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

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.

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

Filler metals for welding
The sizes listed below are Sandvik stock standard. The local stocks carry sizes in common demand on the market. For technical information on the filler metals please refer to brochures S-2361-ENG and S-2362-ENG.

Wire electrodes and filler wire/rods: Sandvik 19.12.3.L: 0.80, 1.00, 1,20, 1.60, 2.00, 2.40, 3.00, 3.20, 4.00 mm

Covered electrodes Sandvik 19.12.3.LR: 1.6, 2.0, 2.5, 3.25, 4.0 mm
Sandvik 19.12.3.LB: 2.0, 2.5, 3.25, 4.0, 5.0 mm Sandvik 19.12.3.LRHD: 2.5, 3.25, 4.0, 5.0 mm

CORROSION RESISTANCE

General corrosion
Sandvik 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
Sandvik 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 Sandvik SAF 2304, Sandvik 10RE51 or Sandvik 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 Sandvik Sanmac® 316/316L has substantially higher resistance to attack than steels of type AISI 304 and 304L.

Gas corrosion
Sandvik 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.

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
Rp0.2[a]	Rp1.0[a]	Rm	A[b]	A2"	HRB
MPa	MPa	MPa	%	%	
≥220	≥250	515-690	≥45	≥35	≤90

Imperial units

Proof strength		Tensile strength	Elong.		Hardness
Rp0.2[a]	Rp1.0[a]	Rm	A[b]	A2"	HRB
ksi	ksi	ksi	%	%	
≥32	≥36	75-100	≥45	≥35	≤90

1 MPa = 1N/mm2

a) Rp0.2 and Rp1.0 correspond to 0.2% offset and 1.0% offset yield strength, respectively.

b) Based on L0 = 5.65 ÖS0 where L0 is the original gauge length and S0 the original cross-section area.

c) NFA 49-317 with min 45% can be fulfilled

Impact strength

Due to its austenitic microstructure, Sandvik 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	Rp0.2 [a]	Rp1.0
	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	Rp0.2 [a]	Rp1.0
	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

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

Datasheet updated 6/19/2019 3:13:49 PM (supersedes all previous editions)

Thermal expansion, **mean values in temperature ranges (x10- 6)**

Temperature, °C	Per °C	Temperature, °F	Per °F
30-600	18.5	86-1200	10.5
30-700	18.5	86-1400	10.5

Modulus ofelasticity, **(x10³)**

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

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.

WELDING

Suitable welding methods for Sandvik Sanmac® 316/316L are manual metal-arc welding (MMA) with covered electrodes and gas-shielded arc welding with the TIG and MIG methods as first choice. Preheating and post-weld heat treatment are normally not necessary.

Due to the fact that this material is alloyed in such a way that it shall have good machinability there can be a higher amount of surface oxides on the weld beads compared to standard 316L steels. This may lead to arc instability during TIG welding, especially at autogenous welding. A correct setting of the welding current is of great importance. However, when filler metal is used, the weldability is the same as for standard 316L steels.

When filler metal is used, Sanmac® 316/316L has the same behavior as standard 316/316L at welding.

Since the material has low thermal conductivity and high thermal expansion, welding must be carried out with a low heat input and with welding plans well thought out in advance so that the deformation of the welded joint can be kept under control. If, despite these precautions, it is foreseen that the residual stresses might impair the function of the weldment, we recommend that the entire structure be stress relieved. See recommendations under "
Recommendations of fillermetal:

TIG (GTAW/141)	19.12.3L or19.12.3LSi
MIG (GMAW/131)	19.12.3L or19.12.3LSi
MMA (SMAW/111)	19.12.3L ,19.12.3LSi or19.12.3.LRHD

MACHINING

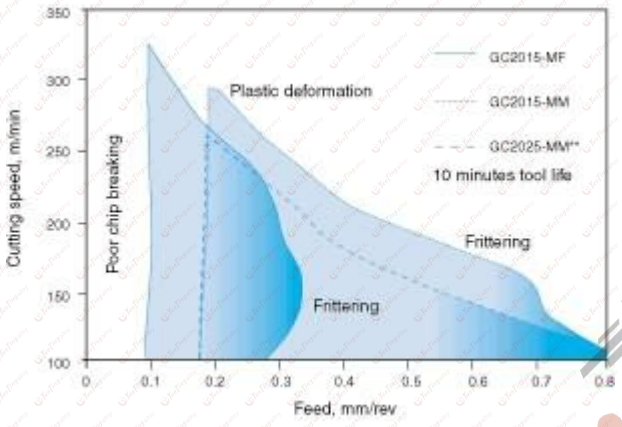
Sanmac® stands for Sandvik Machinability Concept. In Sanmac® materials, machinability has been improved without jeopardizing properties such as corrosion resistance and mechanical strength.

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 (built-up-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.

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

Datasheet updated 6/19/2019 3:13:49 PM (supersedes all previous editions)