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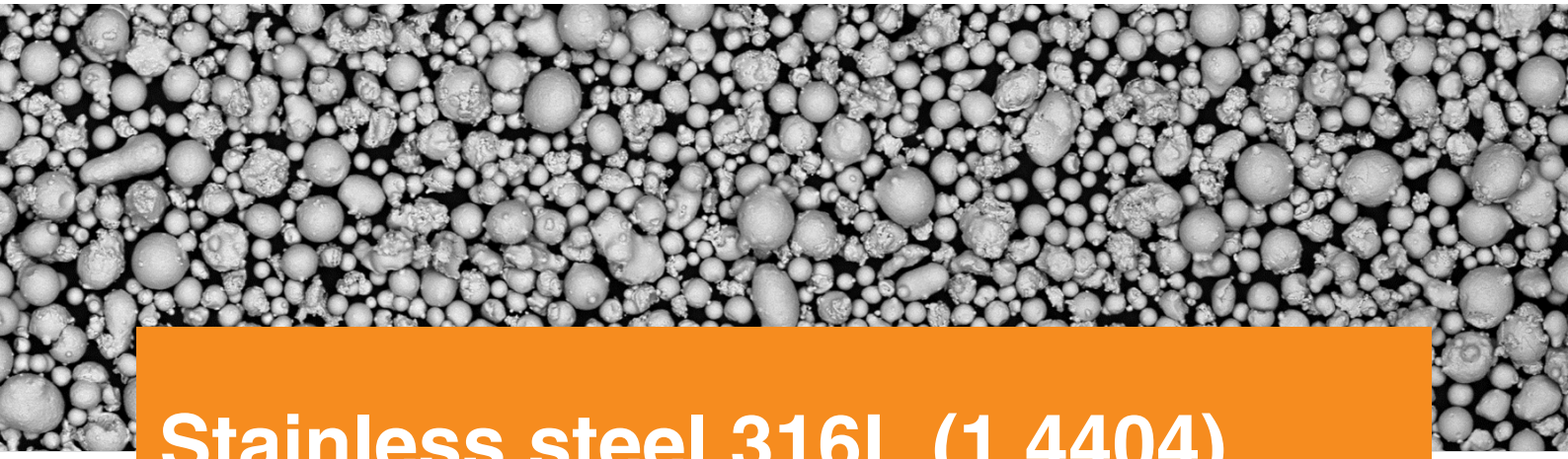

Stainless steel 316L (1.4404)

Parameter set options

Layer thickness	Optimised for	Laser mode	Page
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
70 µm	Single laser per part	Continuous wave	7

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

Material description

Stainless steel 316L alloy (DIN/W.Nr 1.4404) is an austenitic stainless steel which comprises of iron alloyed with chromium of mass fraction up to 18%, nickel up to 14% and molybdenum up to 3%, along with other minor elements.

Due to its low carbon content, stainless steel 316L is not resistant to sensitisation (carbide precipitation at grain boundaries) and displays good welding characteristics. It also has high stress to rupture and tensile strength at high temperatures.

Material properties

- High hardness and toughness
- High corrosion resistance
- High machinability
- Can be highly polished

Applications

- Plastic injection, pressure die-casting moulds and extrusion dies
- Surgical tools
- Cutlery and kitchenware
- Maritime components
- Spindles and screws
- General engineering

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	8 g/cm^3
Thermal conductivity	16 W/mK
Melting temperature	1 371 °C to 1 399 °C
Coefficient of thermal expansion [1]	16×10^{-6} K^{-1}

[1] In the range of 20 °C to 100 °C.

Recommended composition of powder

Element	Mass (%)
Iron	Balance
Chromium	16.00 to 18.00
Nickel	10.00 to 14.00
Molybdenum	2.00 to 3.00
Manganese	≤ 2.00
Silicon	≤ 1.00
Nitrogen	≤ 0.10
Oxygen	≤ 0.10
Phosphorus	≤ 0.05
Carbon	≤ 0.03
Sulphur	≤ 0.03

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: 12.5 cm^3/h	Four lasers: 49.9 cm^3/h

Material files: SS316L_500QS_B30_M_01_A (meander scan strategy)
SS316L_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.

		As built	Solution annealed [1]
Bulk density [2]		≥ 99.8%	-
Ultimate tensile strength [3]	Horizontal (XY)	708 MPa ±2 MPa	667 MPa ±3 MPa
	Vertical (Z)	651 MPa ±4 MPa	629 MPa ±3 MPa
Yield strength [3]	Horizontal (XY)	591 MPa ±3 MPa	420 MPa ±3 MPa
	Vertical (Z)	532 MPa ±5 MPa	395 MPa ±2 MPa
Elongation after fracture [3]	Horizontal (XY)	48% ±2%	53% ±1%
	Vertical (Z)	60% ±2%	66% ±2%
Modulus of elasticity [3]	Horizontal (XY)	191 GPa ±14 GPa	185 GPa ±10 GPa
	Vertical (Z)	199 GPa ±18 GPa	192 GPa ±15 GPa
Hardness (Vickers) [4]	Horizontal (XY)	209 HV0.5 ±5 HV0.5	204 HV0.5 ±3 HV0.5
	Vertical (Z)	214 HV0.5 ±6 HV0.5	203 HV0.5 ±5 HV0.5
Surface roughness [5]	Vertical (Z) (Median Ra)	9 µm ±2 µm	10 µm ±2 µm
	Vertical (Z) (Median Rz)	71 µm ±9 µm	73 µm ±8 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 Solution annealing method used for testing: Under vacuum, heat at 13 °C/min to 900 °C ± 15 °C, then hold temperature for 2 hours. Gas quench with argon at 1 bar to room temperature.

2 Measured optically on 10 mm × 10 mm × 10 mm samples 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	
60 µm	Single laser per part	Continuous wave	190 m^3/h	One laser: 23.8 cm^3/h	Four lasers: 95.2 cm^3/h

Material files: SS316L_500QS_B60_M_01_A (meander scan strategy)
SS316L_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.

		As built	Solution annealed [1]
Bulk density [2]		≥ 99.8%	-
Ultimate tensile strength [3]	Horizontal (XY)	699 MPa ±6 MPa	673 MPa ±3 MPa
	Vertical (Z)	631 MPa ±3 MPa	635 MPa ±4 MPa
Yield strength [3]	Horizontal (XY)	564 MPa ±6 MPa	418 MPa ±3 MPa
	Vertical (Z)	495 MPa ±3 MPa	396 MPa ±3 MPa
Elongation after fracture [3]	Horizontal (XY)	40% ±2%	55% ±1%
	Vertical (Z)	47% ±1%	65% ±3%
Modulus of elasticity [3]	Horizontal (XY)	198 GPa ±8 GPa	196 GPa ±8 GPa
	Vertical (Z)	208 GPa ±19 GPa	189 GPa ±7 GPa
Hardness (Vickers) [4]	Horizontal (XY)	214 HV0.5 ±3 HV0.5	200 HV0.5 ±4 HV0.5
	Vertical (Z)	226 HV0.5 ±5 HV0.5	201 HV0.5 ±3 HV0.5
Surface roughness [5]	Vertical (Z) (Median Ra)	14 µm ±1 µm	14 µm ±1 µm
	Vertical (Z) (Median Rz)	93 µm ±12 µm	89 µm ±8 µm
Plastometrex Yield strength [6]	Horizontal (XY)	-	338 MPa ±10 MPa
Plastometrex Ultimate Tensile Strength [6]	Horizontal (XY)	-	723 MPa ±27 MPa

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 Solution annealing method used for testing: Under vacuum, heat at 13 °C/min to 900 °C ± 15 °C, then hold temperature for 2 hours. Gas quench with argon at 1 bar to room temperature.

2 Measured optically on 10 mm × 10 mm × 10 mm samples 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).

6 Plastometrex's standard indentation procedure was used to generate the data. Indents were carried out on 10 mm × 10 mm × 10 mm samples. Values are based on 5 indents from 3 samples.

Parameter set summary

Layer thickness	Optimised for	Laser mode	Gas flow rate	Build rate
60 µm	Multiple laser per part	Continuous wave	190 m^3/h	Four lasers: 95.2 cm^3/h

Material files: SS316L_500QS_C60_S_02_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.

		As built	Solution annealed [1]
Bulk density [2]		≥ 99.8%	-
Ultimate tensile strength [3]	Horizontal (XY)	693 MPa ±3.5 MPa	674 MPa ±3 MPa
	Vertical (Z)	631 MPa ±3 MPa	636 MPa ±3 MPa
Yield strength [3]	Horizontal (XY)	565 MPa ±3.5 MPa	421 MPa ±2 MPa
	Vertical (Z)	495 MPa ±3 MPa	395 MPa ±3 MPa
Elongation after fracture [3]	Horizontal (XY)	53% ±2%	57% ±2%
	Vertical (Z)	47% ±1%	67% ±1%
Modulus of elasticity [3]	Horizontal (XY)	205 GPa ±12 GPa	193 GPa ±5 GPa
	Vertical (Z)	208 GPa ±19 GPa	170 GPa ±24 GPa
Hardness (Vickers) [4]	Horizontal (XY)	199 HV0.5 ±3 HV0.5	191 HV0.5 ±5 HV0.5
	Vertical (Z)	213 HV0.5 ±5 HV0.5	193 HV0.5 ±4 HV0.5
Surface roughness [5]	Vertical (Z) (Median Ra)	11 µm ±2 µm	11 µm ±2 µm
	Vertical (Z) (Median Rz)	77 µm ±14 µm	71 µm ±9 µm

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

1 Solution annealing method used for testing: Under vacuum, heat at 13 °C/min to 900 °C ± 15 °C, then hold temperature for 2 hours. Gas quench with argon at 1 bar to room temperature.

2 Measured optically on 10 mm × 10 mm × 10 mm samples 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	
70 µm	Single laser per part	Continuous wave	190 m^3/h	One laser: 36.3 cm^3/h	Four lasers: 145.2 cm^3/h

Material files: SS316L_500QS_B70_M_01_A (meander scan strategy)
SS316L_500QS_B70_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.

		As built
Bulk density [1]		≥ 99.8%
Ultimate tensile strength [2]	Horizontal (XY)	594 MPa ±5.1 MPa
	Vertical (Z)	669 MPa ±6.5 MPa
Yield strength [2]	Horizontal (XY)	555 MPa ±5.1 MPa
	Vertical (Z)	513 MPa ±5.2 MPa
Elongation after fracture [2]	Horizontal (XY)	49% ±2.7%
	Vertical (Z)	55% ±2.6%
Modulus of elasticity [2]	Horizontal (XY)	185 GPa ±9.8 GPa
	Vertical (Z)	177 GPa ±16.4 GPa
Hardness (Vickers) [3]	Horizontal (XY)	204 HV0.5 ±4.6 HV0.5
	Vertical (Z)	-
Surface roughness [4]	Vertical (Z) (Median Ra)	10 µm ±1.5 µm

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

1 Measured optically on 10 mm × 10 mm × 10 mm samples at 75× magnification.

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

3 Tested to ASTM E384-11 after polishing.

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

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