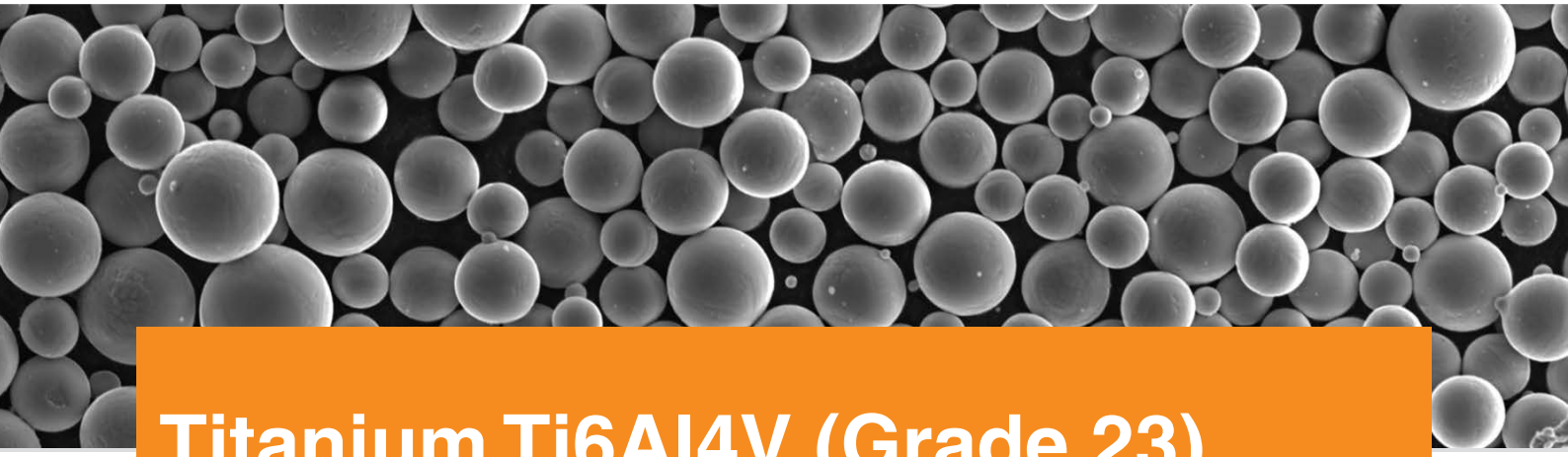
RENISHAW
apply innovation™



Titanium Ti6Al4V (Grade 23)

Parameter set options

Layer thickness	Optimised for	Laser mode	Page number
30 µm	Single laser per part	Continuous wave	4
60 µm	Single laser per part	Continuous wave	5
60 µm	Multiple lasers per part	Continuous wave	6
90 µm	Single laser per part	Continuous wave	7

To download the latest material files, visit **www.renishaw.com/softwarelicensing.**

Material description

Ti6Al4V alloy comprises of titanium alloyed with aluminium and vanadium, along with other minor elements. Ti6Al4V grade 23 is otherwise referred to as Extra Low Interstitial (ELI) with regards to the interstitial impurities oxygen, carbon, and nitrogen. It is a higher purity version of Ti6Al4V grade 5, where the reduced interstitial elements in grade 23 lead to an increase in both ductility and fracture toughness.

Ti6Al4V has excellent specific strength (strength to weight ratio), which makes it an ideal choice where weight saving load structures are required. It has good corrosion resistance and biocompatibility, so can be used for a range of surgical and dental applications.

Material properties

- High specific strength
- High corrosion resistance
- Excellent biocompatibility
- Good osseointegration
- Low thermal expansion
- Low thermal conductivity

Applications

- Medical and dental
- Aerospace and defence
- Motorsport
- Jewellery and art
- Maritime applications
- High-end sports equipment

Disclaimer

The mechanical property data featured in this document were obtained from tests performed in Renishaw's laboratories and they indicate the mechanical properties that can be achieved. The data is not intended as a guaranteed minimum specification.

Glossary of terms

Term	Definition
Scan strategy	Determines the path the laser will take to melt the cross-sectional area of the parts featured in each layer of the build process.
Meander	A scan strategy that takes the form of a straight-line vector path that bounces back and forth from each side of the part border. Meander strategy is quick and ideal for parts with a small XY cross section.
Stripe	A scan strategy where the area within the part border is split into strips and a meander technique is used within each strip. Stripe is ideal for parts with a large XY cross section.

Typical wrought material properties

Material property	Wrought material value
Density	4.4 g/cm^3
Thermal conductivity	6 W/mK to 8 W/mK
Melting temperature	1 635 °C to 1 665 °C
Coefficient of thermal expansion [1]	8×10^{-6} K^{-1} to 9×10^{-6} K^{-1}

[1] In the range of 20 °C to 100 °C.

Recommended composition of powder

Element	Mass (%)
Titanium	Balance
Aluminium	5.50 to 6.50
Vanadium	3.50 to 4.50
Iron	≤ 0.25
Oxygen	≤ 0.13
Carbon	≤ 0.08
Nitrogen	≤ 0.03
Hydrogen	≤ 0.01
Yttrium	≤ 0.01
Residual elements	≤ 0.10 each, ≤ 0.40 total

Recommended powder size distribution: 15 µm to 45 µm.

The values shown in this table are for ASTM standard composition powder. Renishaw powders are supplied to a tighter specification to minimise batch-to-batch variations. Results quoted in this data sheet are from samples produced using Renishaw's tighter-specification powder. To purchase powder from Renishaw, visit the online store at **www.renishaw.com/shop**.

Please contact Renishaw for further information about specifications or if you require support in qualifying non-Renishaw powders.

Parameter set summary

Layer thickness	Optimised for	Laser mode	Gas flow rate	Build rate	
30 µm	Single laser per part	Continuous wave	190 m^3/h	One laser: 10.26 cm^3/h	Four lasers: 41.04 cm^3/h

Material files: Ti6Al4V_500QS_B30_M_01_A (meander scan strategy)
Ti6Al4V_500QS_B30_S_01_A (stripe scan strategy)

Properties of additively manufactured components

NOTE: This parameter set is optimised for bulk density. The material properties in this table are indicative only. Further modification of the material file may be required to suit your application.

		Annealed [1]
Bulk density [2]		≥ 99.8%
Ultimate tensile strength [3]	Horizontal (XY)	1054 MPa ±3 MPa
	Vertical (Z)	1018 MPa ±8 MPa
Yield strength [3]	Horizontal (XY)	990 MPa ±12 MPa
	Vertical (Z)	908 MPa ±18 MPa
Elongation after fracture [3]	Horizontal (XY)	17% ±1%
	Vertical (Z)	20% ±1%
Modulus of elasticity [3]	Horizontal (XY)	123 GPa ±10 GPa
	Vertical (Z)	124 GPa ±7 GPa
Hardness (Vickers) [4]	Horizontal (XY)	359 HV0.5 ±9 HV0.5
	Vertical (Z)	364 HV0.5 ±7 HV0.5
Surface roughness (Ra) [5]	Vertical (Z) (Median Ra)	12 µm ±1 µm
	Vertical (Z) (Median Ra)	79 µm ±7 µm

Mechanical test samples were created using four lasers, one laser per sample and with no downstream processing. Meander scan strategy was used for vertical samples. Stripe scan strategy was used for horizontal samples

1 Annealing method used for testing: Under vacuum, heat at 13 °C/min to 800 °C ±10 °C, then hold temperature for 4 hours. Furnace cool to room temperature.

2 Measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

3 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on 16 samples for vertical, 12 for horizontal.

4 Tested to ASTM E384-11 after polishing.

5 Tested on as-built vertical surfaces using laser interferometry. Tested to JIS B 0601-2001 (ISO 4287:1997).

Parameter set summary

Layer thickness	Optimised for	Laser mode	Gas flow rate	Build rate	
60 µm	Single laser per part	Continuous wave	190 m^3/h	One laser: 30.8 cm^3/h	Four lasers: 123 cm^3/h

Material files: Ti6Al4V_500QS_B60_M_01_A (meander scan strategy)
Ti6Al4V_500QS_B60_S_01_A (stripe scan strategy)

Properties of additively manufactured components

NOTE: This parameter set is optimised for bulk density. The material properties in this table are indicative only. Further modification of the material file may be required to suit your application.

		Annealed [1]
Bulk density [2]		≥ 99.8%
Ultimate tensile strength [3]	Horizontal (XY)	1033 MPa ±3 MPa
	Vertical (Z) - Meander	1065 MPa ±5 MPa
	Vertical (Z) - Stripe	1063 MPa ±4 MPa
Yield strength [3]	Horizontal (XY)	938 MPa ±10 MPa
	Vertical (Z) - Meander	956 MPa ±9 MPa
	Vertical (Z) - Stripe	994 MPa ±17 MPa
Elongation after fracture [3]	Horizontal (XY)	16% ±1%
	Vertical (Z) - Meander	18% ±1%
	Vertical (Z) - Stripe	22% ±1%
Modulus of elasticity [3]	Horizontal (XY)	115 GPa ±2 GPa
	Vertical (Z) - Meander	115 GPa ±3 GPa
	Vertical (Z) - Stripe	123 GPa ±5 GPa
Hardness (Vickers) [4]	Horizontal (XY)	353 HV0.5 ±5 HV0.5
	Vertical (Z)	349 HV0.5 ±6 HV0.5
Surface roughness (Ra) [5]	Vertical (Z) (Median Ra)	11 µm ±1 µm
	Vertical (Z) (Median Ra)	70 µm ±8 µm

Mechanical test samples were created using four lasers, one laser per sample and with no downstream processing. The scan strategy used for vertical samples is indicated in the table above. Stripe scan strategy was used for horizontal samples.

1 Annealing method used for testing: Under vacuum, heat at 13 °C/min to 800 °C ±10 °C, then hold temperature for 4 hours. Furnace cool to room temperature.

2 Measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

3 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on 16 samples for vertical, 12 for horizontal.

4 Tested to ASTM E384-11 after polishing.

5 Tested on as-built vertical surfaces using laser interferometry. Tested to JIS B 0601-2001 (ISO 4287:1997).

Parameter set summary

Layer thickness	Optimised for	Laser mode	Gas flow rate	Build rate
60 µm	Multiple lasers per part	Continuous wave	190 m^3/h	Four lasers: 123 cm^3/h

Material files: Ti6Al4V_500QS_C60_S_01_A (stripe scan strategy)

Properties of additively manufactured components

NOTE: This parameter set is optimised for bulk density. The material properties in this table are indicative only. Further modification of the material file may be required to suit your application.

		Annealed [1]
Bulk density [2]		≥ 99.8%
Ultimate tensile strength [3]	Horizontal (XY)	1031 MPa ±5 MPa
	Vertical (Z)	1057 MPa ±4 MPa
Yield strength [3]	Horizontal (XY)	938 MPa ±11 MPa
	Vertical (Z)	986 MPa ±16 MPa
Elongation after fracture [3]	Horizontal (XY)	16% ±1%
	Vertical (Z)	21% ±1%
Modulus of elasticity [3]	Horizontal (XY)	115 GPa ±2%
	Vertical (Z)	122 GPa ±7 GPa
Hardness (Vickers) [4]	Horizontal (XY)	348 HV0.5 ±7 HV0.5
	Vertical (Z)	344 HV0.5 ±6 HV0.5
Surface roughness (Ra) [5]	Vertical (Z) (Median Ra)	10 µm ±1 µm
	Vertical (Z) (Median Ra)	67 µm ±5 µm

Mechanical test samples were created using four lasers, multiple lasers per sample and with no downstream processing. Stripe scan strategy was used for all samples.

1 Annealing method used for testing: Under vacuum, heat at 13 °C/min to 800 °C ±10 °C, then hold temperature for 4 hours. Furnace cool to room temperature.

2 Measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

3 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on 16 samples.

4 Tested to ASTM E384-11 after polishing.

5 Tested on as-built vertical surfaces using laser interferometry. Tested to JIS B 0601-2001 (ISO 4287:1997).

Parameter set summary

Layer thickness	Optimised for	Laser mode	Gas flow rate	Build rate	
90 µm	Single laser per part	Continuous wave	190 m^3/h	One laser: 63.5 cm^3/h	Four lasers: 254 cm^3/h

Material files: Ti6Al4V_500QS_B90_M_01_A (meander scan strategy)
Ti6Al4V_500QS_B90_S_01_A (stripe scan strategy)

Properties of additively manufactured components

NOTE: This parameter set is optimised for bulk density. The material properties in this table are indicative only. Further modification of the material file may be required to suit your application.

		Annealed [1]
Bulk density [2]		≥ 99.8%
Ultimate tensile strength [3]	Horizontal (XY)	1043 MPa ±3 MPa
	Vertical (Z)	1038 MPa ±8 MPa
Yield strength [3]	Horizontal (XY)	961 MPa ±8 MPa
	Vertical (Z)	969 MPa ±15 MPa
Elongation after fracture [3]	Horizontal (XY)	16% ±1%
	Vertical (Z)	19% ±1%
Modulus of elasticity [3]	Horizontal (XY)	118 GPa ±6 GPa
	Vertical (Z)	118 GPa ±8 GPa
Hardness (Vickers) [4]	Horizontal (XY)	351 HV0.5 ±5 HV0.5
	Vertical (Z)	351 HV0.5 ±7 HV0.5
Surface roughness (Ra) [5]	Vertical (Z) (Median Ra)	9 µm ±1 µm
	Vertical (Z) (Median Ra)	60 µm ±5 µm

Mechanical test samples were created using four lasers, multiple lasers per sample and with no downstream processing. Stripe scan strategy was used for all samples.

1 Annealing method used for testing: Under vacuum, heat at 13 °C/min to 800 °C ±10 °C, then hold temperature for 4 hours. Furnace cool to room temperature.

2 Measured optically on a 10 mm × 10 mm × 10 mm sample at 75× magnification.

3 Tested at ambient temperature to ASTM E8. Machined prior to testing. Values based on 16 samples.

4 Tested to ASTM E384-11 after polishing.

5 Tested on as-built vertical surfaces using laser interferometry. Tested to JIS B 0601-2001 (ISO 4287:1997).

RENISHAW
apply innovation™

www.renishaw.com/additivemanufacturing

#renishaw

+44 (0) 1453 524524 uk@renishaw.com

Part no.: H-5800-6797-03-A
Issued: 08.2024