Stainless Steel 316/316l (UNS S31600)

Stainless Steel 316 has superior corrosion resistance properties as well as elevated temperature prolong performance potential. It offers good resistance to pitting and crevice corrosion in the various chemical conditions. Excellent aqueous corrosion resistance. High oxidation resistance up to 870oC. SS 316 is used in digesters, containers, evaporating systems, fabric production equipments, spacejet engine parts, mining and medical apparatus and in welding applications.

The nominal carbon content of 316L paired with an inclusion of nitrogen empowers 316L to fulfill the mechanical properties need of 316. Steel 316L offers resistance to atmospheric corrosion and moderate reducing and oxidizing conditions. It also offers resistance to corrosion in polluted marine applications. Steel 316L offers resistance to intergranular corrosion in the welded form. It has high strength and hardness at cryogenic temperatures. It is non magnetic in the annealed condition and becomes slightly magnetic by cold processing or welding. It can be conveniently welded and worked by normal fabrication methods.

Chemical Composition

Carbon (C)	0.03 %
Manganese (Mn)	2 %
Silicon (Si)	.75 %
Phosphorous (P)	0.045 %
Sulfur (S)	0.03 %
Chromium (Cr)	16 to 18 %
Molybdenum (Mo)	2 to 3 %
Nickel (Ni)	10 to 14 %
Nitrogen (N)	0.10 %

Physical Properties

Density	7.87 to 8.07 Mg/m3 or 491.308 lb/ft2 to 503.794 lb/ft3
Bulk Modulus	134 to 152 GPA or 19.435 to 22.0457 x 10(6) psi

Compressive strength	170 to 310 Mpa or 24.6 to 44.9617 ksi
Ductility	0.3 to 0.51
Elastic limit	170 to 310 Mpa or 24.6 to 45 ksi
Endurance limit	256 to 307 Mpa or 37.1 to 44.53 ksi
Hardness	1700 to 2200 Mpa or 246.5 to 319 ksi
Rupture modulus	170 to 310 Mpa or 24.7 to 44.96 ksi
Poisson ratio	0.265 to 0.275
Shear modulus	74 to 82 Gpa or 10.7 to 11.8 x 10(6) psi
Tensile strength	480 to 620 Mpa or 69.6 to 89.92 ksi
Young Modulus	190 to 205 Gpa or 27.56 to 29.73 x 10(6) psi
Latest heat of fusion	260 to 285 kj/kg or 111.7 to 122.5 BTU/lb
Highest operation temperature	1023 to 1198 K or 1381 to 1696oF
Melting temperature	1648 to 1673 K or 2506 to 2551oF
Lowest operation temperature	-459.7oF
Specific heat	490 to 530 J/Kg.K or 0.38 to 0.41 BTU/lb.f
Thermal conductivity	13 to 17 W/m.K or 24.3364 to 31.82 BTU.ft/h.ft^2.F
Thermal expansion	15 to 18 10^{-6}/K or 27 to 32.4 10^{-6}/°F
Electric resistivity	69 to 81 x 10^{-8}ohm.m

Modulus of Elasticity

oF	oC	Modulus	Psi x 10(6)	GPa
80 oF	27 oC	Tension	28 Psi x 10(6)	193 GPa
200 oF	93 oC	Tension, shear	28.1 Psi x 10(6), 11 Psi x 10(6)	194 GPa, 76 GPa
300 oF	149 oC	Tension, shear	27.5 Psi x 10(6), 10.6 Psi x 10(6)	190 GPa, 73 GPa
400 oF	204 oC	Tension, shear	26.9 Psi x 10(6), 10.3 Psi x 10(6)	185 GPa, 71 GPa
500 oF	260 oC	Tension, shear	26.3 Psi x 10(6), 10 Psi x 10(6)	181 GPa, 69 GPa
600 oF	316 oC	Tension, shear	25.6 Psi x 10(6), 9.7 Psi x 10(6)	177 GPa, 67 GPa
700 oF	371 oC	Tension, shear	24.9 Psi x 10(6), 9.4 Psi x 10(6)	172 GPa, 65 GPa
800 oF	427 oC	Tension, shear	24.2 Psi x 10(6), 9.1 Psi x 10(6)	167 GPa, 63 GPa
900 oF	482 oC	Tension, shear	23.5 Psi x 10(6), 8.8 Psi x 10(6)	162 GPa, 61 GPa
1000 oF	538 oC	Tension , shear	22.8 Psi x 10(6), 8.5 Psi x 10(6)	157 GPa, 59 GPa
1100 oF	593 oC	Tension, shear	22.2 Psi x 10(6), 8.3 Psi x 10(6)	153 GPa, 57 GPa
1200 oF	649 oC	Tension, shear	21.5 Psi x 10(6), 8.1 Psi x 10(6)	148 GPa, 56 GPa
1300 oF	704 oC	Tension, shear	20.8 Psi x 10(6), 7.6 Psi x 10(6)	143 GPa, 54 GPa
1400 oF	760 oC	Tension, shear	20 Psi x 10(6), 7.9 Psi x 10(6)	138 GPa, 53 GPa
1500 oF	816 oC	Tension, shear	19.1 Psi x 10(6), 7.5 Psi x 10(6)	132 GPa, 52 GPa

Mechanical Properties

Alloy	Tensile strength	Yield strength	Elongation	Hardness
316	75 ksi	30 ksi	40 %	95 HRB
316	70 ksi	25 ksi	40 %	95 HRB
1.4404	75 ksi	34.81 ksi	40 %	
1.4401	75 ksi	34.81 ksi	40 %	

Annealed sheet mechanical properties

Temperature	Yield strength	Tensile strength	Elongation,	Reduction of area, %	Hardness Rockwell

oF	oC	Ksi	Mpa	Ksi	Mpa	%		B
80 oF	27 oC	42 Ksi	290 Mpa	84 Ksi	579 Mpa	50 %	-	79 B
300 oF	149 oC	29.2 Ksi	201 Mpa	75 Ksi	517 Mpa	53 %	77 %	-
500 oF	260 oC	25 Ksi	172 Mpa	73 Ksi	503 Mpa	49 %	75 %	-
700 oF	371 oC	23 Ksi	159 Mpa	72.5 Ksi	500 Mpa	47 %	69 %	-
900 oF	482 oC	21.5 Ksi	148 Mpa	70.2 Ksi	484 Mpa	47 %	69 %	-
1100 oF	593 oC	20.3 Ksi	140 Mpa	65.5 Ksi	452 Mpa	44 %	63 %	-
1300 oF	704 oC	19 Ksi	131 Mpa	50 Ksi	345 Mpa	43 %	58 %	-
1500 oF	816 oC	16 Ksi	110 Mpa	27 Ksi	186 Mpa	42 %	55 %	-
1700 oF	927 oC	-	-	11.6 Ksi	80 Mpa	67 %	60 %	-
1900 oF	1038 oC	-	-	5.6 Ksi	39 Mpa	60 %	47 %	-
2000 oF	1093 oC	-	-	4 Ksi	28 Mpa	75 %	55 %	-

High temperature tensile properties

Temp	Tensile strength, MPa	0.2 % Proof stress	Elongation
100 oC	540 Mpa	235 Mpa	52 %
300 oC	500 Mpa	165 Mpa	48 %
500 oC	480 Mpa	145 Mpa	47 %
600 oC	450 Mpa	140 Mpa	44 %
700 oC	350 Mpa	130 Mpa	43 %
800 oC	205 Mpa	115 Mpa	42 %
900 oC	100 Mpa	-	63 %
1000 oC	50 Mpa	-	62 %
1100 oC	25 Mpa	-	76 %

Creep and rupture properties

Temp, oC	Stress to create 1% strain		Stress to create rupture	
	10,00 hours	100,00 hours	1000 hours	10,000 hours
550 oC	225 Mpa	125 Mpa	320 Mpa	270 Mpa
600 oC	145 Mpa	80 Mpa	220 Mpa	170 Mpa
650 oC	95 Mpa	55 Mpa	160 Mpa	110 Mpa
700 oC	65 Mpa	35 Mpa	110 Mpa	70 Mpa
750 oC	40 Mpa	20 Mpa	75 Mpa	45 Mpa
800 oC	30 Mpa	15 Mpa	55 Mpa	30 Mpa
850 oC	20 Mpa	10 Mpa	35 Mpa	20 Mpa

Sub zero temperature properties

Temp	Tensile strength	0.2 % Proof stress	Elongation	Impact energy
20 oC	584 Mpa	235 Mpa	61 %	170 J
0 oC	680 Mpa	260 Mpa	70 %	191 J
-10 oC	832 Mpa	336 Mpa	69 %	186 J
-50 oC	1105 Mpa	380 Mpa	65 %	183 J
-140 oC	1136 Mpa	417 Mpa	61 %	155 J
-196 oC	1360 Mpa	444 Mpa	58 %	166 J

Prolong High temperature exposure effect on mechanical properties

10,000 hours		Yield strength		Tensile strength		Elongation in 2 inch	Reduction of area
oF	oC	Ksi	MPa	Ksi	MPa	%	%
900 oF	482 oC	45 Ksi	310 MPa	91.9 Ksi	634 MPa	60 %	73 %
1050 oF	566 oC	41.8 Ksi	288 MPa	97.2 Ksi	670 MPa	49 %	65 %

1200 oF	649 oC	50.5 Ksi	348 MPa	113 Ksi	779 MPa	31 %	49 %

Corrosion Resistance

In different operations, alloy 316/316L has excellent corrosion resistance over steel 304/304L. The process conditions that do not corrode alloy 304/304L do not cause corrosion of this steel type except oxidizing acids like nitric acid however stainless steels comprising of molybdenum are minor resistant. Steel grade 316L offers good performance in the sulfur conditions that occur in the pulp and paper commerce. It can be utilized in high contents at temperatures about 120oF. It offers excellent resistance to pitting corrosion in phosphoric and acetic acid. It can be utilized in the food and medical processing industries to handle hot organic and fatty acids to reduce contamination.

Corrosion rate in hydrofluoric acid

Alloy	Concentration %	Temperature		Time	Corrosion rate	
		oC	oF		Mm/y	mpy
316	10 %	16 oC	60 oF	30 days	.002 Mm/y	.1 mpy
316	38 %	110 oC	230 oF	2 days	51 Mm/y	2000 mpy
316	40 %	20 oC	68 oF	-	Poor	Poor
316	70 %	21 oC	70 oF	42 days	1.24 Mm/y	49 mpy
316	98 %	34 oC to 44 oC	95 oF to 110 oF	3.5 days	.05 Mm/y	2 mpy
316	60 % to 65 %	-1.1 oC to 26 oC	30 oF to 80 oF	28 days	Poor	Poor
316	72 %	176 oC	350 oF	14 days	6 Mm/y	240 mpy
316	72 %	176 oC	350 oF	14 days	10 Mm/y	380 mpy
316	12 %	83 oC	182 oF	7.2 days	18 Mm/y	700 mpy
316	50 %	176 oC	350 oF	7 days	2.6 Mm/y	103 mpy
316	50 %	176 oC	350 oF	7 days	28 Mm/y	113 mpy
316	50 %	RT to 60 oC	140 oF	4 days	2.5 Mm/y	100 mpy
316	37 %	75 oC	167 oF	9.3 days	Poor	Poor
316	29 %	60 oC	140 oF	10.3 days	2.5 Mm/y	100 mpy
316	70 %	21 oC	70 oF	42 days	12 Mm/y	490 mpy
316	6 %	135 oC	275 oF	226 days	0.3 Mm/y	12 mpy
316	46.5 %	98 oC to 104 oC	210 oF to 220 oF	49 days	0.03 Mm/y	1 mpy
316	38 %	110 oC	230 oF	2 days	50 Mm/y	2000 mpy

Stainless steel type 316 offers good functionality in fresh water service in fact in the presence of concentrated chlorides. It has superior corrosion resistance in the seawater conditions. The high concentration of molybdenum ensures the outstanding pitting resistance in the chloride conditions. In several cases, the corrosion resistance steel 316 and 316L show similar performance. But to avoid intergranular corrosion attack of welds and heat affected zone, alloy 316L should be utilized that has lower content of carbon. Steel type 316/316L can be conveniently welded and processed through standard fabrication

Fabrication

Hot Forging: The processing temperature of 1700oF to 2200oF is preferred for common hot processing operations. For highest corrosion resistance, the alloy should be annealed at 1900oF at least and water cooling or quickly cooled through other ways subsequent to hot processing.

Cold Forging :Steel 316/316L is highly ductile and formable. The cold processing enhances its strength and toughness and provides magnetic features.

Welding: Steel 316L can be easily welded through common methods. The post weld heat processing is not essential.

Machining: 316l steel type is subjected to work toughening while deformation and it is subjected to chip breaking. The superior machining outcomes are obtained with slow speed, large feed rate, superior lubrication, sharp tooling and strong devices.

Available Forms

Wire, Mesh, Flanges, Pipe, Strip, Foil, Plate, Sheet, Rod, Bar