AISI: ≈ 316 L JIS: SUS 316L EN: ≈ X2CrNiMo 17 13 2 DIN: X2CrNiMo 18 14 3 Wst Nr: 1.4435

History

Recognising that certain demanding industries have specific needs, like high **improved machinability**, corrosion resistance and bio-compatibility, our Swiss laboratory developed the 316L-PM™. This enhanced 316L features an improved 1.4435 chemistry, achieved by the optimisation of the composition and microstructure as well as by the **absence of hard inclusions**.

Description

The 316L-PM™ is an austenitic Chromium-Nickel-Molybdenum stainless steel, based on the 316L 1.4435 chemistry. Its very tight requirements on the microstructure, especially on the microcleanliness, leads to very consistent mechanical and chemical characteristics between different batches. Its strongest point is a very high corrosion resistance, especially against pitting corrosion in saline or chlorine environment. **Moreover, due to the absence of hard inclusions, a superb polished finish is consistently achieved.**

This stainless steel contains a controlled sulphur concentration of 0.015 - 0.03% that improves machinability as compared to the standard grade 316L 1.4435.

Equivalence

The 316L-PM™ (Wst Nr 1.4435) belongs to the same group as the 316L alloys (Wst Nr 1.4435 and 1.4404) and the 316LS-PXQ™ (Wst Nr 1.4427 So). Therefore the 316L-PM™ may be used in conjunction with these alloys without risk of corrosion caused by differences in electrical potential.

Chemical Composition (% weight)

Carbon	< 0.030	Sulphur	0.015 ~ 0.03
Silicon	< 1.00	Nickel	12.5 - 15.0
Manganese	< 2.00	Chromium	17.0 -19.00
Phosphorus	< 0.045	Molybdenum	2.50 - 3.00

Other Elements

To limit the risk of formation of hard oxide detrimental to the polishability, the content of Titanium, Aluminium and Nobium is kept to a minimum, typically below 0.010%. On another hand, Copper impurities are controlled below 0.40%, well below the concentration at which it could potentially reduce the corrosion resistance.

Microstructure

Unique steps are taken during the alloy elaboration and casting to guarantee a very fine grain structure (ASTM 6 or finer), low delta ferrite, the absence of sigma phase and a very low level of inclusions. The typical microcleanliness of the 316L-PM™, according to ASTM Practice E 45 Method A, except using Plate III, is better than:

Sulfide **A**		Alumina **B**		Silicate **C**		Globular Oxide **D**	
Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
1.5	1.0	1.5	1.0	1.5	1.0	1.5	1.0

Physical Properties

Density, ρ [$kg \cdot m^{-3}$]	7,980	Thermal conductivity, λ [$W \cdot m^{-1} \cdot K^{-1}$]	15.0
Electrical resistivity, ρ [$\mu\Omega \cdot m$]	0.75	Thermal expansion at 100°C, α [$10^{-6.o}C^{-1}$]	16.5
Mean specific heat, C_p [$J \cdot kg^{-1} \cdot K^{-1}$]	500	Modulus of elasticity at 20°C, E [Gpa]	200

Mechanical Properties

Condition	Yield Strength 20° [Mpa]	Tensile Strength Rm [Mpa]	Elongation [%]	Hardness [Hv]
Annealed	200	500 - 700	40	160 - 200 +/-20
Full Hard	1300	1400	5	430 +/-20

Magnetic Properties

This alloy is non-magnetic in the annealed condition, but may become very slightly magnetic as a result of extreme cold work.

Corrosion Resistance

The combination of a PRE value above 26, minimum Copper content and controlled inclusions level, give the 316L-PM™ a more consistent and higher pitting corrosion resistance than commercially available austenitic stainless steel grades (e.g. 304L, 316L).

Its low Carbon content make this alloy not sensitive to Chromium Carbide precipitate ($Cr_{23}C_6$), even after repeated heat treatments, thus intergranular corrosion is unlikely.

		Pit Density [pits/cm^2]			
Alloy	PRE	$FeCl_3$, 0.5 °/00 50°C, 2 hours	$FeCl_3$, 0.1 °/00 37°C, 15 days	NaCl, 0.5 °/00 37°C, 26 days	NIHS sweat 37°C, 30 days
316L-PM™	26.0				
AISI 316F	22.8				
AISI 303	17.0				
316L 1.4435	25.3				
AISI 316L	22.6				
JIS SUS 316L	22.6				
AISI 304L	18.0				

Note: Results are for information only. Tests were conducted as per ASTM G 48, 4 samples per alloy per test. Pit density is the average results of the 4 samples. Samples section around 12 x 6 mm, taken longitudinally. PRE is the minimum value guaranteed by the chemistry specification given in the Stahlschlussel.

Biocompatibility

Owing to its very high corrosion resistance to chlorine and saline environments, the 316L-PM™ is highly biocompatible. Initial testing have shown than imperceptible amount of Nickel were released upon contact with human skin.

The 316L-PM™ complies with the standard EN 1811 and can be used for products in direct and prolonged contact with human skin.

Note: the Nickel release of an alloy has been shown to be closely interrelated to the corrosion resistance of the said alloy. Therefore heat treatment, grain size, contaminant, surface finish, surface treatment, etc. may have a significant impact on the amount of Nickel released by an alloy.

Machining

The machining of the 316L-PM™ requires an abundance of cutting fluid, preferably water based. A positive feed should be maintained at all time, to ensure that work hardened material is removed **The absence of hard inclusions and hard oxides of this alloy prolong tool life and therefore saves your manufacturing cost.**

Drilling

Tool material	Diameter [mm]	Feed [mm/min]	Speed [rpm]
Carbide	0.90	105	4,200
Carbide	1.20	80	3,200
Carbide	1.70	55	2,300

Sawing (Slitting saw)

Tool material	Diameter [mm]	Feed [mm/min]	Speed [rpm]
Carbide	96 / 100	65	750
Carbide	63	65	1,150
Carbide + coating	96 / 100	80	950
Carbide + coating	63	80	1,450

Heat Treatment

The annealing of the 316L-PM™ is done between 1,020°C and 1,080°C with a holding time between 15 to 60 minutes, depending on the mass of the parts being treated, and followed by a rapid cooling. Due to its low impurities content grain growth can easily occur, leading to an “orange skin” surface, therefore temperature and holding time should be carefully controlled. For bright annealing, use a protective atmosphere of H_2, $H_2 + N_2$ or cracked NH_3.

This alloy cannot be hardened by heat treatment and hardens only by cold working.

Chemical Treatment

The 316L-PM™ can be pickled in a hot bath of 8-11% sulphuric acid, at 65°C to 80°C between 5 to 45 minutes. This operation should be done only on material in an annealed condition.

This alloy can be passivated in a bath of 20-50% nitric acid, at room temperature to 40°C to 70°C between 30 to 60 minutes. This must be followed by neutralisation.

Cold Working

The 316L-PM™ can be drawn, rolled and stamped without difficulty. Since this alloy work hardens, severe forming operations should be followed by annealing.

Welding

This alloy may be welded with TIG or MicroPlasma. After welding, a stress relief annealing at 1,050°C, under a protective atmosphere of H_2, H_2 + N_2 or cracked NH_3, is advisable. Welding electrodes : 1.4430, 1.4576

Brazing

The brazing of 316L-PM™ in a temperature range of 950°C to 1,100°C is not particularly challenging. To achieve the best possible result, the use of a conveyor furnace under a protective atmosphere of H_2, H_2 + N_2 or cracked NH_3, is highly recommended.

The usage of the following filler alloys are recommended to achieve the strongest bond:

- Ag-Cu-Ni filler alloys, melting point around 900°C
- Palladium filler alloys
- 8 to 18 carat gold filler alloys, melting point around 850°C

Available Products

- Wires
- Bars
- Profiles

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