Material Data Sheet

SLM SOLUTIONS

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

General

Ti6Al4V is the most frequently used titanium alloy worldwide and, due to its density of 4.43 g/cm³ [2], ranks among the lightweight alloys. High strength at low density and also excellent corrosion resistance allow a broad range of applications of titanium parts. Titanium and its alloys have been used successfully in the automotive and aerospace industry since the 1950s. Furthermore, titanium stands out through thermal expansion coefficient. Due to titanium's biocompatibility, it can also be used in medical technology. Thus, implants for dentistry or individual hip implants can be manufactured of Ti6Al4V ELI Grade 23 (extra low interstitials, small amount of interstitial iron and oxygen atoms).

Material Structure

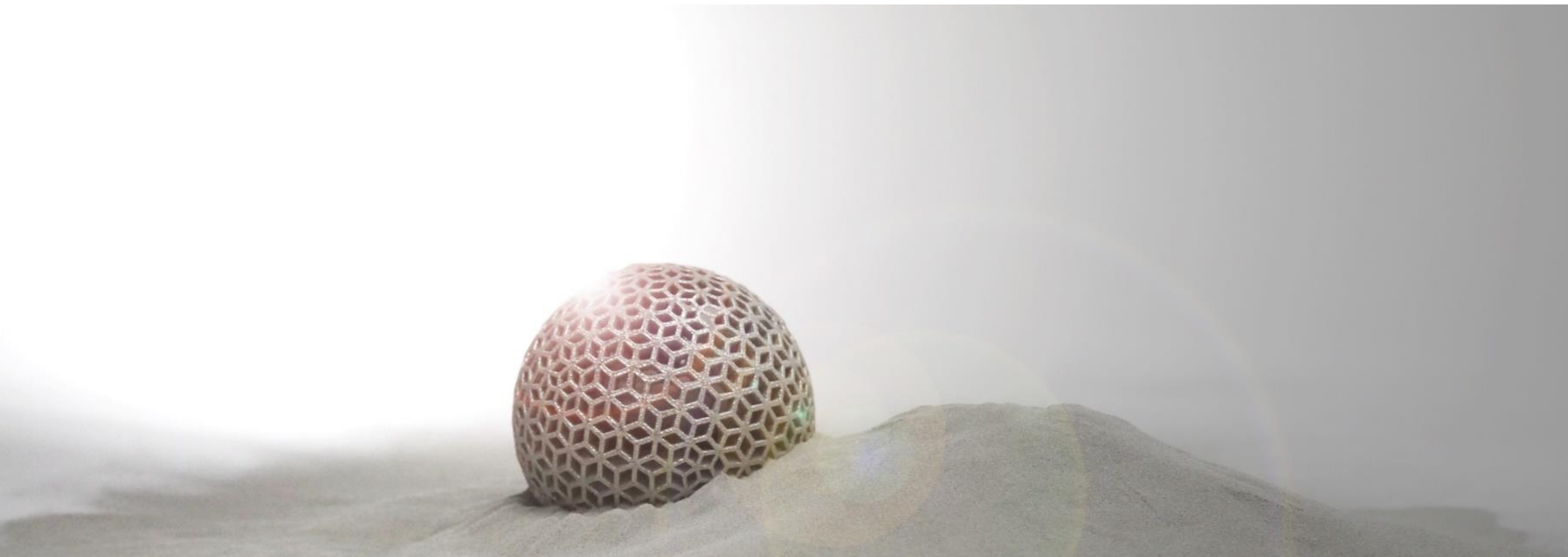
SLM®-processed components made of Ti6Al4V show a homogenous, nearly non-porous structure, with mechanical characteristic values in the range of material specifications. Through subsequent processing such as heat-treatments (e.g. stress-relief annealing, recrystallization annealing, precipitation hardening) or hot isostatic pressing (HIP), the components' properties can be adapted to meet specific requirements. For Ti6Al4V-components produced with SLM®, a heat treatment at 940 °C for 4 h under inert argon atmosphere is recommended. Alternatively, HIP can be performed at 920 °C and 1000 bar for 2 h.

Chemical composition [Mass fraction in %][9]

Ti	Al	V	C	O	N	Fe	H	Other each	Other each	Cu	Mn
Balance	5.50 – 6.50	3.50 – 4.50	0.08	0.13	0.03	0.25	0.0125	0.10	0.40	/	/

Powder properties

Particle size[9]	20 – 63 µm	Particle shape[10]	Spherical
Mass density[5]	4.43 g/cm³	Thermal conductivity	7.1 W/(m·K)



Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

30 µm / 400 W[3]				As-built		Heat-treated [15]		HIP[16]	
Build-up rate [8]	[cm³/h]			18.14 cm³/h					
Component density[7]	[%]			> 99.5 %					
Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1281	7	956	5	962	2
			V	1289	17	960	4	1002	7
Offset yield strength	$R_{p0,2}$	[MPa]	H	1076	30	851	12	821	21
			V	1170	26	887	12	935	12
Elongation at break	A	[%]	H	8	1	13	1	14	1
			V	9	1	14	1	14	1
Reduction of area	Z	[%]	H	19	3	47	3	42	3
			V	29	7	50	2	41	4
Young's modulus	E	[GPa]	H	113	1	120	5	124	11
			V	117	2	126	1	124	6
Hardness test[12]				M	SD	M	SD	M	SD
Vickers hardness	HV10			362	11	307	4	316	10
Tenacity test[13]				M	SD	M	SD	M	SD
Impact energy	KV	[J]		11	1	29	3	23	3

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	6	1
Mean roughness depth	Rz	[µm]	76	6	39	3

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60 µm / 400 W[4]			As-built		Heat-treated [15]		HIP[16]	

Build-up rate [8]	[cm³/h]	28.51 cm³/h
Component density[7]	[%]	> 99.5 %

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1351	17	987	4	1021	3
			V	1330	12	991	3	1027	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1189	49	894	5	885	11
			V	1196	26	905	11	953	7
Elongation at break	A	[%]	H	7	1	12	1	15	1
			V	9	1	15	1	15	1
Reduction of area	Z	[%]	H	13	2	45	5	39	2
			V	26	3	49	1	38	9
Young's modulus	E	[GPa]	H	113	7	112	5	127	6
			V	120	4	130	8	125	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Tenacity test[13]			M	SD	M	SD	M	SD
Impact energy	KV	[J]	14	1	27	2	21	2

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	6	1
Mean roughness depth	Rz	[µm]	71	6	36	3

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60 µm / 700 W[5]				As-built		Heat-treated [15]		HIP[16]	
Build-up rate [8]	[cm³/h]			38.88 cm³/h					
Component density[7]	[%]			> 99.5 %					

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1251	11	963	6	1104	5
			V	1260	12	964	4	998	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1098	68	870	3	860	15
			V	1129	23	883	8	926	6
Elongation at break	A	[%]	H	8	1	16	1	15	2
			V	8	2	14	1	15	1
Reduction of area	Z	[%]	H	17	3	50	1	34	3
			V	22	11	46	3	38	2
Young's modulus	E	[GPa]	H	108	8	113	5	121	17
			V	115	4	124	3	125	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	11	1	5	1
Mean roughness depth	Rz	[µm]	70	6	34	4

Ti-Alloy Ti6Al4V ELI (Grade 23) / 3.7165 / B348 / F136[1]

90 µm / 700 W[6]		As-built	Heat-treated [15]	HIP[16]
Build-up rate [8]	[cm³/h]	53.46 cm³/h		
Component density[7]	[%]	> 99.5 %		

Tensile test[11]				M	SD	M	SD	M	SD
Tensile strength	R_m	[MPa]	H	1271	11	966	7	981	2
			V	1215	30	952	20	999	3
Offset yield strength	$R_{p0,2}$	[MPa]	H	1108	31	872	7	857	22
			V	1108	23	868	16	924	2
Elongation at break	A	[%]	H	7	1	15	1	15	1
			V	10	2	14	1	15	1
Reduction of area	Z	[%]	H	16	5	47	1	37	4
			V	24	9	50	2	39	3
Young's modulus	E	[GPa]	H	111	8	114	4	128	15
			V	117	4	123	2	124	3

Hardness test[12]		M	SD	M	SD	M	SD
Vickers hardness	HV10	-	-	-	-	-	-

Roughness measurement[14]			As-built		Corundum blasted	
			M	SD	M	SD
Roughness average	Ra	[µm]	12	1	7	1
Mean roughness depth	Rz	[µm]	70	4	43	8

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The properties and mechanical characteristics apply to powder that is tested and sold by SLM Solutions, and that has been processed on SLM Solutions machines using the original SLM Solutions parameters in compliance with the applicable operating instructions (including installation conditions and maintenance). The part properties are determined based on specified procedures. More details about the procedures used by SLM Solutions are available upon request.

The specifications correspond to the most recent knowledge and experience available to us at the time of publication and do not form a sufficient basis for component design on their own. Certain properties of products or parts or the suitability of products or parts for specific applications are not guaranteed. The manufacturer of the products or parts is responsible for the qualified verification of the properties and their suitability for specific applications. The manufacturer of the products or parts is responsible for protecting any third-party proprietary rights as well as existing laws and regulations.

[1] Ti6Al4V ELI (Grade 23) according to DIN 17851:1990, ASTM B348, F136.

[2] Material density varies within the range of possible chemical composition variations.

[3] Material data file: Ti6Al4V_SLM_MBP3.0_30_CE2_400W_Stripes_V1.4

[4] Material data file: Ti6Al4V_SLM_MBP3.0_60_CE2_400W_Stripes_V1.2

[5] Material data file: Ti6Al4V_SLM_MBP3.0_60_CE2_700W_Stripes_V1.0

[6] Material data file: Ti6Al4V_SLM_MBP3.0_90_CE2_700W_Stripes_V1.0.

[7] Optical density determination by light microscopy.

[8] Theoretical build-up rate for each laser = layer thickness x scan speed x track distance.

[9] With respect to powder material.

[10] According to DIN EN ISO 3252:2001.

[11] Tensile test according to DIN EN ISO 6892-1:2017 B (DIN 50125:2016 – D6x30); orientation: 0°, 90°.

[12] Hardness testing according to DIN EN ISO 6507-1:2018.

[13] Charpy pendulum impact test according to DIN EN ISO 148-1:2017-05.

[14] Roughness measurement according to DIN EN ISO 4288:1998; λc = 2,5 mm.

[15] Specimens were heated up in vacuum atmosphere at a rate of < 450 °C/h up to 910 °C, then with < 300 °C/h up to 940 °C. Subsequent holding at 940 ± 10 °C for 4 h -0/+30 min. Cooling down in vacuum at a rate of 40 ± 10 °C/h to 760 ± 15 °C, then in argon with 560 ± 100 °C/h to ≤ 480 °C, followed by gas fan quenching at any rate to ≤ 50 °C.

[16] Specimens were HIPed with 920 ± 10 °C and 1000 bar for 2 h.

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