Stainless steel 316/316L

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Stainless steel 316/316L is a chromium-nickel-molybdenum alloy steel that is fabricated to provide excellent corrosion resistance over steel 304L in the intermediate corrosion conditions. It is commonly used in the process steam comprising of chlorides or halides. An inclusion of molybdenum enhances corrosion and chloride pitting resistance. It also offers high creeping, stress rupturing and tensile strength at high temperatures.

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

Chemical composition of Stainless Steel 316/316L

Element	316	316L
Chromium	16.0 min. – 18.0 max.	16.0 min. – 18.0 max.
Nickel	10.0 min. – 14.0 max.	10.0 min. – 14.0 max.
Molybdenum	2.00 min. – 3.00 max	2.00 min. – 3.00 max
Carbon	0.08	0.030
Manganese	2.00	2.00
Phosphorous	0.045	0.045
Sulfur	0.03	0.03
Silicon	0.75	0.75
Nitrogen	0.1	0.1
Iron	Balance	Balance

Physical properties of stainless steel 316/316L

Density	0.285 lbs / in3	7.90 g /cm3
Modulus of Elasticity	29.0 x 106 psi	200 GPa
Melting Range	2450 – 2630°F	1390 – 1440°C
Specific Heat	0.11 BTU/lb-°F (32 – 212°F)	450 J/kg-°K (0 –100°C)
Thermal Conductivity 212°F (100°C)	10.1 BTU/hr/ft2/ft/°F	14.6 W/m-°K
Electrical Resistivity	29.1 Microhm-in at 68°F	74 Microhm-cm at 20°C

Mean coefficient of thermal expansion

Temperature Range			
oF	oC	in/in/°F	cm/cm °C
68 – 212	20 – 100	9.2 x 10-6	16.6 x 10-6
68 – 932	20 – 500	10.1 x 10-6	18.2 x 10-6
68 – 1832	20 – 1000	10.8 x 10-6	19.4 x 10-6

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. The steel 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. The steel 316L 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.

Mechanical Properties

	Typical*	ASTM	
		316	316L
Ultimate Tensile Strength, ksi	85	75 minimum	70 minimum
0.2% Offset Yield Strength, ksi	44	30 minimum	25 minimum
Elongation in 2 inches, %	56	40 minimum	40 minimum
Reduction in Area, %	69	-	-
Hardness, Rockwell B	81	95 maximum	95 maximum

Corrosion Resistance

Alloy	Composition (Weight Percent)					
	Cr	Mo	N	PREn1	CCT2	CPT3
Type 304	18	-	0.06	19.0	<27.5 (<-2.5)	- -
Type 316	16.5	2.1	0.05	24.2	27.5 (-2.5)	59 15
Type 317	18.5	3.1	0.06	29.7	35.0 (1.7)	66 18.9
SSC-6MO	20.5	2.1	0.22	44.5	110 (43.0)	149 65

Minimum temperature at which corrosion rate crosses 5mpy

Corrosion Condition	316L steel	304 Steel	2205 steel	2507 steel
0.2% Hydrochloric Acid	>Boiling	>Boiling	>Boiling	>Boiling
1% Hydrochloric Acid	86	86p	185	>Boiling
10% Sulfuric Acid	122	--	140	167
60% Sulfuric Acid	>54	-	<59	<57
96% Sulfuric Acid	113	-	77	86
85% Phosphoric Acid	203	176	194	203
10% Nitric Acid	>Boiling	>Boiling	>Boiling	>Boiling
65% Nitric Acid	212	212	221	230
80% Acetic Acid	>Boiling	212p	>Boiling	>Boiling
50% Formic Acid	104	>=50	194	194

50% Sodium Hydroxide	194	185	194	230
83% Phosphoric Acid + 2% Hydrofluoric Acid	149	113	122	140
60% Nitric Acid + 2% Hydrochloric Acid	>140	>140	>140	>140
50% Acetic Acid + 50% Acetic Anhydride	248	>Boiling	212	230
1% Hydrochloric Acid + 0.3% Ferric Chloride	77p	68p	113ps	203ps
10% Sulfuric Acid + 2000ppm Cl- + N2	77	-	95	122
10% Sulfuric Acid + 2000ppm Cl- + SO2	<<59p	-	<59	104
WPA1, High Cl- Content	<=50	<<50	113	203
WPA2, High F- Content	<=50	<<50	140	167

P refers to pitting may occur, Ps refers to pitting and crevice may occur

Stainless steel 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 of alloy 316L should be utilized that has lower content of carbon.

Fabrication Properties

The steel 316/316L can be conveniently welded and processed through standard fabrication methods.

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

The steel 316L 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.

Machining conditions:

operation	**Tool**	**Lubrication**	**Conditions**					
			Depth-mm	Depth-in	Feed-mm/t	Feed-in/t	Speed-m/min	Speed-ft/min

Turning	High Speed Steel	Cutting Oil	6	.23	0.5	.019	11 – 16	36 .1 – 52.5
			3	.11	0.4	.016	18 – 23	59.1 – 75.5
			1	.04	0.2	.008	25 – 30	82 – 98.4
	Carbide	Dry or Cutting Oi	6	.23	0.5	.019	70 – 80	229.7 – 262.5
			3	.11	0.4	.016	85 – 95	278.9 – 312.7
			1	.04	0.2	.008	100 – 110	328.1 – 360.9
Cutting	High Speed Steel	Cutting Oil	15	.06	0.03 – 0.05	.0012 – .0020	16-21	52 .5 – 68.9
			3	.11	0.04 – 0.06	.0016 – .0024	17-22	55.8 – 72.2
			6	.23	0.05 – 0.07	.0020 – .0027	18-23	59 – 75.45
Drilling	High Speed Steel	Cutting Oil	15	.06	0.02 – 0.03	.0008 – .0012	10-14	32.8 – 45.9
			3	.11	0.05 – 0.06	.0020 – .0024	12-16	39.3 – 52.5
			6	.23	0.08 – 0.09	.0031 – .0035	12-16	39.3 – 52.5
			12	.48	0.09 – 0.10	.0035 – .0039	12-16	39.3 – 52.5
Drilling	High Speed Steel				0.05 – 0.10	.002 – .004	10 – 20	32.8 – 65.6

Applications of Stainless steel 316L

1. Chemical and Petrochemical Processing — pressure vessels, tanks, heat exchangers, piping systems, flanges, fittings, valves and pumps
2. Food and Beverage Processing
3. Marine operations
4. Medical industry
5. Petroleum refining
6. Paper and pulp industry
7. Water processing

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