Sanmac® 316/316L
Hollow bar
Datasheet

Sanmac® 316/316L is a molybdenum-alloyed austenitic chromium-nickel steel with improved machinability.

Standards

- ASTM: MT 316, MT 316L
- UNS: S31600, S31603
- EN Number: 1.4401, 1.4404
- EN Name: X 5 CrNiMo 17-12-2, X 2 CrNiMo 17-12-2
- JIS: SUS316TKA

Product standards

- EN 10216-5*, EN 10297-2, EN 10294-2
- ASTM A511
- JIS G3446

* The leakage test is deferred to the finished component

Approval
JIS Approval No. SE9402 for Stainless Steel Tubes

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo
≤0.030	≤0.75	≤2.00	≤0.040	≤0.030	16.5	11	2.1

Applications

Sanmac® 316/316L is used for a wide range of industrial applications where steels of type ASTM 304/304L have insufficient corrosion resistance. Typical applications are:

- Machined parts for tube and pipe fittings
- Components for valves, pumps, heat exchangers and vessels
- Different tubular shafts in chemical, petrochemical, fertilizer, pulp and paper and power industries as well as in the production of pharmaceuticals, foods and beverages

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Corrosion resistance

General corrosion

Sanmac® 316/316L has good resistance to:

- Organic acids at high concentrations and temperatures, with the exception of formic acid and acids with corrosive contaminants
- Inorganic acids, e.g. phosphoric acid, at moderate concentrations and temperatures, and sulfuric acid below 20% at moderate temperatures.
  The steel can also be used in sulfuric acid of concentrations above 90% at low temperature.
- E.g. sulfates, sulfides and sulfites
- Caustic environments

Intergranular corrosion

Sanmac® 316/316L has a low carbon content and therefore good resistance to intergranular corrosion.

Stress corrosion cracking

Austenitic steels are susceptible to stress corrosion cracking. This may occur at temperatures above about 60°C (140°F) if the steel is subjected to tensile stresses and at the same time comes into contact with certain solutions, particularly those containing chlorides. In applications demanding high resistance to stress corrosion cracking, the austenitic-ferritic steels SAF 2304, Alleima 10RE51 or Sanmac® 2205 have higher resistance to stress corrosion cracking than 316L.

Pitting and crevice corrosion

Resistance to these types of corrosion improves with increasing molybdenum content. Thus, the molybdenum-alloyed Sanmac® 316/316L has substantially higher resistance to attack than steels of type AISI 304 and 304L.

Gas corrosion

Sanmac® 316/316L can be used in:

- Air up to 850°C (1560°F)
- Steam up to 750°C (1380°F)

Creep behavior should also be taken into account when using the steel in the creep range. In flue gases containing sulfur, the corrosion resistance is reduced. In such environments the steel can be used at temperatures up to 600-750°C (1110-1380°F) depending on service conditions. Factors to consider are whether the atmosphere is oxidizing or reducing, i.e. the oxygen content, and whether impurities such as sodium and vanadium are present.

Forms of supply

Hollow bar-Finishes, dimensions and tolerances
Hollow bar Sanmac® 316/316L is stocked in a large number of sizes up to 250 mm outside diameter in the solution-annealed and white-pickled condition.
See catalogue S-110-ENG or S-1492-ENG.

Dimensions are given as outside and inside diameter with guaranteed component sizes after machining.
Outside diameter +2 / -0 %, but minimum +1 / -0 mm
Inside diameter +0 / -2 %, but minimum +0 / -1 mm
Straightness +/-1.5mm/m
Other tolerances can be supplied against special order.

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Other forms of supply
Bar
Steel with improved machinability, Sanmac, is also available in bar.

Heat treatment

Hollow bar is delivered in heat treated condition. If further heat treatment is needed after further processing the following is recommended:

Stress relieving
850-950°C (1560-1740°F), cooling in air.

Solution annealing
1000-1100°C (1830-2010°F), rapid cooling in air or water.

Mechanical properties

For hollow bar with wall thicknesses greater than 10 mm (0.4 in.) the proof strength may fall short of the stated values by about 10 MPa (1.4 ksi).

At 20°C (68°F)

Metric units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	$A_{2"}$	HRB
MPa	MPa	MPa	%	%	
≥220	≥250	515-690	≥45	≥35	≤90

Imperial units

Proof strength		Tensile strength	Elong.		Hardness
$R_{p0.2}$[a]	$R_{p1.0}$[a]	R_m	A[b]	$A_{2"}$	HRB
ksi	ksi	ksi	%	%	
≥32	≥36	75-100	≥45	≥35	≤90

1 MPa = 1N/mm^2
a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strength, respectively.
b) Based on L_0 = 5.65 ÖS_0 where L_0 is the original gauge length and S_0 the original cross-section area.
c)NFA 49-317 with min 45% can be fulfilled

Impact strength

Due to its austenitic microstructure, Sanmac® 316/316L has very good impact strength both at room temperature and at cryogenic temperatures.
Tests have demonstrated that the steel fulfils the requirements (60 J (44 ft-lb) at -196 °C (-320 °F)) according to the European standards EN 13445-2 (UFPV-2) and EN 10216-5.

At high temperatures

Metric units

Temperature	Proof strength	
°C	$R_{p0.2}$[a]	$R_{p1.0}$
	MPa	MPa
	min.	min.
50	210	240
100	180	215
150	165	195
200	150	180
250	140	170
300	135	160

350
130
155
400
125
150
450
123
148
500
120
145
550
115
140
600
110
135

Imperial units

Temperature
Proof strength
°F
R
p0.2
a
R
p1.0
ksi
ksi
min.

min.
200
27
32
400
22
26
600
19
23
800
18
22
1000
17
20
1100
16
20

Physical properties

Density: 8.0 g/cm^3, 0.29 lb/in^3

Thermal conductivity

Temperature, °C	W/m °C	Temperature, °F	Btu/ft h °F
20	14	68	8
100	15	200	8.5
200	17	400	10
300	18	600	10.5
400	20	800	11.5
500	21	1000	12.5
600	23	1100	13

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Specific heat capacity

Temperature, °C	J/kg °C	Temperature, °F	Btu/lb °F
20	485	68	0.11
100	500	200	0.12
200	515	400	0.12
300	525	600	0.13
400	540	800	0.13
500	555	1000	0.13
600	575	1100	0.14

Thermal expansion, mean values in temperature ranges (x10^{-6})

Temperature, °C	Per °C	Temperature, °F	Per °F
30-100	16.5	86-200	9.5
30-200	17	86-400	9.5
30-300	17.5	86-600	10
30-400	18	86-800	10
30-500	18	86-1000	10
30-600	18.5	86-1200	10.5
30-700	18.5	86-1400	10.5

Modulus of elasticity, (x10^3)

Temperature, °C	MPa	Temperature, °F	ksi
20	200	68	29.0
100	194	200	28.2
200	186	400	26.9
300	179	600	25.8
400	172	800	24.7
500	165	1000	23.5

Welding

The weldability of SANMAC® 316/316L is good. Suitable methods of fusion welding are manual metal-arc welding (MMA/SMAW) and gas-shielded arc welding, with the TIG/GTAW method as first choice.

Since this material is alloyed in such a way to improve its machinability, the amount of surface oxides on the welded beads might be higher compared to that of the standard 316L steels. This may lead to arc instability during

TIG/GTAW welding, especially welding without filer material. However, the welding behavior of this material is the same as for standard 316L steels when welding with filler material.

For SANMAC® 316/316L, heat input of <2.0 kJ/mm and interpass temperature of <150°C (300°F) are recommended. Preheating and post-weld heat treatment are normally not necessary.

Recommended filler metals

TIG/GTAW or MIG/GMAW welding

ISO 14343 S 19 12 3 L / AWS A5.9 ER316L (e.g. Exaton 19.12.3.L)

MMA/SMAW welding

ISO 3581 E 19 12 3 L R / AWS A5.4 E316L-17(e.g. Exaton 19.12.3.LR)

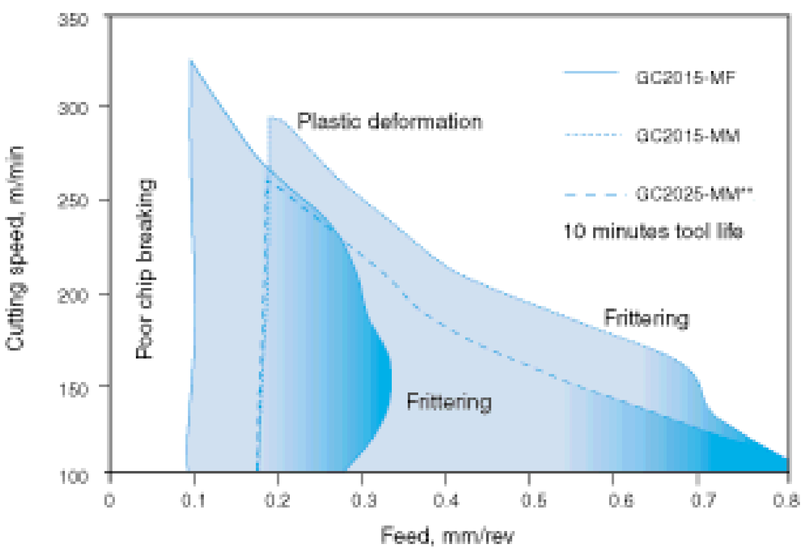
Machining

Sanmac is our trademark for the Alleima machinability concept. In Sanmac® materials, machinability has been improved without jeopardizing properties such as corrosion resistance and mechanical strength.
The improved machinability is owing to:

- Optimized non-metallic inclusions
- Optimal chemical composition
- Optimized process and production parameters

Detailed recommendations for the choice of tools and cutting data regarding turning, thread cutting, parting/grooving, drilling, milling and sawing are provided in the brochure S-02909-ENG.

The diagram shows the ranges within which data should be chosen in order to obtain a tool life of minimum 10 minutes when machining austenitic Sanmac® 316/316L.



** MR for SANMAC 316/316L hollow bar

The ranges are limited in the event of low feeds because of unacceptable chip breaking. In the case of high cutting speeds, plastic deformation is the most dominant cause of failure. When feed increases and the cutting speed falls, edge frittering (chipping) increases significantly. The diagram is applicable for short cutting times. For long, continuous cuts, the cutting speeds should be reduced somewhat.

The lowest recommended cutting speed is determined by the tendency of the material to stick to the insert (builtup-edge), although the integrity of insert clamping and the stability of the machine are also of great significance.

It is important to conclude which wear mechanism is active, in order to optimize cutting data with the aid of the diagram.

Datasheet last updated 5/9/2025 6:37:57 AM (supersedes all previous editions)