LaserForm® AlSi7Mg0.6 (A)

AlSi7Mg0.6 fine-tuned for use with ProX® DMP 320 and DMP 350 metal printers to produce industrial parts with a combination of good mechanical properties and improved thermal conductivity.

LaserForm AlSi7Mg0.6 (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 and DMP 350 series metal 3D printers to deliver high part quality and consistent part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging metal production parts in various materials year over year. And for 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable results.

Material Description

AlSi7Mg0.6 combines silicon and magnesium as alloying elements, which results in good mechanical properties. Due to the very rapid melting and solidification during Direct Metal Printing, LaserForm AlSi7Mg0.6 (A) in as-printed condition shows a fine microstructure and obtains a good combination of strenght and ductility. Lower silicon content improves electrical and thermal conductivity properties compared to AlSi10Mg while the increased magnesium content maintains mechanical properties similar to AlSi10Mg. Heat treatment allows electrical and thermal conductivity to be fine-tuned to the needs of the application. Additionally, the lower silicon content improves the anodization quality as well as the corrosion resistance.

LaserForm AlSi7Mg0.6 (A)'s low material density is well suited for the aerospace and automotive industry. Innovative applications such as mold design and specific heat exchanger applications make use of the high thermal conductivity of this alloy.

Mechanical Properties[1,2,3]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS-BUILT	AFTER STRESS RELIEF	DIRECT AGEING	AS-BUILT	AFTER STRESS RELIEF	DIRECT AGEING
Young's modulus (GPa | ksi)	ASTM E1876						
Horizontal direction - XY Vertical direction - Z		NA 70-72	NA 75-76	NA 73-74	NA 10100-10500	NA 10800-11000	NA 10600-10900
Ultimate strength (MPa | ksi)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		410 ± 20 390 ± 40	280 ± 20 290 ± 50	430 ± 20 430 ± 30	59 ± 3 56 ± 6	41 ± 3 42 ± 7	62 ± 3 62 ± 5
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		240 ± 30 210 ± 30	160 ± 40 180 ± 40	310 ± 20 280 ± 20	35 ± 5 30 ± 5	23 ± 6 26 ± 6	45 ± 3 40 ± 3
Plastic elongation (%)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		14 ± 4 11 ± 5	18 ± 3 11 ± 6	10 ± 3 5 ± 3	14 ± 4 11 ± 5	18 ± 3 11 ± 6	10 ± 3 5 ± 3
Hardness, Rockwell B (HRB)	ASTM E18	60 ± 3	39 ± 10	69 ± 2	60 ± 3	39 ± 10	69 ± 2

Thermal Properties

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS BUILT	AFTER STRESS RELIEF	AFTER DIRECT AGEING	AS BUILT	AFTER STRESS RELIEF	AFTER DIRECT AGEING
Thermal conductivity[4,5] (W/(m.K) | Btu/(h.ft.°F))	at 20°C / 68°F	120-140	180-190	150-170	70-80	105-110	85-100
CTE - Coefficient of thermal expansion[6] (µm/(m.°C) | µ inch/(inch.°F))	in the range of 20 to 100 °C	typical 21.4			typical 11.9		
Melting range[6] (°C | °F)		typical 557 - 613			typical 1035-1135		

Electrical Properties[5,7]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS BUILT	AFTER STRESS RELIEF	AFTER DIRECT AGEING	AS BUILT	AFTER STRESS RELIEF	AFTER DIRECT AGEING
Electrical conductivity (10^6 S/m)	ASTM B193 at 20°C / 68°F	17-19	25-27	22-24	17-19	25-27	22-24

1 Parts manufactured with standard parameters on a ProX DMP 320, Config B
2 Values based on average and double standard deviation
3 Surface condition of test samples: Horizontal samples (XY) tested in machined surface condition only, vertical (Z) tested in as-printed and machined surface condition
4 Thermal conductivity values are calculated via the Wiedemann-Franz law using the measured electrical resistivity values
5 Results are based on limited sample size, not statistically representative
6 Values based on literature
7 Electrical resistivity measurements are based on the four point contact method according to ASTM B193

LaserForm® AlSi7Mg0.6 (A)

Physical Properties

MEASUREMENT	CONDITION	METRIC	U.S.
Density			
Relative, based on pixel count[1,2,4] (%)	Optical method	> 99.2 tpical 99.8	> 99.2 tpical 99.8
Absolute theoretical[3] (g/cm^3 | lb/in^3)		2.67	0.096

Surface Quality[4,5]

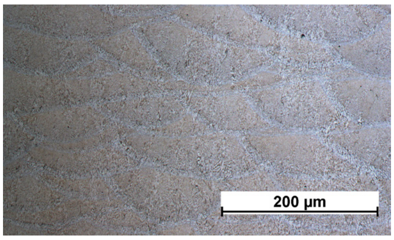
MEASUREMENT	CONDITION	SAND BLASTED METRIC	SAND BLASTED U.S.
Surface Roughness R_a	ISO 25178		
Layer Thickness 30µm (µm | µin)			
Vertical side surface[6]		typical 5-7	typical 200-280
Layer Thickness 60µm (µm | µin)			
Vertical side surface[6]		typical 10-20	typical 400-800

Chemical Composition

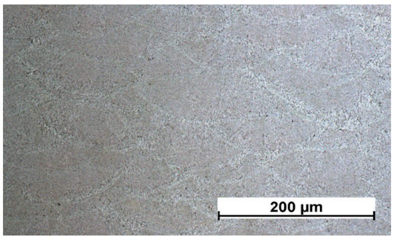
The chemical composition of LaserForm AlSi7Mg0.6 (A) conforms to the requirements EN AC-42200, and is indicated in the table below in wt%.

ELEMENT	% OF WEIGHT
Al	Balance
Si	6.50-7.50
Mg	0.45-0.70
Fe	≤0.15
Cu	≤0.03
Mn	≤0.10
Ni	≤0.05
Zn	≤0.07
Pb	≤0.05
Sn	≤0.05
Ti	≤0.18
Other (each)	≤ 0.03
Other (total)	≤ 0.10

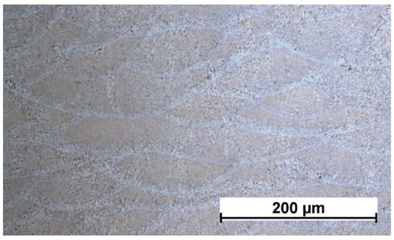
[1] Minimum value based on 95% confidence interval. Tested on typical density test coupons
[2] May deviate depending on specific part geometry
[3] Values based on literature
[4] Parts manufactured with standard parameters on a ProX DMP 320, Config B
[5] Sand blasting performed with zirconia blasting medium at 2 bar
[6] Vertical side surface measurement along the building direction



Microstructure as built



Microstructure after stress relief



Microstructure after direct ageing

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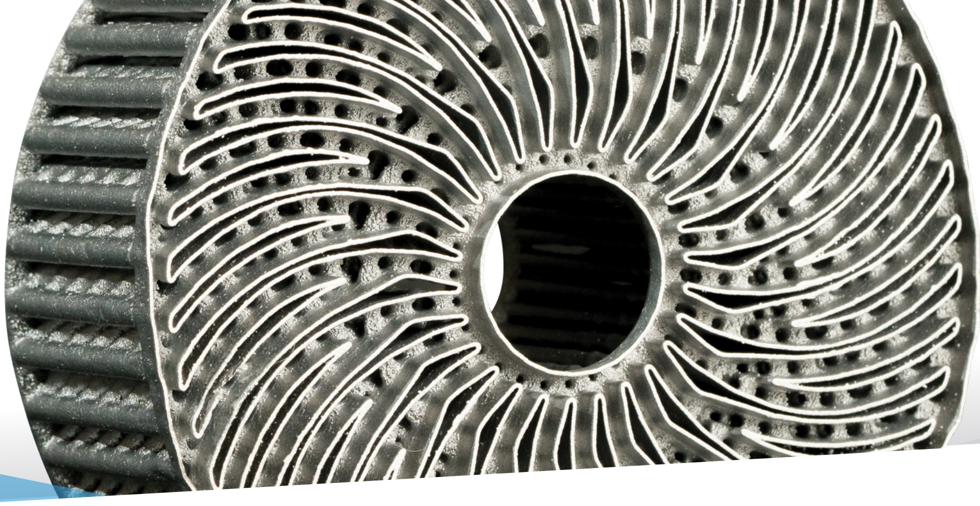
PN 10116B 07-20



LaserForm AlSi10Mg (A)

AlSi10Mg fine-tuned for use with ProX® DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 printers producing industrial parts with a combination of good mechanical properties and good thermal conductivity.

LaserForm AlSi10Mg (A) is formulated and fine-tuned specifically for 3D Systems ProX® DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 metal 3D printers to deliver high part quality and consistent part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing more than 1,000,000 challenging metal production parts in various materials year over year. Based on a multitude of test samples, the properties listed below provide high confidence to the user in terms of job-to-job and machine-to-machine repeatability. Using the LaserForm material enables the user to experience consistent and reliable part quality.

Material Description

AlSi10Mg combines silicon and magnesium as alloying elements, which results in a significant increase in strength and hardness compared to other aluminum alloys. Due to the very rapid melting and solidification during Direct Metal Printing, LaserForm AlSi10Mg (A) in as-printed condition shows fine microstructure and high strengths.

In the aerospace and automotive industry, LaserForm AlSi10Mg (A) is used for its light weight. Both innovative approaches to mold design and specific heat exchanger applications make use of the high thermal conductivity of this alloy.

CLASSIFICATION:

Parts built with LaserForm AlSi10Mg (A) have a chemical composition that complies with EN AC-43000 and ASTM F3318.

Mechanical Properties

PROX DMP 320, DMP FLEX 350, DMP FACTORY 350 - LT 30[1,4,5]	TEST METHOD	METRIC			U.S.		
		NHT	SR1	SR2	NHT	SR1	SR2
Ultimate tensile strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8	470 ± 10 460 ± 25	300 ± 20 300 ± 20	400 ± 15 430 ± 15	68 ± 1 67 ± 4	44 ± 3 44 ± 3	58 ± 2 62 ± 2
Yield strength Rp0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z		280 ± 10 240 ± 10	190 ± 20 180 ± 20	270 ± 10 250 ± 10	41 ± 1 35 ± 1	28 ± 3 26 ± 3	39 ± 1 36 ± 1
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z		13.2 ± 4.8 8.3 ± 4.0	15.6 ± 3.6 15.8 ± 2.7	9.2 ± 3.8 5.2 +3.7/-2.6	13.2 ± 4.8 8.3 ± 4.0	15.6 ± 3.6 15.8 ± 2.7	9.2 ± 3.8 5.2 +3.7/-2.6

PROX DMP 320, DMP FLEX 350, DMP FACTORY 350 – LT 60[2,4,5]	TEST METHOD	METRIC			U.S.		
		NHT	SR1	SR2	NHT	SR1	SR2
Ultimate tensile strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8	440 ± 30 425 ± 50	290 ± 20 290 ± 20	390 ± 20 400 ± 40	64 ± 4 62 ± 7	42 ± 3 42 ± 3	57 ± 3 58 ± 6
Yield strength Rp0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z		260 ± 15 225 ± 10	170 ± 20 170 ± 20	255 ± 10 230 ± 10	38 ± 2 33 ± 1	25 ± 3 25 ± 3	37 ± 1 33 ± 1
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z		8.9 ± 5.0 7.6 ± 4.9	14.0 ± 5.3 13.2 ± 6.0	8.6 ± 2.0 5.1 ± 2.8	8.9 ± 5.0 7.6 ± 4.9	14.0 ± 5.3 13.2 ± 6.0	8.6 ± 2.0 5.1 ± 2.8

DMP FACTORY 500 – LT 60[3,4,5]	TEST METHOD	METRIC			U.S.		
		NHT	SR1	SR2	NHT	SR1	SR2
Ultimate tensile strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8	NA	290 ± 20 300 ± 20	405 ± 20 420 +20/-60	NA	42 ± 3 44 ± 3	59 ± 3 61 +3/-9
Yield strength Rp0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z		NA	170 ± 20 180 ± 20	270 +15/-30 250 ± 20	NA	25 ± 3 26 ± 3	39 +2/-4 36 ± 3
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z		NA	17.5 ± 4.9 13.3 ± 5.7	9.4 ± 5.5 5.8 ± 3.4	NA	17.5 ± 4.9 13.3 ± 5.7	9.4 ± 5.5 5.8 ± 3.4

[1] Parts manufactured with standard parameters and protocols on a ProX DMP 320, DMP Flex and Factory 350, Config B, using layer thickness 30 μm (LT30)

[2] Parts manufactured with standard parameters and protocols on a ProX DMP 320, DMP Flex and Factory 350, Config B, using layer thickness 60 μm (LT60)

[3] Parts manufactured with standard parameters and protocols on a DMP Factory 500, using layer thickness 60 μm (LT60)

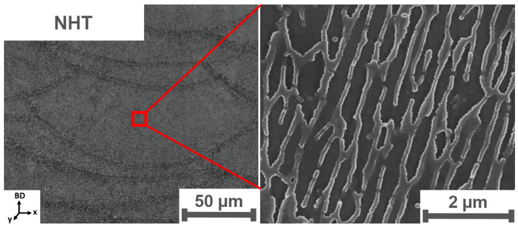
[4] NHT is non-heat-treated sample condition; SR1 is a heat treatment at 285 °C for 2 h; SR2 is a heat treatment at 190 °C for 6h. Values based on average and 95% tolerance interval with 95% confidence

[5] Tested according to ASTM E8 using round tensile test specimen type 4

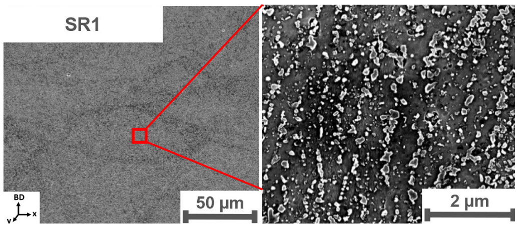
Printed Part Properties[6]

DENSITY	TEST METHOD	METRIC	U.S.
Theoretical density[7] (g/cm³ | lb/in³)	Value from literature	2.68	0.097
Relative density (%), layer thickness 30 µm [1, 8]	Optical method (pixel count)	≥ 99.7 Typical 99.9	≥ 99.7 Typical 99.9
Relative density (%), layer thickness 60 µm [2, 3, 8]	Optical method (pixel count)	≥ 99.5 Typical 99.8	≥ 99.5 Typical 99.8

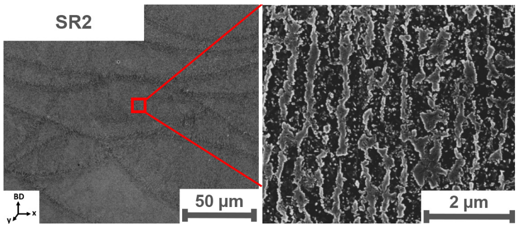
SURFACE ROUGHNESS R_a[9,10]	TEST METHOD	METRIC	U.S.
Vertical side surface (µm | µin) Layer thickness 30 µm	ISO 25178	Typically, around 8	Typically, around 315
Vertical side surface (µm | µin) Layer thickness 60 µm	ISO 25178	Typically, around 15	Typically, around 591



Microstructure without heat treatment (NHT)



Microstructure after SR1



Microstructure after SR2

Thermal Properties

MEASUREMENT	CONDITION	METRIC			U.S.		
		NHT	SR1	SR2	NHT	SR1	SR2
Thermal conductivity[11,12] (W/(m.K) | BTU·in/h·ft²·°F	at 20 °C / 68 °F	120-130	160-170	140-160	833-902	1110 -1180	971-1110
CTE - Coefficient of thermal expansion[7] (µm/(m.°C) | µ inch/(inch . °F))	in the range of 20 to 100 °C	typical 20.9			typical 11.6		
Melting range[7] (°C | °F)		typical 557 - 596			typical 1035 - 1105		

Electrical Properties[12,13]

MEASUREMENT	CONDITION	METRIC			U.S.		
		NHT	SR1	SR2	NHT	SR1	SR2
Electrical conductivity (10^6 S/m)	ASTM B193 at 20°C / 68°F	17-18	22-24	20-22	17-18	22-24	20-22

Chemical Composition

ELEMENT	% OF WEIGHT
Al	Balance
Si	9.00-11.00
Mg	0.20-0.45
Fe	≤0.55
Cu	≤ 0.03
Mn	≤0.35
Ni	≤0.05
Zn	≤0.10
Pb	≤0.05
Sn	≤0.05
Ti	≤0.15
Other (each)	≤ 0.05
Other (total)	≤ 0.15

[6] May deviate depending on specific part geometry
[7] Values based on literature
[8] Minimum values based on 95% tolerance interval with 95% confidence. Tested on specific 3DS density test coupons
[9] Surface treatment performed with zirconia blasting medium at 2 bar
[10] Vertical side surface measurement along the building direction
[11] Thermal conductivity values are calculated by the Wiedemann-Franz law using the respective electrical resistivity values
[12] Results are based on limited sample size, not statistically representative. Samples printed on a ProX DMP 320, Config B
[13] Electrical resistivity measurements are based on four point contact method according to ASTM B193

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PN10104E 07-21

Certified Scalmalloy® (A)

Thoroughly developed print parameters and certification process support for APWORKS Scalmalloy material on 3D Systems DMP Flex 350 printers. Scalmalloy is the highest strength aluminum alloy processable by laser powder bed fusion.

3D Systems offers an optimized print parameter database license for Certified Scalmalloy (A) on the DMP Flex 350 metal 3D printer that can be applied using the integrated additive manufacturing workflow software, 3DXpert. 3D Systems' metal print parameters have been extensively developed, tested, and optimized in 3D Systems' part production facilities, which have the unique distinction of printing more than 1,000,000 challenging metal production parts in various materials, year over year. Based on a multitude of test samples, the properties listed below provide high confidence to the user in terms of job-to-job and machine-to-machine repeatability.

For companies looking to use the Scalmalloy brand name internally and externally on their DMP Flex 350 printers, 3D Systems offers a cost-effective standard service for smooth APWORKS certification through its Application Innovation Group (AIG).

Material Description

Scalmalloy is an aluminum alloy, with a chemical composition optimized for laser based powder bed fusion processes such as direct metal printing (DMP). Scalmalloy bridges the gap between traditional aluminum cast alloys (e.g., AlSi10Mg) and Ti Gr23, and provides a combination of high specific strength (strength-to-weight ratio), excellent corrosion resistance, and good thermal and electrical conductivity.

Within the aerospace, motorsports, semiconductor machinery, and transportation industries, Scalmalloy is used for its high strength-to-weight ratio, enabling customers to further reduce mass. The material is ideally suited for highly loaded, safety critical parts. Parts printed in Scalmalloy are corrosion resistant and can be chemically cleaned to meet the strict purity requirements of fluid flow applications.

CLASSIFICATION:

Scalmalloy is an approved material under the FIA regulations.

Mechanical Properties

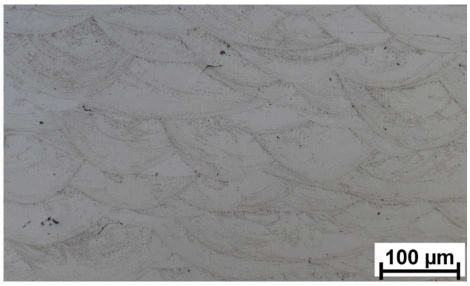
DMP FLEX 350 - LT 30[1,3,4,5]	TEST METHOD	METRIC	U.S.
		SR	SR
Ultimate tensile strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8	520 ± 10 520 ± 15	75 ± 2 75 ± 2
Yield strength Rp0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z		490 ± 10 490 ± 15	71 ± 2 71 ± 2
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z		15.8 ± 2.7 15.8 ± 2.6	15.8 ± 2.7 15.8 ± 2.6

DMP FLEX 350 - LT 60[2,3,4,5]	TEST METHOD	METRIC	U.S.
		SR	SR
Ultimate tensile strength (MPa | ksi) Horizontal direction - XY Vertical direction - Z	ASTM E8	530 ± 10 520 ± 10	77 ± 2 75 ± 2
Yield strength Rp0.2% (MPa | ksi) Horizontal direction - XY Vertical direction - Z		500 ± 10 490 ± 10	72 ± 2 71 ± 2
Plastic elongation (%) Horizontal direction - XY Vertical direction - Z		14.0 ± 3.4 13.1 ± 3.0	14.0 ± 3.4 13.1 ± 3.0

[1] Parts manufactured with standard parameters and protocols on a DMP Flex 350, Config B, using layer thickness 30 µm (LT30)
[2] Parts manufactured with standard parameters and protocols on a DMP Flex 350, Config B, using layer thickness 60 µm (LT60)
[3] SR is a heat treatment at 325 °C for 4 h, followed by air cooling (heat treatment advised by APWORKS)
[4] Tested according to ASTM E8 using round tensile test specimen type 4
[5] values based on average and 95% tolerance interval with 95% confidence

Thermal Properties

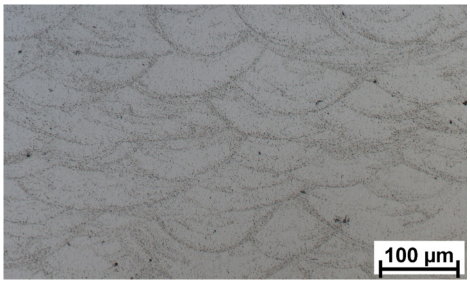
MEASUREMENT	CONDITION	METRIC	U.S.
		SR	SR
Thermal conductivity[6,7] (W/(m.K) | BTU·in/h·ft^2·°F	at 20 °C / 68 °F	95-100	660-695
CTE - Coefficient of thermal expansion[8] (µm/(m.°C) | µ inch/(inch . °F))	in the range of 20 to 100 °C	Typical 23.5	Typical 13.1
Melting range[8] (°C | °F)		Typical 600 – 800	Typical 1110 – 1470



Microstructure without heat treatment (NHT)

Electrical Properties[6]

MEASUREMENT	CONDITION	METRIC	U.S.
		SR	SR
Electrical conductivity (10^6 S/m)	ASTM B193 at 20°C / 68°F	13-14	13-14



Microstructure after SR

Printed Part Properties[6]

DENSITY	TEST METHOD	METRIC	U.S.
Theoretical density[8] (g/cm^3 | lb/in^3)	Value from literature	2.67	0.096
Relative density (%), layer thickness 30 µm [9,10]	Optical method (pixel count)	≥ 99.6 Typical 99.8	≥ 99.6 Typical 99.8
Relative density (%), layer thickness 60 µm [9,10]	Optical method (pixel count)	≥ 99.5 Typical 99.7	≥ 99.5 Typical 99.7

SURFACE ROUGHNESS R_a [11,12]	TEST METHOD	METRIC	U.S.
Vertical side surface (µm | µin) Layer thickness 30 µm	ISO 25178	Typically, around 11	Typically, around 435
Vertical side surface (µm | µin) Layer thickness 60 µm	ISO 25178	Typically, around 13	Typically, around 510

To confirm the suitability of this material for your specific application, please contact the 3D Systems Application Innovation Group (AIG) (https://www.3dsystems.com). Once confirmed, Scalmalloy powder can be purchased directly from Toyal (https://www.toyalgroup.net/).

APWORKS Toyal

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[6] Parts manufactured with standard parameters and protocols on a DMP Flex 350, Config B using layer thickness 30 µm and 60 µm
[7] Thermal conductivity values are calculated by the Wiedemann-Franz law using the respective electrical resistivity values
[8] Values adopted from APWORKS material datasheet
[9] Minimum values based on 95% tolerance interval with a 95% confidence. Tested on specific 3DS density test coupons
[10] May deviate depending on specific part geometry
[11] Surface treatment performed with zirconia blasting medium at 2 bar
[12] Vertical side surface measurement along the building direction

PN 10123A 08-21

LaserForm® CoCrF75 (A)

Cobalt-chromium-molybdenum alloy fine-tuned for use with ProX DMP 320 metal printer producing industrial parts with high corrosion and wear resistance that also require high temperature resistance. In addition to various industrial applications, LaserForm CoCrF75 (A) is also suitable for medical applications.

LaserForm CoCrF75 (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 metal 3D Printers to deliver high part quality and consistent part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging metal production parts in various materials year over year. And for your 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable results.

Material Description

Cobalt-chromium-molybdenum alloys are known for their high strength and hardness and retain these properties even at elevated temperatures. In addition, they spontaneously form a protective passive film, which makes LaserForm CoCrF75 (A) both corrosion resistant and biocompatible.

These benefits make LaserForm CoCr75 (A) the ideal material for medical tools and devices, molds and dies, industrial, high wear applications and parts requiring high strength at elevated temperatures. In biomedical applications, LaserForm CoCr75 (A) is ideal for dental implants and prostheses.

Classification

The chemical composition of LaserForm® CoCr F75 conforms to the requirements of the ASTM F75, ISO 5832 and ISO 22674 standards, and is indicated in the table below in wt%.

Mechanical Properties[1,2,3]

MEASUREMENT	CONDITION	METRIC		U.S.	
		AFTER ANNEAL	AFTER HIP	AFTER ANNEAL	AFTER HIP
Youngs modulus (GPa | ksi)	ASTM E8M	225 ± 5	225 ± 5	32650 ± 730	32650 ± 730
Ultimate strength (MPa | ksi)	ASTM E8M				
Horizontal direction - XY Vertical direction - Z		1030 ± 70 1000 ± 30	1020 ± 70 950 ± 40	150 ± 10 145 ± 5	150 ± 10 140 ± 5
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M				
Horizontal direction - XY Vertical direction - Z		540 ± 30 520 ± 30	510 ± 30 475 ± 20	80 ± 5 75 ± 5	75 ± 5 70 ± 5
Elongation at break (%)	ASTM E8M				
Horizontal direction - XY Vertical direction - Z		29 ± 6 29 ± 4	29 ± 6 23 ± 3	29 ± 6 29 ± 4	29 ± 6 23 ± 3
Hardness, Rockwell C	ASTM E18	25 ± 5	39 ± 3	25 ± 5	39 ± 3
Impact toughness[4] (J | ft-lb)	ASTM E23	52 ± 3	NA	39±2	NA

Thermal Properties[5]

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu/(h.ft².°F))	at 20°C / 120 °F	14	8
CTE - Coefficient of thermal expansion (μm/(m.°C) | μ inch/(inch. °F))	in the range of 20 to 600 °C	14	8
Melting range (°C | °F)		1350 - 1430	2460 - 2610

1 Parts manufactured with standard parameters on a ProX DMP 320, Config B
2 Values based on average and standard deviation
3 HIP indicates hot isostatic pressing post treatment
4 Tested with Charpy V-notch impact test specimens type A at room temperature
5 Values based on literature
NA = Not available

LaserForm® CoCrF75 (A)

Electrical Properties[5]

MEASUREMENT	METRIC	U.S.
Electrical resistivity (nΩ.m | µΩ.in)	874	34

Physical Properties

MEASUREMENT	METRIC		U.S.	
	AS BUILT AND AFTER STRESS RELIEF	AFTER HIP	AS BUILT AND AFTER STRESS RELIEF	AFTER HIP
Density				
Relative, based on pixel count[1] (%)	>99,9	≈100	>99,9	≈100
Absolute theoretical[5] (g/cm³ | lb/in³)	8.35		0.302	

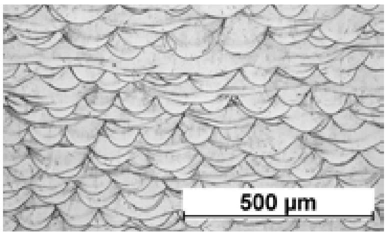
Surface Quality[1]

MEASUREMENT	METRIC		U.S.	
	AS BUILT	SAND BLASTED	AS BUILT	SAND BLASTED
Surface Roughness R_a				
Vertical direction (Z) (µm | µin)	9 - 13	3 - 5	350 - 510	120 - 200

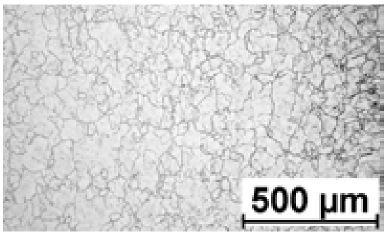
Chemical Composition

ELEMENT	% OF WEIGHT
Co	Bal.
Cr	27.00-30.00
Mo	5.00-7.00
Ni	≤0.50
Fe	≤0.75
C	≤0.35
Si	≤1.00
Mn	≤1.00
W	≤0.20
P	≤0.020
B, S	≤0.010
N	≤0.25
Al, Ti	≤0.10

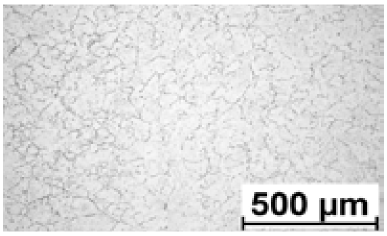
[1] Parts manufactured with standard parameters on a ProX DMP 320, Config B
[5] Values based on literature



Microstructure as built



Microstructure after anneal



Microstructure after HIP

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LaserForm® Ni625 (A)

Ni625 fine-tuned for use with ProX® DMP 320 metal printer producing industrial parts with high heat resistance, high strength and high corrosion resistance. LaserForm Ni626 (A) is especially resistant to crevice and pitting corrosion.

LaserForm Ni625 (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 metal 3D Printers to deliver high part quality and consistent part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging metal production parts in various materials year over year. And for your 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable results.

Material Description

Ni625 is known for its combination of high strength and excellent corrosion resistance. LaserForm Ni625 (A) is the ideal material for industries where these two strengths need to come together: chemical, marine, aerospace and nuclear industry. Applications include: reaction vessels, tubing, heat exchangers, valves, engine exhaust systems, turbine seals, propeller blades, submarine fittings, propulsion motors, reactor core and control-rod components in nuclear water reactors.

Classification

The chemical composition of LaserForm Ni625 (A) corresponds to ASTM F3056, UNS N06625, Werkstoff Nr. 2.4856, DIN NiCr22Mo9Nb and AMS 5666 and is indicated in the table below in wt%.

Mechanical Properties[1,2]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS-BUILT	AFTER STRESS RELIEF	AFTER LOW SOLUTION ANNEAL	AS-BUILT	AFTER STRESS RELIEF	AFTER LOW SOLUTION ANNEAL
Ultimate strength (MPa | ksi)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		1040 ± 20 1030 ± 20	1110 ± 60 1050 ± 30	1030 ± 20 980 ± 20	150 ± 3 150 ± 3	160 ± 9 153 ± 5	150 ± 3 142 ± 3
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		770 ± 30 730 ± 20	750 ± 60 700 ± 40	640 ± 20 600 ± 20	110 ± 5 105 ± 3	110 ± 9 100 ± 6	93 ± 3 87 ± 3
Elongation at break (%)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		22 ± 2 33 ± 1	19 ± 3 23 ± 3	27 ± 3 34 ± 3	22 ± 2 33 ± 1	19 ± 3 23 ± 3	27 ± 3 34 ± 3
Reduction of area (%)							
Vertical direction – Z	ASTM E8M	30 ± 2	26 ± 2	31 ± 1	30 ± 2	26 ± 2	31 ± 1
Hardness, Rockwell C	ASTM E18	29 ± 3	32 ± 3	28 ± 4	29 ± 3	32 ± 3	28 ± 4
Impact toughness[3] (J | ft-lb)	ASTM E23	NA	NA	84 ± 7	NA	NA	62 ± 5

Thermal Properties[4]

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu/(h.ft².°F))	at 21 °C / 70 °F	9.8	5.7
CTE - Coefficient of thermal expansion (µm/(m.°C) | µ inch/(inch . °F))	at 93 °C / 200 °F at 538°C / 1000°F at 871°C/1600°F	12.8 14.0 15.8	7.1 7.8 8.8
Melting range (°C | °F)		1290 - 1350	2355 - 2465

[1] Parts manufactured with standard parameters on a ProX DMP 320, Config B
[2] Values based on average and standard deviation
[3] Tested with Charpy V-notch impact test specimens type A at room temperature
[4] Values based on literature
NA = Not available

LaserForm® Ni625 (A)

Physical Properties

MEASUREMENT	METRIC	U.S.
	AS BUILT AND AFTER STRESS RELIEF	
Density		
Relative, based on pixel count[1] (%)	>99,9	>99,9
Absolute theoretical[4] (g/cm^3 | lb/in^3)	8.44	0.305

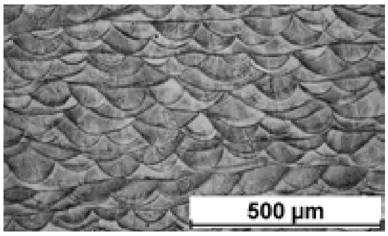
Surface Quality[1]

MEASUREMENT	METRIC		U.S.	
	AS BUILT	SAND BLASTED	AS BUILT	SAND BLASTED
Surface Roughness R_a				
Horizontal direction (XY) (µm | µin)	4 - 7	1 - 4	160 - 275	40 - 160
Vertical direction (Z) (µm | µin)	8 - 11	4 - 7	320 - 433	160 - 275

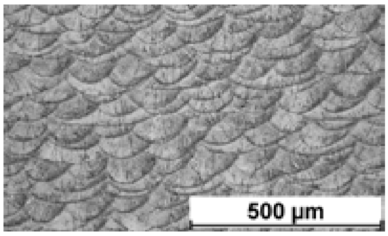
Chemical Composition

The chemical composition of LaserForm Ni625 (A) corresponds to UNS N06625, Werkstoff Nr. 2.4856, DIN NiCr22Mo9Nb and AMS5 5666 and is indicated in the table below in wt%.

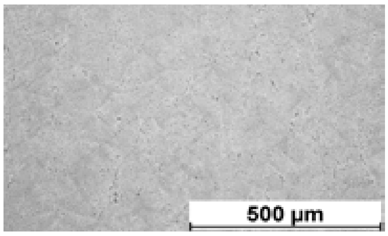
ELEMENT	% OF WEIGHT
Ni	≥ 58.00
Cr	20.00 - 23.00
Mo	8.00 - 10.00
Fe	≤ 5.00
Co	≤1.00
Nb	3.15 - 4.15
Ta	≤ 0.05
Ti	≤ 0.40
Al	≤ 0.40
Cu	≤ 0.50
Mn	≤ 0.50



Microstructure as built



Microstructure after stress relief



Microstructure after low solution anneal

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[1] Parts manufactured with standard parameters on a ProX DMP 320, Config B
[4] Values based on literature

LaserForm Ni718 (A)

A Nickel-based alloy fine-tuned for use with ProX® DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 metal printers, producing parts for high temperature applications. LaserForm Ni718 (A) has outstanding corrosion resistance in various corrosive environments and excellent cryogenic properties.

LaserForm Ni718 (A) is formulated and fine-tuned specifically for 3D Systems ProX DMP 320, DMP Flex 350, DMP Factory 350 and DMP Factory 500 metal 3D printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing more than 1,000,000 challenging production parts year over year. Based on a multitude of test samples, the properties listed below provide high confidence to the user in terms of job-to-job and machine-to-machine repeatability. Using the LaserForm material enables the user to experience consistent and reliable part quality.

Material Description

LaserForm Ni718 (A) is a nickel-based heat resistant alloy. This precipitation-hardening nickel-chromium alloy is characterized by good tensile, fatigue, creep and rupture strength at temperatures up to 700°C. Moreover it has outstanding corrosion resistance in various corrosive environments as well as excellent cryogenic properties.

These benefits make LaserForm Ni718 (A) ideal for many high temperature applications such as gas turbine parts, instrumentation parts, power and process industry parts etc. Parts can be post-hardened over 1400 MPa Ultimate Tensile Strength (UTS) by precipitation-hardening heat treatments. The parts can be machined, spark-eroded, welded, shot-peened, polished and coated if required.

Classification

Parts built with LaserForm Ni718 Type (A) have a chemical composition that complies with ASTM F3055.

Mechanical Properties

PROX DMP 320, DMP FLEX 350, DMP FACTORY 350 – LT 30, 60[1, 2, 3, 4]	TEST METHOD	METRIC		U.S.	
		NHT	HSAA	NHT	HSAA
Ultimate Tensile Strength (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8/E8M	NA 930 ± 20	1400 ± 60 1340 ± 40	NA 135 ± 6	203 ± 10 194 ± 6
Yield strength Rp0.2% (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8/E8M	NA 660 ± 20	1230 ± 60 1200 ± 40	NA 96 ± 6	178 ± 10 174 ± 10
Elongation at break (%) Horizontal direction — XY Vertical direction — Z	ASTM E8/E8M	NA 30 ± 4	15 ± 4 14 ± 8	NA 30 ± 4	15 ± 4 14 ± 8

DMP FACTORY 500 – LT 60[5, 6, 7, 8]	TEST METHOD	METRIC		U.S.	
		NHT	HAA	NHT	HAA
Ultimate Tensile Strength (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8	1080 ± 20 1010 ± 25	1520 -40/+20 1440 -40/+20	157 ± 3 146 ± 4	220 -6/+3 209 -6/+3
Yield strength Rp0.2% (MPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E8	790 ± 25 660 ± 30	1350 -40/+30 1280 ± 50	115 ± 4 96 ± 4	196 -6/+4 186 ± 7
Plastic elongation (%) Horizontal direction — XY Vertical direction — Z	ASTM E8	29 ± 6 32 ± 4	16 ± 4 18 ± 5	29 ± 6 32 ± 4	16 ± 4 18 ± 5

HIGH TEMPERATURE TENSILE PROPERTIES DMP FACTORY 500 – LT60[9]	TEST METHOD	METRIC		U.S.	
		NHT	HAA	NHT	HAA
Ultimate Tensile Strength (MPA | ksi) Vertical direction – Z	ASTM E21, at 650°C	NA	1185 ± 25	NA	172 ± 4
Yield strength Rp0.2% (MPa| ksi) Vertical direction – Z	ASTM E21, at 650°C	NA	1055 ± 20	NA	153 ± 3
Plastic elongation (%) Vertical direction – Z	ASTM E21, at 650°C	NA	20 ± 3	NA	20 ± 3

[1] Parts manufactured with standard parameters on a DMP Flex 350 and DMP Factory 350, Config B using layer thickness 30 µm and layer thickness 60 µm
[2] Values based on average and double standard deviation
[3] NHT refers to non-heat-treated sample condition; HSAA refers to a modified homogenization followed with solutioning and double aging as prescribed in ASTM F3055
[4] NHT samples tested according to ASTM E8M using round tensile test specimen type 4. HSAA samples tested according to ASTM E8 using rectangular tensile test specimen type 8
[5] Parts manufactured with standard parameters on a DMP Factory 500, using layer thickness 60 µm (LT60)
[6] Values based on average and 95% tolerance interval with 95% confidence
[7] Tested according to ASTM E8 using round tensile test specimen type 4
[8] NHT refers to non-heat-treated sample condition; HAA refers to the homogenization with double aging (HAA) heat treatment as prescribed in ASTM F3055
[9] High temperature tensile properties based on limited sample size. For information only. Values based on average and double standard deviation

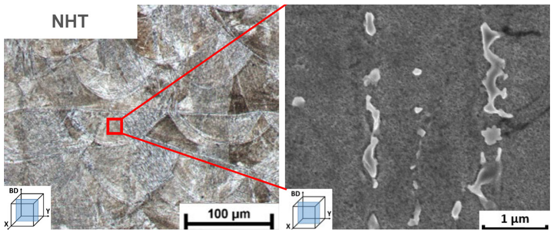
Printed Part Properties[10]

DENSITY	TEST METHOD	METRIC	U.S.
Theoretical density[11] (g/cm³ | lb/in³)	Value from literature	8.2	0.296
Relative density (%), ProX DMP 320, DMP Flex 350, DMP Factory 350[12, 13]	Optical method (pixel count)	≥ 99.6 Typical 99.9	≥ 99.6 Typical 99.9
Relative density (%), DMP Factory 500[12, 13]	Optical method (pixel count)	≥ 99.7 Typical 99.9	≥ 99.7 Typical 99.9

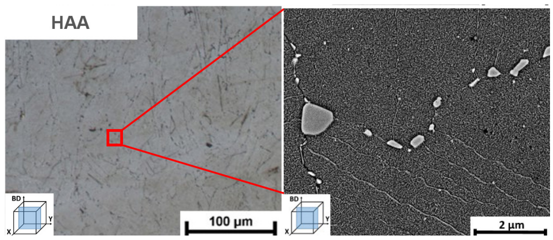
SURFACE ROUGHNESS R_a[12, 13, 14, 15]	TEST METHOD	METRIC	U.S.
Vertical side surface (µm | µin) ProX DMP 320, DMP Flex 350, DMP Factory 350	ISO 25178	Typically, around 5	Typically, around 197
Vertical side surface (µm | µin) DMP Factory 500	ISO 25178	Typically, around 5	Typically, around 197

Thermal Properties[11]

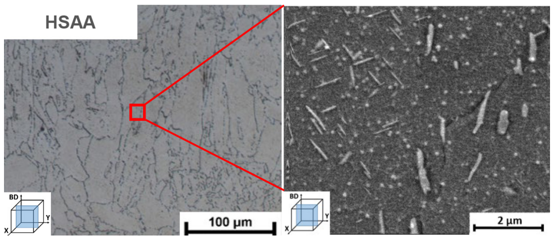
MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | BTU·in/h·ft²·°F)	At 21 °C/ 69.8 °F	11.4	79
	At 100°C / 212°F	18.3	127
Coefficient of Thermal Expansion (µm/m-°C | µinch/(inch.°F)	At 200°C / 392°F	13.2	7.33
	At 600°C / 1112°F	13.9	7.72
Melting range (°C | °F)		1260-1335	2300-2435



Microstructure NHT



Microstructure after HAA



Microstructure after HSAA

Chemical Composition

ELEMENT	% OF WEIGHT
Al	0.20-0.8
B	≤0.006
C	≤0.08
Co	≤1.00
Cr	17.00-21.00
Cu	≤0.30
Fe	Bal.
Mn,Si	≤0.35
Mo	2.80-3.30
Nb+Ta	4.75-5.50
Ni	50.00-55.00
P,S	≤0.015
Ti	0.65-1.15

[10] May deviate depending on specific part geometry
[11] Values based on literature
[12] Parts manufactured with standard parameters on a DMP Flex and Factory 350, Config B using layer thickness 30 µm and 60 µm. Parts manufactured on a DMP Factory 500, using layer thickness 60 µm
[13] Minimum values based on 95% tolerance interval with a 95% confidence. Tested on specific 3DS test coupons
[14] Surface treatment performed with Finox zirconia blasting medium at 5 bar
[15] Vertical side surface measurement along the building direction

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PN 10120C 08-21

LaserForm® Maraging Steel (A)

Maraging steel fine-tuned for use with ProX® DMP 320 metal 3D printers to produce industrial parts and tool inserts with a combination of high-strength and excellent hardness.

LaserForm Maraging Steel (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 metal 3D Printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on extensive testing the below listed part quality data and mechanical properties give you high planning security. For a 24/7 production operation, 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

Material Description

With properties like 1.2709, this steel is easily heat-treatable in a simple age-hardening process resulting in excellent hardness and strength. LaserForm Maraging Steel (A) has good wear resistance. In regards to post-processing, the material shows good weldability and machinability. LaserForm Maraging Steel (A) is ideal for innovative tool and mold designs including conformal cooling channels for injection molding, die casting and extrusion. The material is also used for high-performance aerospace, automotive and other industrial applications which require high strength and wear resistance.

Classification

Parts built with LaserForm Maraging Steel (A) have a chemical composition that conforms to the compositional requirements of Werkstoff Nr. 1.2709.

Mechanical Properties [1,2]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS-BUILT	AGEING 1	AGEING 2	AS-BUILT	AGEING 1	AGEING 2
Ultimate strength (MPa | ksi)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		1230 ± 70 1220 ± 20	2210 ± 30 2120 ± 30	2260 ± 30 2160 ± 90	178 ± 10 177 ± 3	320 ± 5 307 ± 5	328 ± 5 313 ± 13
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M						
Horizontal direction[4] - XY Vertical direction[5] - Z		1080 ± 90 1090 ± 50	2125 ± 30 2030 ± 60	2180 ± 40 2070 ± 80	115 ± 13 158 ± 7	308 ± 4 294 ± 9	316 ± 6 300 ± 12
Elongation at break (%)	ASTM E8M						
Horizontal direction - XY Vertical direction - Z		13 ± 2 13 ± 2	5 ± 2 5 ± 2	5 ± 2 2 ± 1	13 ± 2 13 ± 2	5 ± 2 5 ± 2	5 ± 2 2 ± 1
Hardness, Rockwell C	ASTM E18	35 ± 3	55 ± 3	55 ± 3	35 ± 3	55 ± 3	55 ± 3
Impact toughness[6] (J | ft-lb)[3]	ASTM E23	64 ± 5	8 ± 2	7 ± 2	47 ± 4	6 ± 2	5 ± 2

Thermal Properties [4]

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu/(h.ft².°F))	at 25°C / 36 °F	20.9	145
CTE - Coefficient of thermal expansion (μm/ (m.°C) | μ inch/(inch. °F)	In the range of 0 to 100 °C	10.0	5.6
Melting range (°C | °F)		1430-1450	2610-2640

1 Parts manufactured with standard parameters on a ProX DMP 320, Config B
2 Values based on average and double standard deviation
3 Tested with Charpy V-notch impact test specimens type A at room temperature
4 Values based on literature

LaserForm® Maraging Steel (A)

Physical Properties[1]

MEASUREMENT	METRIC		U.S.	
	AS-BUILT	AGEING	AS-BUILT	AGEING
Density				
Relative, based on pixelcount (%)	> 99.8%			
Absolute theoretical (g/cm^3 | lb/in3) [1]	8.1		0.293	

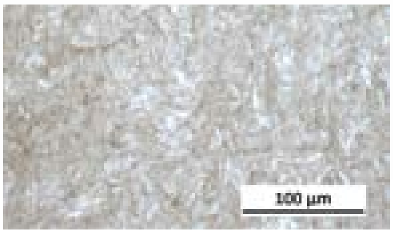
Surface Quality[2]

MEASUREMENT	SANDBLASTED METRIC	SANDBLASTED U.S.
Surface Roughness Ra		
Horizontal direction (XY) (µm | µin)	4 - 7	157 - 276
Vertical direction (Z) (µm | µin)	5 - 6	196 - 236

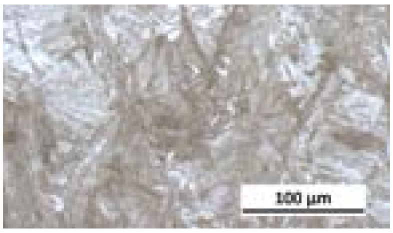
Chemical Composition

ELEMENT	% OF WEIGHT
C	≤ 0.03
Si	≤ 0.10
Mn	≤ 0.15
P	≤ 0.01
S	≤ 0.01
Cr	≤ 0.25
Mo	4.50 - 5.20
Ni	17.0 -19.0
Ti	0.80 - 1.20
Co	8.50 - 10.0
Fe	Rest

Microstructure as built



Microstructure ageing 1



Microstructure ageing 2

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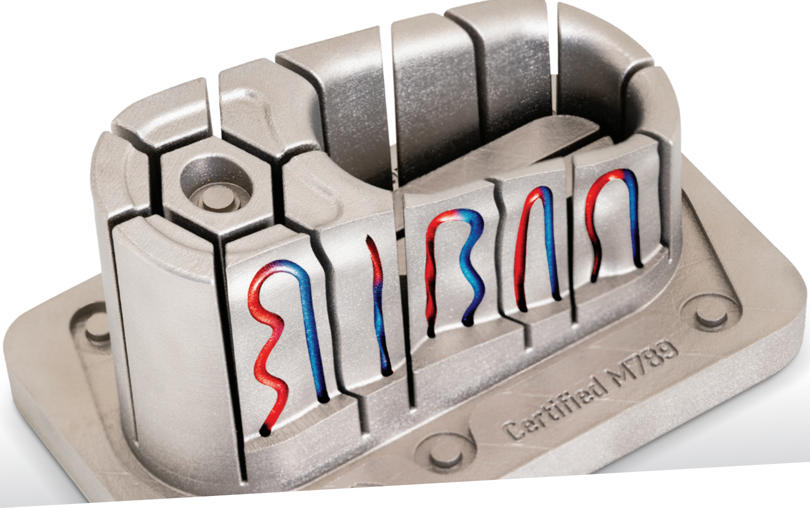
[1] Values based on literature
[2] Values based on minimum and maximum rangers

PN 10115A 11-03



Certified M789 (A)

Thoroughly developed and validated print parameter sets for BÖHLER's AMPO M789 on DMP Flex and Factory 350 as well as ProX® DMP 320 metal 3D printers. M789 is a cobalt-free steel and produces mold inserts, tools and parts with high hardness and excellent corrosion resistance.

The print parameter database license available for Certified M789 (A) in 3DXpert® all-in-one metal AM software for DMP Flex and Factory 350 as well as ProX DMP 320 metal 3d printers has been extensively developed to deliver high repeatable part quality and consistent part properties, tested and optimized by 3D Systems and GF Machining Solutions together with voestalpine BÖHLER Edelstahl and industry partners. Based on producing a multitude of test samples, geometries and endurance jobs at multiple facilities, the properties listed below provide high confidence to the user in terms of job-to-job and machine-to-machine repeatability.

Material Description

M789 combines high hardness with excellent corrosion resistance. M789 displays a broad process window on 3D Systems DMP Flex and Factory 350 and ProX DMP 320 metal printers leading to high density parts across the build plate. No preheating of the powder is required.

In the as printed and solution annealed condition, M789 reaches a hardness of around 30 HRc which allows for easy machinability. During the ageing heat treatment, intermetallic precipitates containing Ni, Ti, Al and Si are formed within the martensitic microstructure. This increases the hardness further up to 52 HRc. Unlike typical maraging steel alloys, cobalt is not needed to facilitate the ageing process. With regards to corrosion resistance M789 is comparable to and sometimes even exceeding that of PH 13-8 Mo, 17-4PH and 1.2083.

In tool and mold making M789 is used for its very high strength paired with corrosion resistance to produce mold and tool inserts with complex surfaces, fine features and conformal cooling channels for improved mold productivity. In the transportation industry typical steel components such as axel components and drive train parts can be quickly produced and reproduced in Metal AM using M789 material. For the oil and gas industry, this material enables the direct production of complex drill heads.

Mechanical Properties

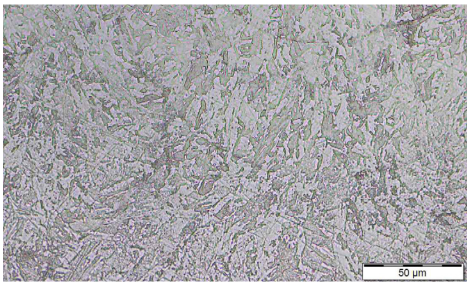
PROX DMP 320, DMP FLEX 350, DMP FACTORY 350[2]	TEST METHOD	METRIC	U.S.	METRIC	U.S.
		SA + A – LT30[4,5]		SA + A – LT60[4,6]	
Ultimate tensile strength (MPa | ksi)[1] Horizontal direction - XY Vertical direction - Z	ASTM E8[3]	1880±25 1830±25	270±4 265±4	1880±25 1840±20	270±4 265±3
Yield strength Rp0.2% (MPa | ksi)[1] Horizontal direction - XY Vertical direction - Z		1730±40 1690±40	250±6 245±6	1740±35 1710±20	250±5 245±3
Plastic elongation (%)[1] Horizontal direction - XY Vertical direction - Z		12±4 9±3		10±3 10±2	
Hardness, Rockwell C (HRC)[1]	ASTM E18	52±1		52±1	
Impact toughness[7] (J | ft.lb)	ASTM E23[8]	6±1.5	4±1	8±2	6±1.5

Printed Part Properties

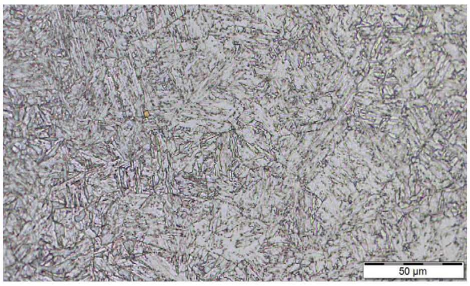
DENSITY[9]	TEST METHOD	METRIC	U.S.
Absolute theoretical[10] (g/cm³ | lb/in³)	Value from literature	7.715	0.2787
Relative density (%), layer thickness 30 µm[2, 11]	Optical method (pixel count)	≥ 99.8 Typical 99.9	
Relative density (%), layer thickness 60 µm[2, 11]		≥ 99.8 Typical 99.9	

1 Values based on average and 90% tolerance interval with 90% confidence. Tested on a minimum of 6 samples
2 Parts manufactured with standard parameters on DMP Flex and Factory 350, Config B using the 15-45 µm BÖHLER M789 AMPO powder
3 Tested according to ASTM E8 using round tensile test specimen type 4 with stress control (10 MPa/s) during the elastic and strain control (20%/min) during plastic regime
4 Solution annealing (SA) performed at 1000°C for 1 hour with subsequent rapid cooling (>75°C/min) to room temperature (<32°C), followed by ageing (A) at 500°C for 3 hours and air cooling
5 Layer thickness 30 µm (LT30)
6 Layer thickness 60 µm (LT60)
7 Values based on average and 2 times standard deviation. Tested on 6 samples.
8 Tested according to ASTM E23 using V-notch Charpy (Simple-Beam) impact test specimens, printed in the Z-direction
9 May deviate depending on specific part geometry
10 Values based on literature
11 Minimum values based on 95% tolerance interval with 95% confidence. Tested on a minimum of 15 samples using specific 3DS test coupons.

SURFACE ROUGHNESS R_a [2, 9, 11, 12, 13]	TEST METHOD	METRIC	U.S.
Vertical side surface (µm | µin) Layer thickness 30 µm	ISO 25178	Typically, around 8	Typically, around 315
Vertical side surface (µm | µin) Layer thickness 60 µm	ISO 25178	Typically, around 10	Typically, around 390



Microstructure as build



Microstructure after solution annealing and aging

Chemical Composition

ELEMENT	TYPICAL % OF WEIGHT
C	<0.02
Si	0.5
Cr	12.2
Ni	10.0
Co	/
Mo	1.0
Al	0.6
Ti	1.0
Fe	Balance

To confirm that Certified M789 (A) material is the best suited for your specific application, please contact the 3D Systems Application Innovation Group (AIG):
https://www.3dsystems.com/consulting/application-innovation-group

Once confirmed, Certified M789 (A) powder powder can be purchased directly from voestalpine BÖHLER Edelstahl GmbH:
https://www.bohler-edelstahl.com/en/products/m789-ampo/
where it is available under the name BÖHLER M789 AMPO 15-45 µm

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[12] Surface treatment performed with zirconia blasting medium at 2 bar
[13] Vertical side surface measurement along the building direction

LaserForm® 17-4PH (A)

LaserForm 17-4PH (A) is fine-tuned for use with ProX® DMP 320 metal printer producing industrial parts with good corrosion resistance, high mechanical strength combined with excellent ductility. Mechanical properties of LaserForm 17-4PH (A) can be varied upon different heat treatments.

LaserForm 17-4PH (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 metal 3D printers to deliver high part quality and consistent properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that holds the unique expertise of printing 500,000 challenging metal production parts in a broad choice of materials year over year. And for your 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable results.

Material Description

LaserForm 17-4PH (A) is known for its outstanding combination of excellent corrosion resistance and high strength with good toughness. These good mechanical properties and corrosion resistance are maintained at temperatures up to 316°C (600°F). With these characteristics, LaserForm 17-4PH (A) is ideal for surgical instruments (sterilizable), aerospace, chemical, petrochemical and general metalworking applications.

Classification

The chemical composition of LaserForm 17-4PH (A) corresponds to a stainless steel 17-4 PH alloy according to ASTM F899, A564, A693 and UNS S17400 specifications. and is indicated in the table below in wt%.

Mechanical Properties[1,2,3]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AS-BUILT	H900	H1150	AS-BUILT	H900	H1150
Ultimate strength (MPa | ksi)	ASTM E8M						
Horizontal direction[4] - XY Vertical direction[5] - Z		NA 1100 ± 90	1450 ± 10 1380 ± 20	1180 ± 10 1080 ± 50	NA 160 ± 13	210 ± 2 200 ± 3	170 ± 2 155 ± 8
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M						
Horizontal direction[4] - XY Vertical direction[5] - Z		NA 830 ± 110	1280 ± 30 1260 ± 100	1130 ± 20 1020 ± 170	NA 120 ± 16	185 ± 5 180 ± 15	165 ± 3 145 ± 25
Elongation at break (%)	ASTM E8M						
Horizontal direction[4] - XY Vertical direction[5] - Z		NA 19 ± 4	11 ± 1 12 ± 2	12 ± 1 16 ± 4	NA 19 ± 4	11 ± 1 12 ± 2	12 ± 1 16 ± 4
Hardness, Rockwell C	ASTM E18	32 ± 4	40 ± 2	35 ± 3	32 ± 4	40 ± 2	35 ± 3
Impact toughness[6] (J | ft-lb)	ASTM E23	71 ± 20	7 ± 2	11 ± 5	52 ± 15	5 ± 2	8 ± 4

Thermal Properties[7]

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu/(h.ft².°F))	at 100°C / 212 °F	18.3	10.6
CTE - Coefficient of thermal expansion (µm/ (m.°C) | µ inch/(inch. °F)	at 0°C	11.6	6.4
Melting range (°C | °F)		1400 - 1450	2550 - 2640

1 Parts manufactured with standard parameters on a ProX DMP 320, Config B
2 Values based on average and double standard deviation
3 H900 and H1150 indicate heat treatments targeting resp. H900 and H1150 conditions
4 Tested on ASTM E8M specimen with rectangular cross sections
5 Tested on ASTM E8M specimen with circular cross sections type 4
6 Tested with Charpy V-notch impact test specimens type A at room temperature
7 Values based on literature
NA = Not available

LaserForm® 17-4PH (A)

Magnetic Properties[1]

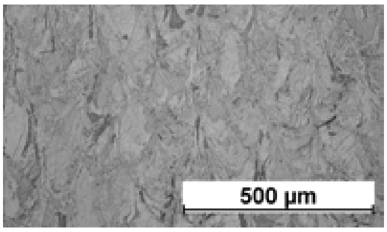
MEASUREMENT	METRIC	U.S.
Relative magnetic permeability	100	100

Physical Properties

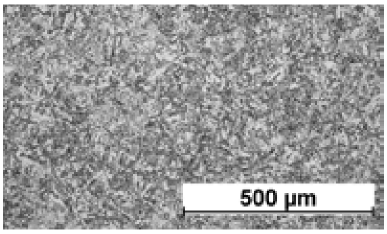
MEASUREMENT	METRIC	U.S.
Density		
Relative, based on pixel count[2] (%)	>99.9	>99.9
Absolute theoretical[1] (g/cm³ | lb/in³)	7.75	0.28

Surface Quality[2]

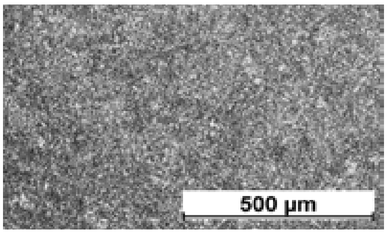
MEASUREMENT	METRIC		U.S.	
	AS BUILT	SAND BLASTED	AS BUILT	SAND BLASTED
Surface Roughness R_a				
Horizontal direction (XY) (µm | µin)	5 - 7	4 - 7	195 - 275	155 - 275
Vertical direction (Z) (µm | µin)	6 - 8	4 - 8	236 - 315	155 - 315



Microstructure as built



Microstructure after H900



Microstructure after H1150

Chemical Composition

ELEMENT	% OF WEIGHT
Fe	Bal.
C	<0.07
Mn	<1.00
P	<0.040
S	<0.030
Si	<1.00
Cr	15.00-17.50
Ni	3.00-5.00
Cu	3.00-5.00
Nb+Ta	0.15-0.45

[1] Values based on literature
[2] Parts manufactured with standard parameters on a ProX DMP 320, Config B

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LaserForm® 316L (A)

Extra low-carbon grade Stainless Steel which is fine-tuned for use with the ProX® DMP 320, producing parts with high corrosion resistance and sterilisability. LaserForm 316L (A) yields crack free and completely dense parts for all your applications.

LaserForm 316L (A) is formulated and fine-tuned specifically for 3D Systems DMP 320 metal 3D Printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on over 1000 test samples the below listed part quality data and mechanical properties give you high planning security. And for a 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

Material Description

Austenitic stainless steel type LaserForm 316L is the extra low carbon grade of 316. This steel is used as a general purpose material with excellent mechanical and corrosion properties at room temperature. Its chloride resistance makes this specific grade of stainless steel suitable for marine applications. 316L stainless steel is also the preferred material for use in hydrogen atmospheres or for hydrogen piping / cooling applications. Furthermore 316L retains good mechanical properties at sub-zero and even cryogenic temperatures and is suitable for structural components in low-temperature applications.

Classification

Parts built with LaserForm 316L alloy have a chemical composition that conforms to the compositional requirements of DIN X2CrNiMo 17-12-2 or Werkstoff Nr. 1.4404.

Mechanical Properties [1,3]

MEASUREMENT	CONDITION	METRIC		U.S.	
		AFTER STRESS RELIEF	FULL ANNEAL	AFTER STRESS RELIEF	FULL ANNEAL
Youngs modulus (GPa | ksi)					
Horizontal direction — XY		180 ± 15	180 ± 15	27600 ± 1500	27600 ± 1500
Ultimate Strength (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		660 ± 20 570 ± 30	610 ± 30 540 ± 30	96 ± 3 83 ± 5	89 ± 5 78 ± 5
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		530 ± 20 440 ± 20	370 ± 30 320 ± 20	77± 3 63 ± 3	54 ± 5 47 ± 3
Elongation at break (%)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		39 ± 5 49 ± 5	51 ± 5 66 ± 5	39 ± 5 49 ± 5	51 ± 5 66 ± 5
Reduction of area (%)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		65 ± 5 65 ± 5	61 ± 5 62 ± 5	65 ± 5 65 ± 5	61 ± 5 62 ± 5
Hardness, Rockwell B (HRB)	ASTM E18	90 ± 6	83 ± 4	90 ± 6	83 ± 4
Impact toughness[2] (J/cm^2 | lb.ft)	ASTM E23	215 ± 15	220 ± 15	158 ± 10	162 ± 10

Thermal Properties [4]

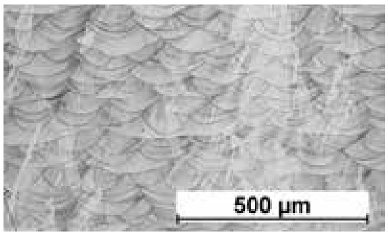
MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu/(h.ft².°F))	At 20 °C/ 68 °F	15	9
Coefficient of Thermal Expansion (μm/m-°C | μin/in-°F)	In the range of 20 - 600°C / 68-1112°F	19.0	10.6
Melting range (°C | °F)		1370-1400	2500-2550

[1] Parts manufactured with standard parameters on a ProX DMP 320, Config B
[2] Tested with charpy V-notch toughness test, DMV probe
[3] Values based on average and standard deviation
[4] Values based on literature

LaserForm® 316L (A)

Physical Properties [4]

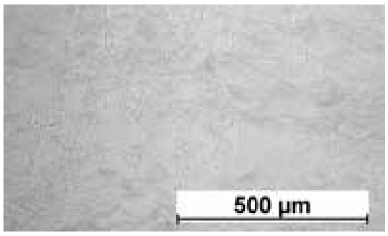
MEASUREMENT	METRIC		U.S.	
	AS BUILT AND AFTER STRESS RELIEF	AFTER FULL ANNEAL	AS BUILT AND AFTER STRESS RELIEF	AFTER FULL ANNEAL
Density — Absolute theoretical[5] (g/cm^3 ∣ lb/in^3)	8.0		0.286	



Microstructure after stress relief

Surface Quality

MEASUREMENT	METRIC	U.S.
	SANDBLASTED	SANDBLASTED
Surface Roughness Vertical direction (Z) (µm ∣ µin)	5-10	200-400



Microstructure after full anneal

Chemical Composition

ELEMENT	% OF WEIGHT
Fe	bal.
Cr	16.50-18.50
Ni	10.00-13.00
C	≤0.030
Mn	≤2.00
Mo	2.00-2.50
N	≤0.11
Si	≤1.00
P	≤0.045
S	≤0.030

[4] Values based on literature

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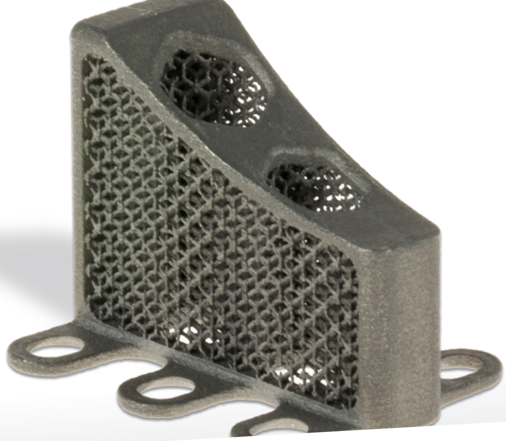


LaserForm® Ti Gr1 (A)

Commercially pure titanium fine-tuned for use with ProX® DMP 320 and DMP 350 printers; metal powder perfectly suited for medical applications and implants as LaserForm Ti Gr1 (A) is the purest Ti grade, known for its excellent biocompatibility and high ductility.

LaserForm Ti Gr1 (A) is formulated and fine-tuned specifically for 3D Systems ProX DMP 320 and DMP 350 metal 3D Printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on over 1000 test samples the below listed part quality data and mechanical properties give you high planning security. And for a 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

Material Description

Commercially pure titanium is perfectly suited for medical applications because of its low stiffness and excellent biocompatibility. Grade 1 titanium is the most ductile medical titanium grade, rendering it ideal for implants, such as bone plates and other fixation devices, which need to be molded manually during surgery to fit the patient. Similar to other titanium grades, Grade 1 titanium has excellent corrosion resistance, including chloride and cavitation corrosion resistance.

Classification

Parts built with LaserForm Ti Gr1 Alloy have a chemical composition that complies with ASTM F3302, ASTM F67, ASTM B265, ASTM B348 (grade 1), ISO 5832-2, ISO 13782 and Werkstoff Nr. 3.7025 standards.

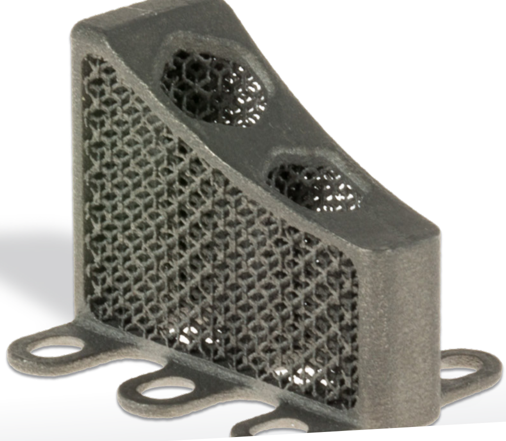
Mechanical Properties [1,2,3]

MEASUREMENT	CONDITION	METRIC		U.S.	
		AFTER STRESS RELIEF 1	AFTER HIP	AFTER STRESS RELIEF 1	AFTER HIP
Youngs modulus (GPa | ksi)	ASTM E8M	105-120	105-120	15000-17500	15000-17500
Ultimate Strength (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		500 ± 30 500 ± 30	460 ± 30 460 ± 30	73 ± 4 73 ± 4	67 ± 4 67 ± 4
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		380 ± 30 380 ± 30	340 ± 20 340 ± 20	55 ± 4 55 ± 4	49 ± 3 49 ± 3
Elongation at break (%)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		29 ± 5 30 ± 5	36 ± 5 36 ± 5	29 ± 5 30 ± 5	36 ± 5 36 ± 5
Reduction of area (%)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		53 ± 5 53 ± 6	58 ± 10 60 ± 10	53 ± 5 53 ± 6	58 ± 10 60 ± 10
Hardness, Rockwell B (HRB)	ASTM E18	85 ± 5	80 ± 5	85 ± 5	80 ± 5

Thermal Properties [4]

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | btu.in/(h.ft.°F))	At 50 °C / 120 °F	16	9.25
Coefficient of Thermal Expansion (µm/m.°C | µin/(in.°F))	In the range of 20 to 600 °C	7.17	3.98
Melting point (°C | °F)		1668	3070

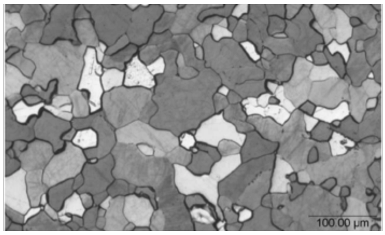
[1] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[2] Values based on average and double standard deviation
[3] Surface condition of test samples: Horizontal samples (XY) tested in machined surface condition only, vertical (Z) tested in as-printed and machined surface condition
[4] Values based on literature



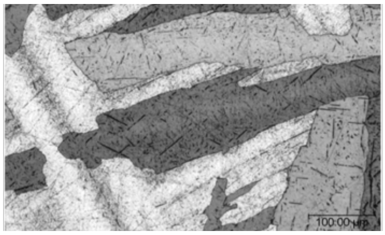
LaserForm® Ti Gr1 (A)

Physical Properties

MEASUREMENT	CONDITION	METRIC		U.S.	
		AS BUILT AND AFTER STRESS RELIEF	AFTER HIP	AS BUILT AND AFTER STRESS RELIEF	AFTER HIP
Density — Relative, based on pixelcount (%)[1,2]	Optical method	> 99.6 typical 99.8		> 99.6 typical 99.8	
Density — Absolute theoretical[3] (g/cm^3 | lb/in^3)		4.51		0.163	



Microstructure after stress relief 1


Microstructure after HIP

Surface Quality[4,5]

MEASUREMENT	CONDITION	METRIC	U.S.
		SANDBLASTED	SANDBLASTED
Surface Roughness Ra Top surface[6] (µm | µin) Vertical side surface[7] (µm | µin)	ISO 25178	 4-8 4-8	 160-310 160-310

Chemical Composition

Ti	Bal.
N	≤0.03
C	≤0.08
H	≤0.015
Fe	≤0.20
O	≤0.18
Residuals (each)	≤0.1
Residuals (total)	≤0.4

[1] Minimum value based on 95% confidence interval Tested on typical density test shapes
[2] May deviate depending on specific part geometry
[3] Values based on literature
[4] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[5] Sand blasting performed with zirconia blasting medium at 2 bar
[6] Top surface measurements along the 2 perpendicular axes of the reference square geometry
[7] Vertical side surface measurement along the building direction

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LaserForm® Ti Gr5 (A)

Titanium alloy fine-tuned for use with ProX® DMP 320 and DMP 350 metal printers. This alloy is used in technical and medical applications because of its high strength, low density and excellent biocompatibility. The essential difference between Ti6Al4V ELI (grade 23) and Ti6Al4V (grade 5) is the allowed higher oxygen and iron content in Ti Gr5. This confers improved strength.

LaserForm Ti Gr5 (A) is formulated and fine-tuned specifically for 3D Systems ProX DMP 320 and DMP 350 metal 3D printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on over 1000 test samples the below listed part quality data and mechanical properties give you high planning security. And for a 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

Material Description

This titanium alloy is commonly used for lightweight and high-strength components such as aerospace and motor sports applications. Because of its excellent biocompatibility Ti Gr5 (A) is also very well suited for medical implants, tools and devices and dental prostheses. The essential difference between Ti6Al4V ELI (grade 23) and Ti6Al4V (grade 5) is the allowed higher oxygen and iron content in Ti Gr5. This confers improved strength while slightly reducing ductility.

These benefits make LaserForm Ti Gr5 (A) the ideal material for light-weight, high-strength components as required for a broad scope of parts in aerospace, sports and marine products. Its high strength and biocompatibility make it the material of choice for medical tools and devices.

Classification

Parts built with LaserForm Ti Gr5 Alloy have a chemical composition that meets the requirements of ASTM B265, B348 (grade 5), F2924, F3302, ISO 5832-3 and Werkstoff Nr. 3.7165.

Mechanical Properties[1,2,3]

MEASUREMENT	CONDITION	METRIC		U.S.	
		AFTER STRESS RELIEF 1	AFTER HIP	AFTER STRESS RELIEF 1	AFTER HIP
Youngs modulus (GPa | ksi)[4]	ASTM E8M	105-120	105-120	15000-17500	15000-17500
Ultimate strength (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		1180 ± 30 1160 ± 50	1000 ± 30 1020 ± 50	171 ± 5 168 ± 8	145 ± 4 148 ± 8
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		1090 ± 30 1080 ± 50	910 ± 30 930 ± 30	158 ± 5 157 ± 8	132 ± 5 134 ± 5
Elongation at break (%)	ASTM E8M				
Horizontal direction — XY Vertical direction — Z		9 ± 2 9 ± 2	15 ± 3 14 ± 3	9 ± 2 9 ± 2	15 ± 3 14 ± 3
Hardness, Rockwell C (HRC)	ASTM E18	40 ± 2	36 ± 2	40 ± 2	36 ± 2

Thermal Properties[4]

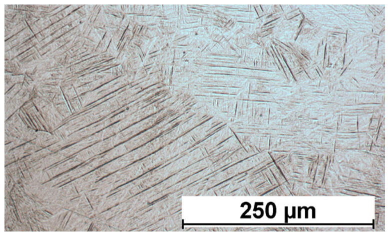
MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity (W/(m.K) | Btu in/(h.ft.°F)	At 50 °C/ 120 °F	6.7	3.9
Coefficient of thermal expansion (µm/m-°C / µin/(in.°F)	In the range of 20 to 100 °C	8.6	4.8
Melting range (°C | °F)		1692-1698	3046-3056

[1] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[2] Values based on average and double standard deviation
[3] Surface condition of test samples: Horizontal samples (XY) tested in machined surface condition only, vertical (Z) tested in as-printed and machined surface condition
[4] Values based on literature

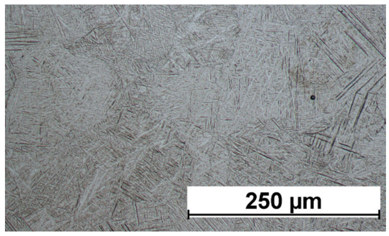
LaserForm® Ti Gr5 (A)

Physical Properties

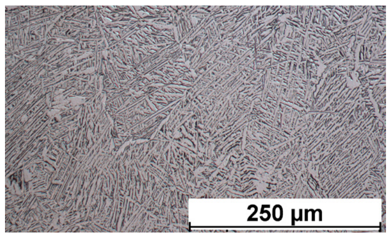
MEASUREMENT	CONDITION	METRIC		U.S.	
		AS BUILT AND AFTER STRESS RELIEF	AFTER HIP	AS BUILT AND AFTER STRESS	AFTER HIP
Density — Relative, based on pixelcount[1,2] (%)	Optical method	> 99.6 typical 99.8		> 99.6 typical 99.8	
Density — Absolute theoretical[3] (g/cm³ | lb/in³)		4.42		0.159	



Microstructure as built



Microstructure after stress relief



Microstructure after HIP

Surface Quality

MEASUREMENT	CONDITION	SANDBLASTED METRIC	SANDBLASTED U.S.
Surface Roughness R_a[4,5]	ISO 25178		
Layer thickness 30µm and 60µm Top surface[6] (µm | µin) Vertical side surface[7] (µm | µin)		typical 3-8 typical 5-7	typical 120-320 typical 200-280
Layer thickness 90µm Top surface[6] (µm | µin) Vertical side surface[7] (µm | µin)		typical 13-19 typical 6-12	typical 500-750 typical 240-480

Chemical Composition

Ti	bal.
N	≤0.05
c	≤0.08
H	≤0.015
Fe	≤0.30
O	≤0.20
Al	5.50-6.75
V	3.50-4.50
Y	≤0.005
residuals each	≤0.10
residuals total	≤0.40

[1] Minimum value based on 95% confidence interval. Tested on typical density test coupons
[2] May deviate depending on specific part geometry
[3] Values based on literature
[4] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[5] Sand blasting performed with zirconia blasting medium at 5 bar
[6] Top surface measurements along the 2 perpendicular axes of the reference square geometry
[7] Vertical side surface measurement along the building direction

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PN 10107C 07-20

LaserForm® Ti Gr23 (A)

Titanium alloy fine-tuned for use with ProX® DMP 320 and DMP 350 metal printers. Metal powder producing technical and medical parts with a combination of high specific strength and excellent biocompatibility. LaserForm Ti Gr23 (A) is ELI (Extra Low Interstitial) grade with lower iron, carbon, and oxygen content and is known for higher purity than LaserForm Ti Gr5 (A) resulting in improved ductility and fracture toughness.

LaserForm Ti Gr23 (A) is formulated and fine-tuned specifically for 3D Systems' ProX DMP 320 and DMP 350 metal 3D printers to deliver highest part quality and best part properties. The print parameter database that 3D Systems provides together with the material has been extensively developed, tested and optimized in 3D Systems' part production facilities that hold the unique expertise of printing 500,000 challenging production parts year over year. Based on over 1000 test samples the below listed part quality data and mechanical properties give you high planning security. And for a 24/7 production 3D Systems' thorough Supplier Quality Management System guarantees consistent, monitored material quality for reliable process results.

Material Description

This titanium alloy is commonly used in aerospace and medical applications because of its high strength, low weight and excellent biocompatibility. The essential difference between Ti6Al4V ELI (grade 23) and Ti6Al4V (grade 5) is the reduction of oxygen content to 0.13% (maximum) in grade 23. This confers improved ductility and fracture toughness, with some reduction in strength.

These benefits make LaserForm Ti Gr23 (A) the most used medical and aerospace titanium grade. It can be used in biomedical applications such as surgical implants, orthodontic appliances or in-joint replacements due to its biocompatibility, good fatigue strength and low modulus.

Classification

Parts built with LaserForm Ti Gr23 (A) Alloy have a chemical composition that complies with ASTM F3001, ASTM F3302, ISO 5832-3, ASTM F136 and ASTM B348 standards.

Mechanical Properties [1,2,3]

MEASUREMENT	CONDITION	METRIC			U.S.		
		AFTER STRESS RELIEF 1	AFTER STRESS RELIEF 2	AFTER HIP	AFTER STRESS RELIEF 1	AFTER STRESS RELIEF 2	AFTER HIP
Youngs modulus (GPa | ksi) Horizontal direction — XY Vertical direction — Z	ASTM E1876	119 ± 3 120 ± 1	119 ± 3 120 ± 1	122 ± 2 NA	17300 ± 730 17400 ± 300	17300 ± 730 17400 ± 300	17700 ± 300 NA
Ultimate Strength (MPa | ksi)	ASTM E8M						
Horizontal direction — XY Vertical direction — Z		1160 ± 20 1170 ± 50	1070 ± 30 1070 ± 30	980 ± 50 980 ± 70	168 ± 3 170 ± 7	155 ± 4 155 ± 4	142 ± 7 142 ± 10
Yield strength Rp0.2% (MPa | ksi)	ASTM E8M						
Horizontal direction — XY Vertical direction — Z		1060 ± 30 1100 ± 60	970 ± 30 1000 ± 60	890 ± 50 890 ± 90	154 ± 4 160 ± 9	141 ± 4 145 ± 9	129 ± 7 129 ± 13
Plastic elongation (%)	ASTM E8M						
Horizontal direction — XY Vertical direction — Z		10 ± 2 10 ± 3	13 ± 2 13 ± 3	14 ± 2 14 ± 2	10 ± 2 10 ± 3	13 ± 2 13 ± 3	14 ± 2 14 ± 2
Reduction of area (%)	ASTM E8M						
Horizontal direction — XY Vertical direction — Z		35 ± 10 40 ± 10	45 ± 10 45 ± 15	45 ± 5 45 ± 5	35 ± 10 40 ± 10	45 ± 10 45 ± 15	45 ± 5 45 ± 5
Hardness, Rockwell C	ASTM E18	37 ± 2	37 ± 4	34 ± 1	37 ± 2	37 ± 4	34 ± 1
Fatigue[4,5] (MPa | ksi)	ASTM E466	NA	typical 637	NA	NA	typical 92	NA

Thermal Properties

MEASUREMENT	CONDITION	METRIC	U.S.
Thermal conductivity[6] (W/(m.K) | Btu in/(h.ft.°F))	At 20 °C/ 68 °F	4.2 ± 0.1	29 ± 1
Coefficient of thermal expansion[7] (μm/(m.°C) | μ inch/(inch.°F))	In the range of 20 to 600 °C	8.6	4.8
Melting range[7] (°C | °F)		1692-1698	3046-3056

[1] Parts manufactured with standard parameters on a ProX DMP 320, Config A
[2] Values based on average and double standard deviation
[3] Surface condition of test samples: Horizontal samples (XY) tested in machined surface condition only, vertical (Z) tested in as-printed and machined surface condition
[4] Force-controlled axial fatigue testing (R=0.1). Endurance limit at 5×10^6 cycles Fatigue samples with machined surface
[5] Results are based on limited sample size, not statistically representative
[6] Thermal conductivity values are calculated by the Wiedemann-Franz law using the respective electrical resistivity values
[7] Values based on literature

Electrical Properties

MEASUREMENT	CONDITION	METRIC	U.S.
Electrical conductivity[1,2] (10^5 S/m)	ASTM B193 at 20°C / 68°F	5.9 ± 0.1	5.9 ± 0.1

Physical Properties

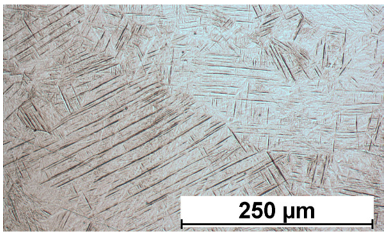
MEASUREMENT	CONDITION	METRIC	U.S.
		AS BUILT	AS BUILT
Density — Relative, based on pixel count[3,4] (%)	Optical method	> 99.6 typical 99.8	> 99.6 typical 99.8
Density — Absolute theoretical[5] (g/cm^3 | lb/in^3)		4.42	0.16

Surface Quality[6,7,8]

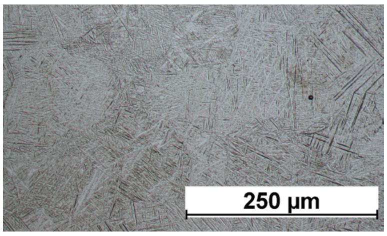
MEASUREMENT	CONDITION	METRIC	U.S.
		SANDBLASTED	SANDBLASTED
Surface Roughness R_a	ISO 25178		
Layer thickness 30µm and 60µm Top surface[9] (µm | µin) Vertical side surface[10] (µm | µin)		typical 3-8 typical 5-7	typical 120-320 typical 200-280
Layer thickness 90µm Top surface[9] (µm | µin) Vertical side surface[10] (µm | µin)		typical 13-19 typical 6-12	typical 500-750 typical 240-480

Chemical Composition

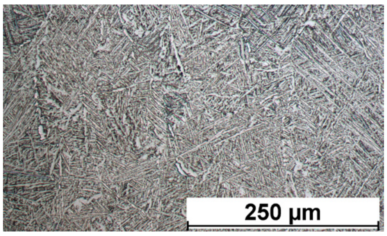
ELEMENT	% OF WEIGHT
Ti	Bal.
N	≤0.03
C	≤0.08
H	≤0.012
Fe	≤0.25
O	≤0.13
Al	5.5 - 6.5
V	3.5 - 4.5
Y	≤0.005
Residuals (each)	≤0.1
Residuals (total)	≤0.4



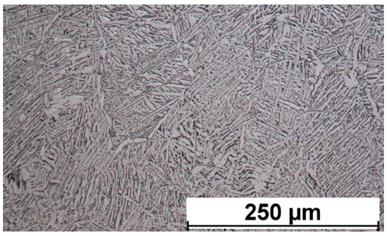
Microstructure as built



Microstructure after stress relief 1



Microstructure after stress relief 2



Microstructure after HIP

3D SYSTEMS

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1 Electrical resistivity measurements are based on four point contact method according to ASTM B193
2 Results are based on limited sample size, not statistically representative
3 Minimum value based on 95% confidence interval. Tested on typical density test shapes
4 May deviate depending on specific part geometry
5 Values based on literature
6 Parts manufactured with standard parameters on a ProX DMP 320, Config A
7 Values based on average and double standard deviation
8 Sand blasting performed with zirconia blasting medium at 5 bar
9 Top surface measurements along the 2 perpendicular axes of the reference square geometry
10 Vertical side surface measurement along the building direction

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