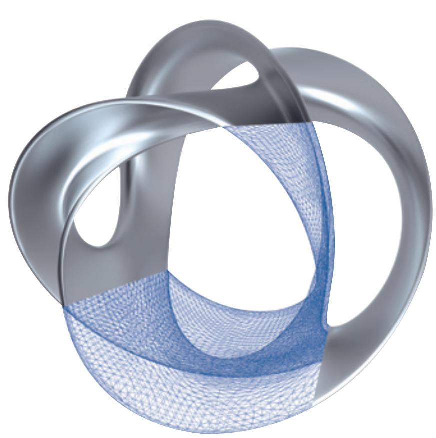
Growing up, this man probably never expected turning into a man of steel, 10 mm tall. However, unlike a well-known super hero, this transformation from human to steel will not pass unnoticed. The very fine detail makes it impossible to keep his true identity safe.

INTEGRATED DESIGN

The pea of the whistle is not visible, but rest assured – it is in there. In our 3D printing process, the integrated pea is built resting on the surrounding layers of metal powder. Once the powder is removed, prepare yourself to get blown away.

ADVANCED GEOMETRY

This complex geometry is a prime example of what Digital Metal is all about: making the seemingly impossible possible. Simply put, this is what we call design beyond your imagination.



SERIAL PRODUCTION OF CUSTOMISED PARTS

In the manufacturing of small and complex components, Digital Metal is a very competitive alternative to conventional mass production technologies. You may also consider the possibility of making every part a unique product.

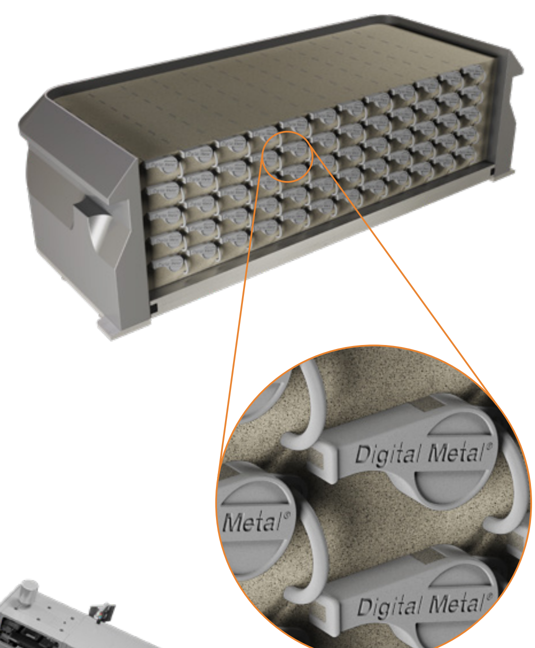
HIGH-VOLUME PRODUCTION

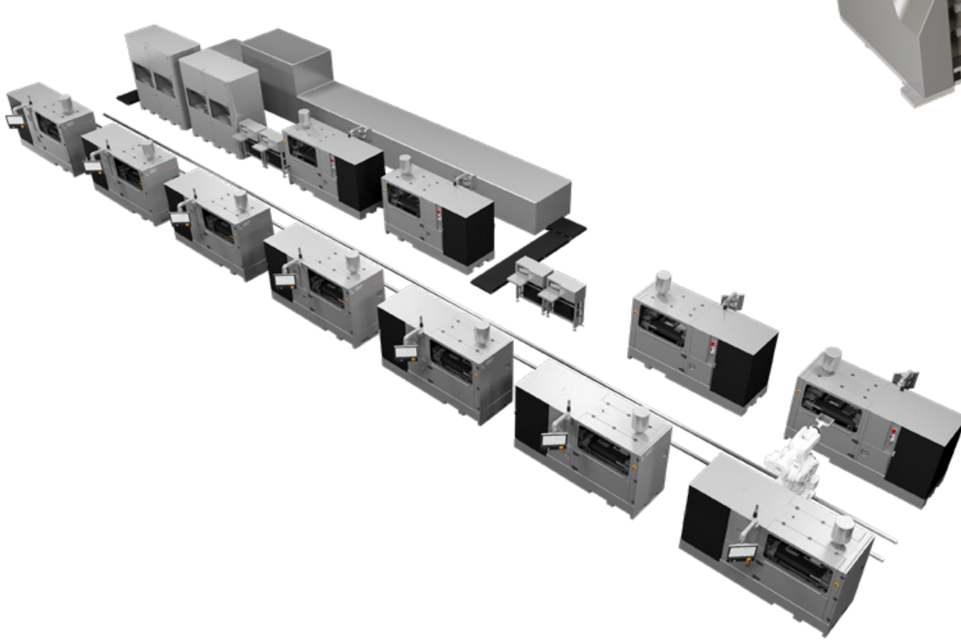
Small part sizes means there is plenty of room for large numbers of components to be printed simultaneously. This is in particular true for Digital Metal. Our high-precision process does not require any support structures, nor does it involve any heat transfer, which means we are able to pack the build box densely. Required spacing between parts to be printed is less than 1 millimetre. Parts can be placed in several layers on top of each other.

Printing without support structures also minimizes waste and post treatment, which speeds up the production process. The high productivity explains why Digital Metal today is one of the first service providers in the world supplying large series of 3D printed products.

MASS CUSTOMISATION

There is time to be saved and money to be earned taking a closer look at the flexibility of Digital Metal. Every single part in a batch of components can be custom-made, no matter the number. This opens up for creative thinking and added marketing value as you are able to supply products customised for your market. Consequently, Digital Metal also enables simultaneous printing of different product series in the same production run.

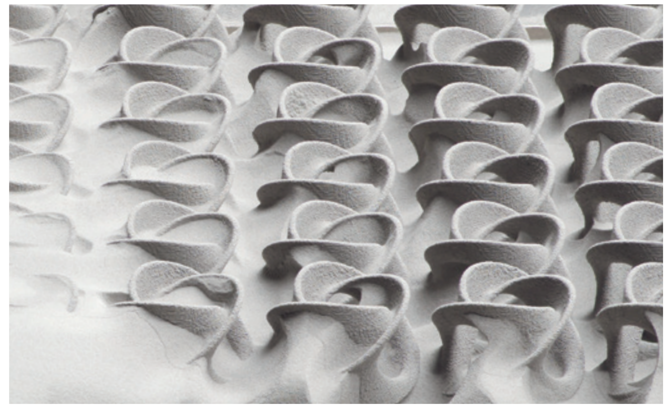




CAPABILITY

MATERIAL DATA – TYPICAL VALUES

	Ultimate tensile strength	Yield strength (0.2%)	Elongation	Hardness	
	MPa	MPa	%	HRB	HRC
316L	520	180	50	55	
17-4PH	900	730	6		25
Ti6Al4V	890	790	8		25
DM 625	660	310	50	78	
DM 247	1,200	750	16		25



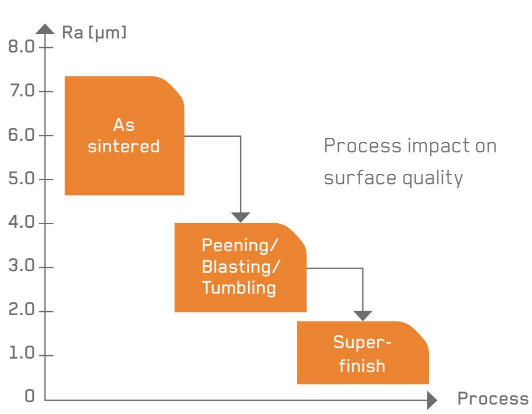
CHEMICAL COMPOSITION (%)

	Fe	Cr	Ni	Mo	Cu	Nb+Ta	Ti	Al	V
316L	Bal	16-18	10-14	2-3	n.a.	n.a.	n.a.	n.a.	n.a.
17-4PH	Bal	15.5-17.5	3-5	n.a.	3-5	0.15-0.45	n.a.	n.a.	n.a.
Ti6Al4V	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Bal	5-7	3-5

	C	Cr	Mo	Nb	Co	B	Ti	Hf	Ta	Zr	W	Al	Fe	Ni
DM 625	n.a.	22.0	9.0	3.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.0	Bal
DM 247	0.13	8.4	0.65	n.a.	10.0	0.015	1.0	1.3	3.0	0.05	9.8	5.4	n.a.	Bal

PROCESS CAPABILITY

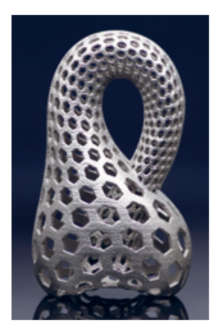
Feature	Typical
Geometrical capability	
Maximum length	Preferably <50 mm
Minimum length	1 mm
Minimum size	1 x 1 x 3 mm
Corner R	35 µm
Chamfer	Steps of 35 µm in z direction
Wall thickness	Preferably >300 µm. Minimum >150 µm
Resolution	Maximum 35 µm in z direction
Holes	>200 µm depending on hole length
Productivity	60 cm^3/h scaled; 100 cm^3/h unscaled
Accepted file formats	STL, STEP



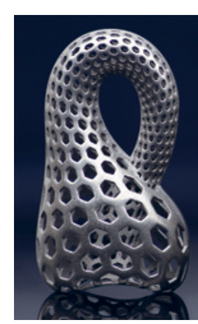
SURFACE QUALITY

With the Digital Metal technology, an average surface quality of Ra 6 µm can be obtained already without any post processing, while other AM processes typically leave a much rougher surface. Surface quality is important for components with internal channels, as post processing of those surfaces are very challenging. Additional operations can be added on external surfaces to achieve a surface that matches your specific need.

As sintered, an average surface quality of Ra 6.0 µm is achievable.



Peening, blasting and tumbling increase surface quality to an average of Ra 3.0 µm.



Superfinish enables even higher surface quality, around Ra 1.0 µm.

DIGITAL METAL®

PART OF HÖGANÄS GROUP

Digital Metal is part of Höganäs Group, the world's largest producer of iron and non-ferrous metal powders with an annual turnover of approximately 1 BUSD. Nearly 99 per cent of the Group's products are sold on international markets. Höganäs was founded in 1797 and has today 3,000 customers in 75 countries. Headquartered in Höganäs, Sweden, the Group offers more than 3,500 products from 18 production centres situated in all main continents.

Read more about Höganäs at hoganas.com

DIGITAL METAL®

DM D2

DM D2 is an alloy based on D2 tool steel, qualified for metal AM in Digital Metal's binder jetting system.

D2 tool steel exhibits high resistance to abrasive wear and good hardenability with decent toughness, making it suitable for a wide range of applications. It is most commonly used for cutting and deformation tools, such as shear cutters, punches, dies and stamping tools.

The material is stable during heat treatments, which allows for tailoring of the final properties through various heat treatments after sintering.

COMPOSITION – TYPICAL VALUES

Cr	Mo	V	Mn	Si	C	Fe
12.0	1.0	0.9	0.5	0.3	1.5	Bal

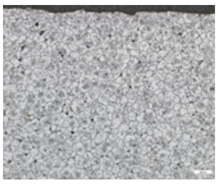
Related standards: UNS T30402, ASTM A681, 1.2379 and SKD11

PHYSICAL PROPERTIES – TYPICAL VALUES

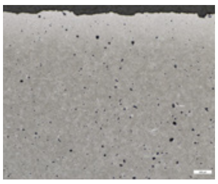
Density	Hardness HRC		
Relative	As sintered	Hardened	Hardened + Tempered
98%	35	62	58

Hardening consists of a solution treatment with subsequent air quenching. Single tempering provides the results displayed.

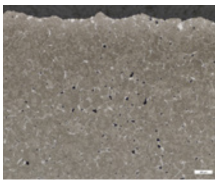
METALLOGRAPHIC STRUCTURE



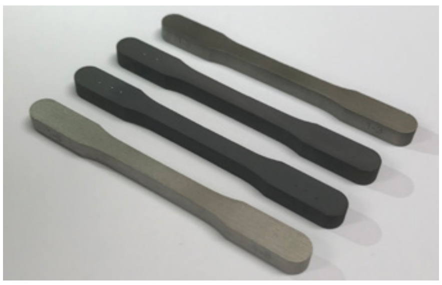
As sintered



Hardened



Hardened + Tempered

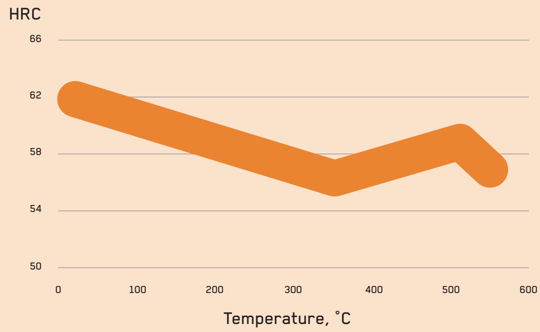


Specimens with subsequent process steps, bottom to top: as sintered, after hardening, after tempering and after blasting.

FEATURES

- Tool steel alloy
- Provides an effective combination of abrasive wear resistance and toughness
- Suitable for a wide range of applications
- Most commonly used for cutting and deformation tools

HARDNESS CURVE FOR TEMPERING OF DM D2



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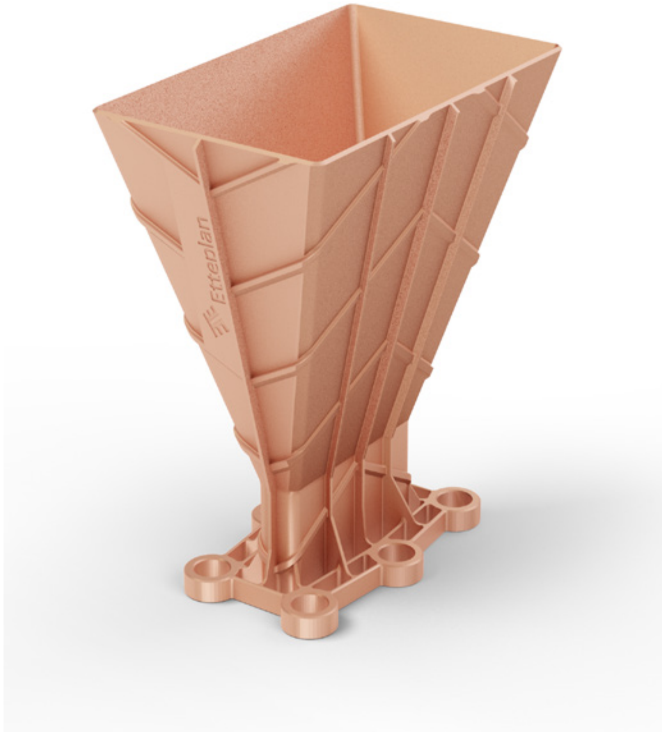
DM Cu

DM Cu is a 99.9 % commercially pure copper quality for use with Digital Metal's proprietary metal binder jetting system.

The excellent electrical and thermal conductivity properties of pure copper make it ideal for a wide range of applications. It is mostly used for electronics, heat exchangers, heat sinks, engine parts as well as in a variety of industry applications that require good conductivity. Printing in copper offers freedom of design and enables optimal functionality with few restrictions.



PHYSICAL PROPERTIES – TYPICAL VALUES

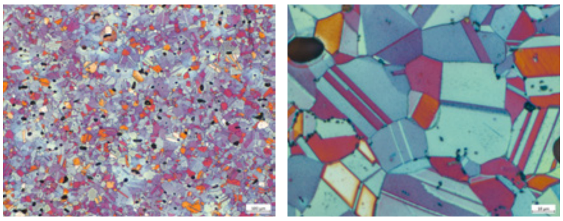
	Typical DM Cu
Ultimate tensile strength (MPa)	195
Yield strength (MPa)	30
Elongation (%)	35
Sintered density (g/cm^3)	8.6

COMPOSITION – TYPICAL VALUES

Composition (% weight)	Typical DM Cu
Cu	99.9
Fe	0.04
Ni	0.015
C	0.02
O	0.003
Others	Balance

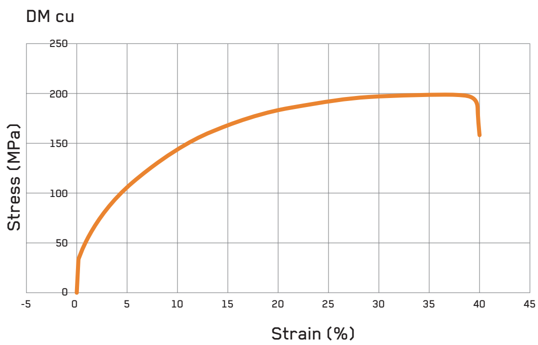
FEATURES

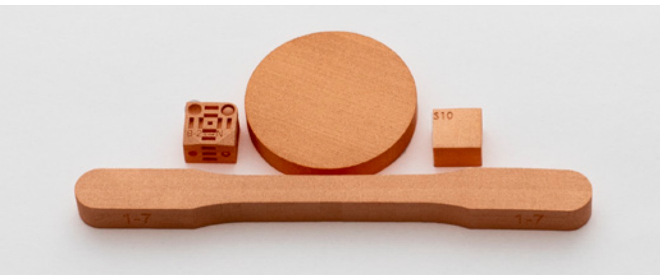
- 99.9 % pure copper
- Excellent thermal and electrical conductivity
- Suitable for a variety of industry applications
- Commonly used for heat sinks, heat exchangers, engine parts and electronics



LOM images: DM Cu etched with Klemm's reagent plus polarized light

TENSILE TEST BEHAVIOUR OF DM CU





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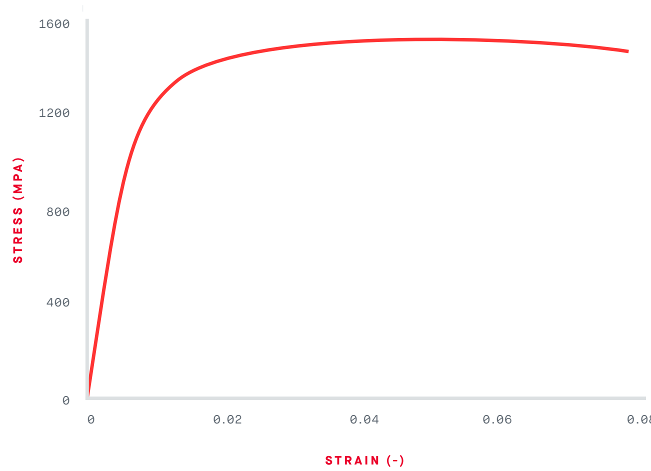
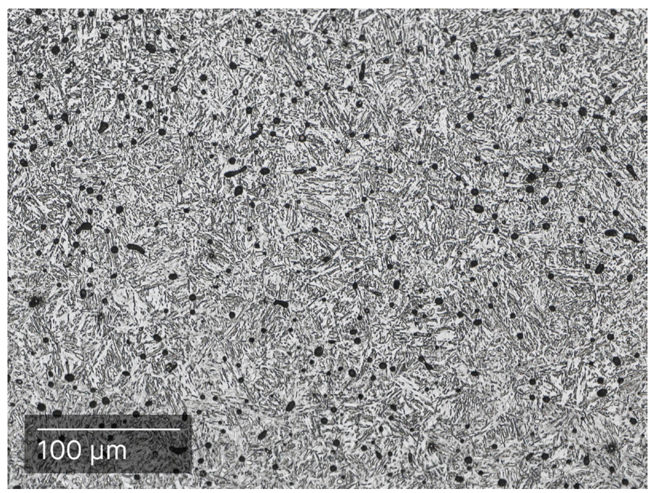
4140
chromoly steel

One of the most versatile steels, 4140 is characterized by its toughness, abrasion resistance, and impact resistance, making it a great all-purpose steel for industrial applications.



Composition %

Cr	**0.8 – 1.2**
Mo	**0.2 – 0.3**
C	**0.3 (typical)**
Si	**0.6 (max)**
Mn	**1.0 (max)**
Fe	**Balance**



Studio System™ heat treated microstructure.

Other standard designations[1]

AISI	4140
UNS	G41400
DIN	1.7200
JIS	G4105

Mechanical properties[2]

	standard	**Studio System** heat treated[3]	MPIF 35-MIM heat treated (min)[4]	Wrought heat treated, for reference[3]
Yield strength (MPa)	ASTM E8	**1060**	1070	1500
Ultimate Tensile Strength (MPa)	ASTM E8	**1450**	1380	1990
Elongation at break	ASTM E8	**5.5%**	3%	10%
Hardness (HRC)	ASTM E18	**40**	46 (typical)	52
Density (relative)		**95%**	95.5%	100%

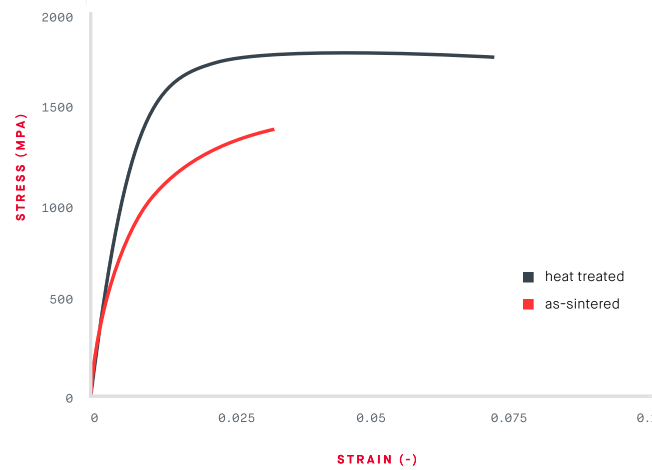
1 Listed designations are for reference purposes only. Composition and mechanical properties may vary.
2 Properties shown reflect beta processing parameters. Properties were obtained for sintering loads between 1.5 kg and 3 kg .
3 Heat treated samples were oil quenched from 857 °C and tempered at 204 °C for 2 hours.
4 Per MPIF Standard 35, Materials Standards for Metal Injection Molded Parts (MPIF 35-MIM, 2018).

End-use material performance is impacted (+/-) by certain factors including but not limited to part geometry and design, application and evaluation conditions, etc.

Desktop Metal

H13
tool steel

Characterized by its stability in heat treatment, exceptional hot hardness, and abrasion resistance, H13 is a tool steel widely used in both hot and cold work applications.

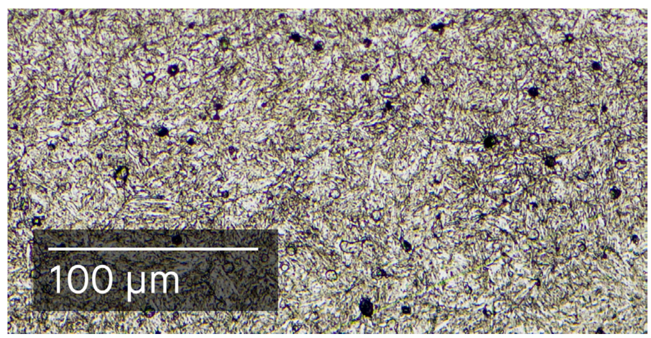


Composition %

Cr	4.8 – 5.5
Mo	1.1 – 1.7
Si	0.8 – 1.2
V	0.8 – 1.2
C	0.3 – 0.45
Mn	0.2 – 0.6
P	0.03 Max
S	0.03 Max
Fe	Balance

Other standard designations[4]

UNS	T20813
DIN	1.2344
JIS	SKD61



Studio System heat treated microstructure.

Mechanical properties[1]

	standard	**Studio System** as-sintered	**Studio System** heat treated[3]	Wrought heat treated, for reference[3]
Yield strength (MPa)	ASTM E8[2]	**650**	**1250**	1525
Ultimate Tensile Strength (MPa)	ASTM E8[2]	**1325**	**1720**	1950
Elongation at break	ASTM E8[2]	**2.3%**	**5.8%**	9%
Hardness (HRC)	ASTM E18	**35**	**45**	54
Density (relative)		**≥ 93.5%**	**—**	100%

1 Properties shown reflect beta processing parameters. Properties were obtained for sintering loads between 1.5 kg and 3 kg
2 Specimens tested according to ASTM E8 with a modified crosshead displacement rate of 0.009 mm/mm/min.
3 Heat treated samples were air quenched at 1040 °C and double tempered at 540 °C.
4 Listed designations are for reference purposes only. Composition and mechanical properties may vary.

End-use material performance is impacted (+/-) by certain factors including but not limited to part geometry and design, application and evaluation conditions, etc

Desktop Metal, Inc.
63 3rd Ave, Burlington MA USA 01803
www.desktopmetal.com

Aluminum AlSi10Mg

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Low weight
- Good thermal properties, strength and hardness
- Fast building
- Excellent machinability

Applications

- Thin walls
- Complex geometries
- Lower cost prototypes
- Aerospace and automotive

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	ENGLISH	METRIC	ENGLISH	METRIC
	STRESS RELIEVED - 35 C PLATFORM		HIP + T6 HEAT TREAT	
Ultimate Tensile Strength	55 ksi	379 MPa	41 ksi	281 MPa
0.2% Yield Strength	34 ksi	232 MPa	32 ksi	221 MPa
Elongation	6.9%	6.9%	14.1%	14.1%
Reduction of Area	10.2%	10.2%	20.7%	20.7%
Modulus of Elasticity	9.91 msi	68.3 GPa	10.29 msi	71.0 GPa
Hardness, Rockwell B	64	64	-	-

ALUMINUM ALSI10MG COMPOSITION

ELEMENT	TYPICAL PERCENTAGES
Aluminum (Al)	balance
Copper (Cu)	≤ 0.05
Iron (Fe)	≤ 0.55
Magnesium (Mg)	0.2 - 0.45
Manganese (Mn)	≤ 0.45
Silicon (Si)	9.0 - 11.0
Titanium (Ti)	≤ 0.15
Zinc (Zn)	≤ 0.10

*The information presented represents typical values intended for reference and comparison purposes only. It should not be used for design specifications or quality control purposes. End-use material performance can be impacted (+/-) by, but not limited to, part design, end-use conditions, test conditions, color etc. Actual values will vary with build conditions. Product specifications are subject to change without notice. *Chemical analysis for specific lots available upon request.*

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Cobalt Chrome

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- High tensile strength and hardness, biocompatible, corrosion and wear resistance, and low ductility.

Applications

- Applications would include medical devices/implants, turbine engines, industrial/mechanical components, and oil and gas.

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	DMLM (AS BUILT)	STRESS RELIEVING @ 750°C FOR 1 HR & FIRING @ 880°C FOR 5 MIN
Ultimate tensile strength	Min.: 800 MPa, 116 ksi (typical: 1050 ± 100 MPa, 152 ± 15 ksi)	Min.: 900 MPa, 131 ksi (typical: 1100 ± 100 MPa, 160 ± 15 ksi)
Proof strength (Rp 0.2 %)	Min.: 600 MPa, 87 ksi (typical: 750 ± 80 MPa, 109 ± 12 ksi)	Min.: 700 MPa, 102 ksi (typical: 900 ± 80 MPa, 131 ± 12 ksi)
Elongation at break, A5	Min.: 10 % (typical: 14 % ± 2 %)	Min.: 2 % (typical: 10 % ± 2 %)
Young's Modulus	Min.: 170 GPa (typical: 200 ± 20 GPa)	Min.: 180 GPa (typical: 200 ± 10 GPa)
Hardness HV10	Min.: 320 HV (typical: 360 ± 20 HV)	Min.: 350 HV (typical: 420 ± 30 HV)
Coefficient of thermal expansion (25 - 500°C)	–	14.0 – 14.5 x 10-6 m/m°C 7.78 – 8.06 x 10-6 in/in°F
Coefficient of thermal expansion (20 - 600°C)	–	14.2 – 14.6 x 10-6 m/m°C 7.89 – 8.11 x 10-6 in/in°F
Melting interval	–	1380 - 1440°C, 2516 – 2624°F

COBALT CHROME COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Cobalt (Co)	61.8 – 65.8 wt-%
Chromium (Cr)	23.7 – 25.7 wt-%
Molybdenum (Mo)	4.6 – 5.6 wt-%
Tungsten (W)	4.9 – 5.9 wt-%
Silicon (Si)	0.8 – 1.2 wt-%
Iron (Fe)	max. 0.50 wt-%
Manganese (Mn)	max. 0.10 wt-%

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Nickel Alloy K500

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Liquid Oxygen (LOX) Compatible
- Corrosion resistant
- Ti, Al precipitates create high strength

Heat Treatment Options

- HIP Hot Isostatic Press & Age Hardenable

Applications

- Liquid Rocket Engine Components
- LOX Manifolds and Injectors
- Parts requiring ductility and high strength
- Parts requiring high corrosion resistance

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	TYPICAL WROUGHT Hot Finished Annealed	DMLM (AS BUILT)	DMLM (HIP)	DMLM (ANNEALED)
0.02% Yield (ksi)	40-60	53.3	69	127
Ultimate Tensile (ksi)	90-110	70.5	121	77.8
Elongation (%)	45-25	40.2	28.8	27.6
Reduction of Area (%)	70-80	76	50	42
Hardness (HRB)	75-90	85	85	90

HIP – Hot Isostatic Press, 2125F at 14.75ksi for 240 min; SHT – Solution Heat Treat, 1850F for 30 minutes Air quench; PHT – Precipitation Heat Treat, 1100F for 8hrs, cool to 900F at 25F/hour, air cool below 900F

PROMOTED COMBUSTION PROPERTIES NASA-STD-6001B, ASTM G124	TYPICAL WROUGHT	DMLM AS BUILT, HIP, ANNEALED & AGE
Threshold Pressure (psi)	> 10,000	> 10,000
Burn Length (in)	-	0.22

NICKEL ALLOY K500 COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Nickel (Ni)	Balance
Carbon (C)	0.25 max
Manganese (Mn)	1.5 max
Sulfur (S)	0.01 max
Silicon (Si)	0.5 max
Iron (Fe)	2.0 max
Aluminum (Al)	2.3 – 3.1
Copper (Cu)	27.0 – 33.0
Titanium (Ti)	0.35 – 0.85

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Nickel Alloy 625

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Nickel based super alloy
- Non-Magnetic
- Corrosion resistant

Applications

- High heat
- Turbine engine components and fuel systems
- Oil well, petroleum, and natural gas industry

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	AMS 5599, 5666 (MIN)	DMLM AS BUILT	DMLM SR	DMLM HIP'ED	DMLM SHT
Ultimate Tensile Strength	120 ksi	146 ksi	138 ksi	132 ksi	128 ksi
0.02% Yield Strength	60 ksi	97 ksi	93 ksi	57 ksi	61 ksi
Modulus	-	26 msi	27 msi	27 msi	27 msi
Elongation	30%	42%	36%	50%	41%
Reduction of Area	-	54%	37%	45%	38%
Hardness (HRC)	24 (MAX)	29	13	TBD	TBD

*SR - Stress Relief, 1950°F for 1.5 hours
*HIP'ed - Hot Isostatic Press, 2125°F for 240 min at 14.75 ksi
*SHT - Solution Heat Treat, (Per AMS5599G) Heat to 1900°F, time commensurate with thickens heating equipment and procedure.
*SR - Stress Releived, 100°F for 1.5 hours, air cooled

NICKEL ALLOY 625 COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Carbon (C)	0.10 max
Silicon (Si)	0.50 max
Manganese (Mn)	0.50 max
Phosphorus (P)	0.015 max
Sulfur (S)	0.015 max
Chromium (Cr)	20.00-23.00
Molybdenum (Mo)	8.00-10.00
Iron (Fe)	5.00 max
Niobium (Nb)	3.15-4.15
Aluminum (Al)	0.40 max
Titanium (Ti)	0.40 max
Nickel (Ni)	58.00 min

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Nickel Alloy 718

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Nickel based super alloy
- Non-Magnetic
- Corrosion resistant

Applications

- High heat
- Turbine engine components, fasteners & instrumentation parts
- Oil well, petroleum, and natural gas industry

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	AMS 5596, 5663 SHT (MAX)	AMS 5596, 5663 PHT (MIN)	DMLM AS BUILT	DMLM SR*	DMLM HIP'ed*	DMLM SHT*	DMLM PHT*
Tensile Strength	140 ksi	180 ksi	127 ksi	133 ksi	185 ksi	119 ksi	198 ksi
0.02% Yield Strength	80 ksi	150 ksi	112 ksi	75 ksi	135 ksi	46 ksi	153 ksi
Modulus (msi)	-	-	26 msi	28 msi	29 msi	26 msi	28 msi
Elongation	30%	12%	30%	42%	24%	29%	20%
Reduction of Area	-	-	40%	48%	49%	44%	28%
Hardness (HRC)	25	36	TBD	TBD	TBD	TBD	TBD

*SR - Stress Relief, 1950°F for 1.5 hours
*HIP'ed - Hot Isostatic Press, 2125°F for 240 min at 14.75 ksi
*SHT - Solution Heat Treat, (Per AMS5596K) Heat to 1725°F to 1850°F, hold for time commensurate with product thickness air cool (or faster)
*PHT - Percipitation Heat Treatment, (Per AMS5596K) Heat to 1325°F to 1400°F, hold for approx 8 hours, cool at 100°F/hr to 1150°F, hold for approx 8 hrs, air cool

NICKEL ALLOY 718 COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Carbon (C)	0.08 max
Silicon (Si)	0.35 max
Manganese (Mn)	0.35 max
Phosphorus (P)	0.015 max
Sulfur (S)	0.015 max
Chromium (Cr)	17.00 - 21.00
Molybdenum (Mo)	3.3 max
Copper (Cu)	0.30 max
Iron (Fe)	Balance
Niobium (Nb)	5.5 max
Aluminum (Al)	0.3 max
Titanium (Ti)	1.15 max
Nickel (Ni)	50.00 - 55.00

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Stainless Steel 17-4

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Pre-alloyed, precipitation hardenable stainless steel
- Good welding and machining characteristics
- Good mechanical properties

Applications

- Parts requiring post-production processing
- Oil and gas industry
- Parts requiring ductility and high strength
- Parts requiring high corrosion resistance

Heat Treatment Options

- Annealed: 1900°F for 2 hours in a vacuum
- H900: Hardens part at 900°F in argon for 1 hour
- H1150: Anneals part at 1150°F in argon for 4 hours
- Heat Treatment 1: HIP + AMS 5604 (SHT+H900)

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	AMS 5604/5643 (MIN REQ.)	TYPICAL WROUGHT	DMLM (AS BUILT)	DMLM (HT1)	DMLM (HIP)	DMLM (ANNEALED)
0.02% Yield	-	-	106 ksi	180 ksi	119 ksi	103 ksi
Ultimate Tensile	-	-	151 ksi	211 ksi	166 ksi	175 ksi
Elongation	-	-	17%	11%	12%	12%
Hardness	-	-	~ 30 HRC	-	-	-

STAINLESS STEEL 17-4 PH COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Carbon (C)	0.07 max
Manganese (Mn)	1.00 max
Phosphorus (P)	0.040 max
Sulfur (S)	0.030 max
Silicon (Si)	1.00 max
Chromium (Cr)	15.00 - 17.50
Nickel (Ni)	3.00 - 5.00
Copper (Cu)	3.00 - 5.00
Niobium plus Tantalum (Cb, Ta)	0.15 - 0.45

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Stainless Steel 316L

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Good strength and creep resistance
- Excellent weldability due to low-carbon
- Molybdenum gives improved corrosion resistance

Applications

- Parts requiring post-production processing
- Consumer/Automotive/Aerospace
- Parts requiring ductility and high strength
- Parts requiring high corrosion resistance

Heat Treatment Options

- Solution annealing not necessary
- Cannot be hardened by heat treat

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	TYPICAL WROUGHT AMS5507G	DMLM (AS BUILT)	
		XY AXIS	Z AXIS
0.02% Yield	172.4 MPa	530 ± 60 MPa	470 ± 90MPa
Ultimate Tensile	482-689 MPa	93 ± 8ksi	78 ± 8ksi
Elongation	45%	40 ± 15%	50 ± 20%
Hardness	79 HRB	typ 85 HRB	

STAINLESS STEEL 316L COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Iron (Fe)	balance
Carbon (C)	0.030 max
Manganese (Mn)	2.00 max
Phosphorus (P)	0.025 max
Sulfur (S)	0.010 max
Silicon (Si)	0.750 max
Chromium (Cr)	17.50 - 18.00
Nickel (Ni)	12.500 - 13.00
Copper (Cu)	0.50 max
Molybdenum (Mo)	2.25 – 2.50

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Titanium Ti64

DIRECT METAL LASER MELTING MATERIAL SPECIFICATIONS

Highlights

- Light alloy characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight and biocompatibility.

Applications

- Ideal for high-performance engineering applications such as aerospace and motor racing and for the production of biomedical implants.

TYPICAL PHYSICAL PROPERTIES

MECHANICAL PROPERTIES	DMLM (AS BUILT)
Ultimate tensile strength	1150 ± 60 MPa (166 ± 9 ksi)
Yield strength (Rp 0.2 %)	1030 ± 70 MPa (150 ± 10 ksi)
Elongation at break	11 % ± 2 %
Young's Modulus	110 ± 7 GPa (16 ± 1 msi)
Hardness	Approx. 400 - 430 HV (41 - 44 HRC)
Maximum long-term operating temperature	350 °C (660 °F)
Relative density with standard parameters	Approx. 100 %
Density with standard parameters	4.43 g/cm³ (0.160 lb/in³)

TITANIUM TI64 COMPOSITION

ELEMENT	TYPICAL PERCENTAGE
Aluminium (A)	(5.5 – 6.5 %)
Vanadium (V)	(3.5 – 4.5 %)
Oxygen (O)	< 2000 ppm
Nitrogen (N)	< 500 ppm
Carbon (C)	< 800 ppm
Hydrogen (H)	< 120 ppm
Iron (Fe)	< 2500 ppm

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Arcam EBM system

Grade 2 Titanium

CAD TO METAL

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Grade 2 Titanium

General characteristics
The high strength, low weight ratio and outstanding corrosion resistance inherent to titanium and its alloys has led to a wide and diversified range of successful applications which demand high levels of reliable performance in surgery and medicine as well as in aerospace, automotive, chemical plant, power generation, oil and gas extraction, sports, and other major industries.

In the majority of these and other engineering applications titanium has replaced heavier, less serviceable or less cost-effective materials. Designing with titanium taking all factors into account has resulted in reliable, economic and more durable systems and components, which in many situations have substantially exceeded performance and service life expectations.

Titanium is available in different grades, unalloyed or alloyed.

Special characteristics
Unalloyed Commercially Pure (CP) Titanium is available in four different grades, 1, 2, 3 and 4, which are used based on the corrosion resistance, ductility and strength requirements of the specific application. Grade 1 has the highest formability, while Grade 4 has the highest strength and moderate formability.

CP Titanium users utilize its excellent corrosion resistance, formability and weldable characteristics in many critical applications.

Titanium Grade 2 is stronger than Grade 1 and equally corrosion-resistant against most applications.

Titanium Grade 2 has numerous applications in the medical industry. Biocompatibility of Titanium Grade 2 is excellent, especially when direct contact with tissue or bone is required.

Applications
Titanium Grade 2 is typically used for:

- Orthopaedic applications, such as implants and prosthesis
- Airframe and aircraft engine parts
- Marine chemical parts
- Condenser tubing
- Heat exchangers

Powder specification
The Arcam Titanium Grade 2 powder has a particle size between 45 and 100 microns. This limit on the minimum particle size ensures safe handling of the powder.

Please refer to the Arcam MSDS (Material Safety Data Sheet) for more information about the handling and safety of the Arcam Titanium Grade 2.

Lattice skull implant manufactured with Arcam EBM.

CHEMICAL SPECIFICATION

	Arcam Titanium Grade 2, Typical	Titanium Grade 2, Required*
Carbon, C	0,005%	<0,08%
Iron, Fe	0,05%	<0,3%
Oxygen, O	0,19%	<0,25%
Nitrogen, N	0,004%	<0,03%
Hydrogen, H	0,0009%	<0,015%
Titanium, Ti	Balance	Balance

*ASTM F67 (Unalloyed Titanium for Surgical Implant Applications)

MECHANICAL PROPERTIES

	Arcam Titanium Grade 2, Typical	Titanium Grade 2, Required*
Yield Strength (Rp 0,2)	540 MPa	275 MPa
Ultimate Tensile Strength (Rm)	570 MPa	345 MPa
Elongation	21%	>20%
Reduction of Area	55%	>30%

*ASTM F67 (Unalloyed Titanium for Surgical Implant Applications)
The mechanical properties of materials produced in the EBM process are comparable to wrought annealed materials and are better than cast materials.

POST PROCESSING

Heat treatment
Hot Isostatic Pressing (HIP) is recommended for fatigue-loaded components. The following HIP parameters are recommended:
- 920° C
- 100 MPa
- 120 minutes

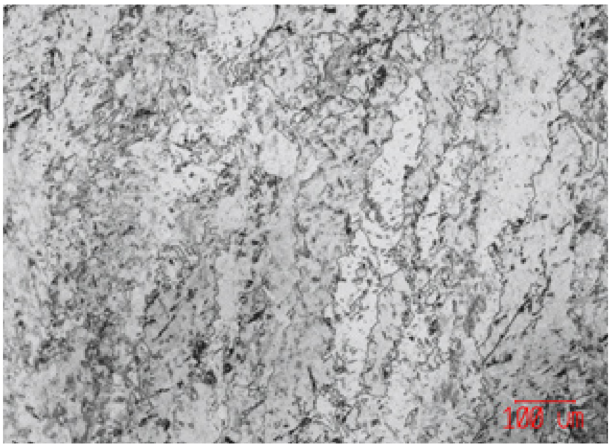
Machining
Titanium Grade 2 parts manufactured in the EBM process feature good machinability and can be machined as stock parts. The following factors contribute to efficient machining of Titanium Grade 2 parts:
- Low cutting speeds
- High feed rate
- Generous quantities of cutting fluid
- Sharp tools
- Rigid setup

Welding
Titanium Grade 2 may be welded by a wide variety of conventional fusion and solid-state processes, although its chemical reactivity typically requires special measures and procedures.

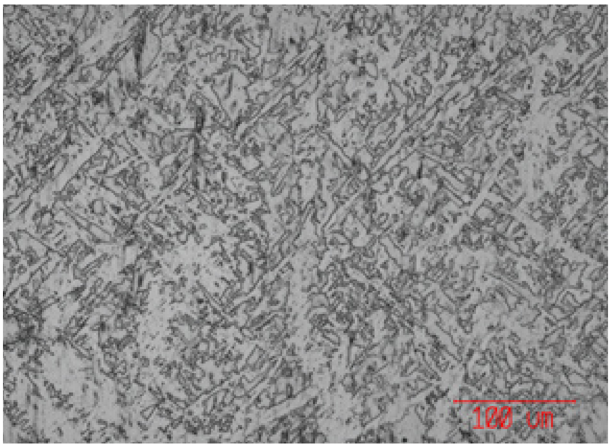
Microstructure

Titanium Grade 2 parts manufactured in the EBM process have a microstructure consisting of fine α-grains, thanks to the rapid cooling of the melt pool.

The build chamber is kept at an elevated temperature throughout the entire build, and the material thus comes out of the EBM process in a naturally aged condition.



Micrograph of Arcam Titanium Grade 2 material, 100x.



Micrograph of Arcam Titanium Grade 2 material, 200x.

CAD TO METAL

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Material data sheet - FlexLine

EOS NickelAlloy HX

EOS NickelAlloy HX is a nickel metal alloy powder intended for processing on EOS DMLS systems.
This document provides information and data for parts built using EOS NickelAlloy HX powder (EOS art.-no. 9011-0023) on the following specifications:

- EOS DMLS system M400-4
- EOSYSTEM: EOSPRINT v.1.5/HCS v.2.4.14
- EOS Parameter set HX FlexLine 40µm

Description

EOS NickelAlloy HX is a nickel-chromium-iron-molybdenum alloy in fine powder form. Its composition corresponds to UNS N06002. While the wrought and cast versions of the alloy generally are solution annealed, the laser sintered version has a high strength and good elongation already in the as-built condition. Solution annealing of the laser sintered material will homogenize the microstructure, relax internal stresses and increase the elongation, while slightly decreasing the strength.

This type of alloy is characterized by having high strength and oxidation resistance also at elevated temperatures, and is often used up to 1200°C. Therefore its applications can be found in aerospace technology, gas turbine parts, etc.

Parts built from EOS NickelAlloy HX can be heat treated and material properties can be varied within specified range. In both as-built and solution heat treated states the parts can be machined, spark-eroded, welded, micro shot-peened, polished, and coated if required. Unexposed powder can be reused.

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Material data sheet - FlexLine

Technical Data

Powder properties

The chemical composition of the powder is reported in the table below.

Material composition	Element	Min	Max
	Ni	Balance	
	Cr	20.5	23.0
	Fe	17.0	20.0
	Mo	8.0	10.0
	W	0.2	1.0
	Co	0.5	2.5
	C	-	0.1
	Si	-	1.0
	Mn	-	1.0
	S	-	0.03
	P	-	0.04
	B	-	0.01
	Se	-	0.0050
	Cu	-	0.5
	Al	-	0.5
	Ti	-	0.15

Max. particle size	
Particles > 63µm [1]	max. 0.5 wt.-%

[1] Sieve analysis according to ASTM B214.

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Material data sheet - FlexLine

General process data

Layer thickness	40 µm
Volume rate [2]	16.8 mm^3/s (60.8 cm^3/h)

[2] The volume rate is a measure of build speed during laser exposure of the skin area. The total build speed depends on this volume rate and many other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings.

Physical and chemical properties of parts

Part density [3]	min. 8.2 g/ cm^3
Surface roughness after shot peening [4]	R_a 4-6.5 µm; R_z 20-50 µm

[3] Weighing in air and water according to ISO 3369.
[4] Measurement according to ISO 4287. The numbers were measured at the horizontal (up-facing) and all vertical surfaces of test cubes. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

Tensile data at room temperature [5, 6]

	As built	**Heat treated [7]**
Ultimate tensile strength, R_m	770 MPa	710 MPa
Yield strength, $R_{p0.2}$	610 MPa	345 MPa
Elongation at break, A	31 %	45 %

[5] The numbers are average values and are determined from samples with horizontal and vertical orientation.
[6] Tensile testing according to ISO 6892-1 B10, proportional test pieces, diameter of the neck area 5 mm (0.2 inch), original gauge length 25 mm (1 inch).
[7] Heat treatment procedure: According to AMS2773 and AMS5390: Solution anneal at 1177°C for 1 hour, followed by rapid air cooling to below 60°C.

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Abbreviations

min.	minimum
max.	maximum
wt.	weight

Legal notes

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

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Material data sheet - FlexLine

EOS NickelAlloy IN718

EOS NickelAlloy IN718 is a heat and corrosion resistant nickel alloy powder intended for processing on EOS DMLS™ systems.

This document provides information and data for parts built using

- EOS Powder: EOS NickelAlloy IN718 (EOS art.-no. 9011-0020)
- EOS Laser Sintering Machine: EOS M400-4
  - HSS Recoater Blade (EOS art.-no. 300007610)
  - DirectBase S40 Building Platform (EOS art.-no. 300000729)
  - Argon atmosphere
  - 63 µm mesh for powder sieving recommended (EOS art.-no. 9044-0032 for IPCM M Extra Sieving Module or EOS art.-no. 200001059 for IPM M Powder Station L)
  - EOSYSTEM v. 2.6 or higher
- EOS Software:
  - EOSPRINT v. 1.6 (EOS art.-no. 7501-4031) / 2.0 (EOS art.-no. 7012-0119) or higher
- EOS Process:
  - IN718 ParameterEditor (EOS art.-no. 7500-3084)
  - Name of the Default Job: IN718_040_FlexM404_100.eosjob

Description

EOS NickelAlloy IN718 chemical composition corresponds to UNS N07718, AMS 5662, AMS 5664, W.Nr 2.4668, DIN NiCr19Fe19NbMo3. This material is ideal for many high temperature applications such as gas turbine parts, instru-mentation parts, power and process industry parts etc. It also has excellent potential for cryogenic applications. 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).

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Material data sheet - FlexLine

Parts can be easily post-hardened by precipitation-hardening 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.

Technical Data

Powder properties

The chemical composition of the powder is reported in the table below.

Material composition

Element	Min	Max
Ni	50	55
Cr	17	21
Nb	4.75	5.5
Mo	2.8	3.3
Ti	0.65	1.15
Al	0.20	0.80
Co	-	1.0
Cu	-	0.30
C	-	0.08
Si, Mn	-	0.35
P, S	-	0.015
B	-	0.006
Fe	-	Balance

Max. particle size	
> 63µm [1]	max 0.3 wt.-%

[1] Sieve analysis according to ASTM B214.

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Material data sheet - FlexLine

General process data

Layer thickness	40 µm
Volume rate [2]	Up to 4 x 4.2 mm^3/s (4 x 15.1 cm^3/h)

[2] The volume rate is a measure of build speed during laser exposure of the skin area per laser scanner. The total build speed depends on this volume rate and other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings, Job design (load, part geometry or overlap settings).

Physical properties of parts

Part density [3]	min. 8.15 g/cm3
Min. wall thickness [4]	Approx. 0.3 - 0.4 mm
Surface roughness after shot peening [5]	Ra < 6.5 µm; Rz 50 µm

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

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

[5] Measurement according to ISO 4287. The numbers were measured at the horizontal (up-facing) and all vertical surfaces of test cubes. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

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Tensile data at room temperature [6]

	Heat treated [7] [8]	
	Horizontal	**Vertical**
Ultimate tensile strength, Rm	1510 MPa	1420 MPa
Yield strength, Rp0.2	1305 MPa	1215 MPa
Elongation at break, A [9]	15 %	16 %

[6] Tensile testing according to. ISO 6892-1 B10, proportional test pieces, diameter of the neck area 5 mm, original gauge length 25 mm.

[7] Heat treatment procedure conform to Aerospace Material Specification AMS 5662:

1. Solution Anneal at 980 °C (1796 °F) for 1 hour per 25mm (0.98 inch) of thickness, air (/argon) cool.
2. Ageing treatment; hold at 718 °C (1325 °F) 8 hours, furnace cool to 621 °C (1150 °F) and hold at 621 °C (1150 °F) for total precipitation time of 18 hours., air (/argon) cool.

[8] The numbers are average values determined from samples with horizontal and vertical orientation respectively

[9] Elongation values are averaged and subject to variations depending on process conditions

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Abbreviations

min. minimum

max. maximum

wt. weight

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Material data sheet - Flexline

EOS Titanium Ti64

EOS Titanium Ti64 is a titanium alloy powder intended for processing on EOS DMLS™ machines.

This document provides information and data for parts built using

- EOS Powder: EOS Titanium Ti64 (EOS art.-no. 9011-0014)
- EOS Laser Sintering Machine: EOS M400-4
  - HSS Recoater Blade (EOS art.-no. 300007610)
  - DirectBase Ti40 Building Platform (EOS art.-no. 300013128)
  - Argon atmosphere
  - 63 µm mesh for powder sieving recommended (EOS art.-no. 9044-0032 for IPCM M Extra Sieving Module or EOS art.-no. 200001059 for IPM M Powder Station L)
  - EOSYSTEM v. 2.6 or higher
- EOS Software:
  - EOSPRINT v. 1.6 (EOS art. no. 7501-4031) / 2.0 (EOS art.-no. 7012-0119) or higher
- EOS Process:
  - Ti64 ParameterEditor (EOS art.-no. 7500-3086)
  - Name of the Default Job: Ti64_060_FlexM404_100.eosjob

Description

EOS Titanium Ti64 has a chemical composition corresponding to ASTM F1472 and ASTM F2924.

Ti64 is well-known light alloy, characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight. Ti64 material is ideal for many high-performance applications.

Parts built with EOS Titanium Ti64 powder can be machined, shot-peened and polished in as-built and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy.

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Technical Data

Powder properties

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

Material composition

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

Max. particle size

>63µm [1]	max. 0.3 wt%

[1] Sieve analysis according to ASTM B214.

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General process data

Layer thickness	60 µm
Volume rate [2]	Up to 4 x 9,0 mm^3/s (4 x 32,4 cm^3/h)

[2] The volume rate is a measure of build speed during laser exposure of the skin area per laser scanner. The total build speed depends on this volume rate and other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings, job design (load, part geometry or overlap settings).

Physical and chemical properties of parts

Part density [3]	Approx. 4.41 g/cm3
Min. wall thickness [4]	Approx. 0.3 - 0.4 mm
Surface roughness after shot peening [5]	Ra 6-15 µm; Rz 30-75 µm

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

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

[5] Measurement according to ISO 4287. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

Hardness

Hardness as build [6]	Approx. 330 ± 30 HV5

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

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Tensile data at room temperature [7,9]

	Heat treated [8]	
	Horizontal	Vertical
Ultimate tensile strength, Rm	1070 MPa	1080 MPa
Yield strength, Rp0.2	955 MPa	990 MPa
Elongation at break, A [10]	13 %	15 %

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

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

[9] The numbers are average values determined from samples with horizontal and vertical orientation respectively

[10] Values are averaged and subject to variations depending on process conditions.

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Abbreviations

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

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

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Material data sheet

EOS Titanium Ti64

EOS Titanium Ti64 is a titanium alloy powder intended for processing on EOS DMLS™ machines.

This document provides information and data for parts built using:

- EOS Titanium Ti64 powder (EOS art.-no. 9011-0014 and 9011-0039)
- EOS DMLS™ machine: EOSINT M 290 400 W
- HSS blade (2200-4073)
  - Argon atmosphere
  - IPCM extra sieving module with 63 µm mesh (9044-0032) recommended
- EOSYSTEM:
  - EOSPRINT v 1.5 or newer
  - HCS v 2.4.14 or newer
- EOS Parameter set: Ti64_Performance_M291 1.10

Description

EOS Titanium Ti64 has a chemical composition corresponding to ASTM F1472 and ASTM F2924.

Ti64 is well-known light alloy, characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight. Ti64 material is ideal for many high-performance applications.

Parts built with EOS Titanium Ti64 powder can be machined, shot-peened and polished in as-built and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy.

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Material data sheet

Technical Data

Powder properties

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

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

Max. particle size	
> 63µm	0.3 wt%

General process data

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

[1] The volume rate is a measure of build speed during laser exposure of the skin area per laser scanner. The total build speed depends on this volume rate and many other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings.

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Material data sheet

Physical and chemical properties of parts

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

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

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

[4] Measurement according to ISO 4287. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

Hardness

Hardness as build [5]	Approx. 320 HV5

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

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Tensile data at room temperature [6, 7]

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

[6] Tensile testing according to ISO 6892-1 A14, proportional test pieces. Horizontal: diameter of the neck area 5 mm (0.2 inch), original gauge length 20 mm (0,79 inch). Vertical: diameter of the neck area 4 mm (0.16 inch), original gauge length 16 mm (0.63 inch).

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

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

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Material data sheet

Abbreviations

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

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

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EOS Titanium Ti64

EOS Titanium Ti64 is a titanium alloy powder intended for processing on EOS DMLS™ machines.

This document provides information and data for parts built using EOS Titanium Ti64 powder (EOS art.-no. 9011-0039) on the following system setup:

- EOS DMLS™ system: EOS M400 SF
  - HSS recoating blade
  - Argon atmosphere
  - IPCM M extra sieving module with 63µm mesh recommended
- EOSPRINT v.1.5/HCS v.2.4 or newer
- EOS Parameter set Ti64_030_FlexM400_100

Description

Parts built in EOS Titanium Ti64 have a chemical composition corresponding to ASTM F1472 and ASTM F2924.

Ti64 is well-known light alloy, characterized by having excellent mechanical properties and corrosion resistance combined with low specific weight. Ti64 material is ideal for many high-performance applications.

Parts built with EOS Titanium Ti64 powder can be machined, shot-peened and polished in as-built and heat treated states. Due to the layerwise building method, the parts have a certain anisotropy.

Quality Assurance

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

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

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Technical Data

Powder properties

Material composition [wt.%]	Element	Min	Max
	Al	5.50	6.75
	V	3.50	4.50
	O	-	0.20
	N	-	0.05
	C	-	0.08
	H	-	0.015
	Fe	-	0.30
	Y	-	0.005
	Other elements, each	-	0.10
	Other elements, total	-	0.40
	Ti		bal.

Particle size	
d50 [1]	39 ± 3 µm

[1] Particle size distribution analysis according to ISO 13320

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General process data

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

[2] The volume rate is a measure of build speed during laser exposure of the skin area. The total build speed depends on this volume rate and many other factors such as exposure parameters of contours, supports, up and downskin, recoating time, Home-In or LPM settings.

Physical properties of parts

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

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

[4] The numbers were measured at the horizontal (up-facing) and all vertical surfaces of test cubes. Due to the layerwise building the roughness strongly depends on the orientation of the surface, for example sloping and curved surfaces exhibit a stair-step effect.

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

Tensile data at room temeprature [6,7]

	As built	**Heat treated [8]**
Ultimate tensile strength	typ. 1270 MPa	typ. 1040 MPa
Yield strength, Rp0.2%	typ. 1100 MPa	typ. 930 MPa
Elongation at break A	typ. 8.7 %	typ. 14.0 %

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

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

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

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Abbreviations

min. minimum

max. maximum

wt. weight

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