Sanmac® 316/316L
Bar
Datasheet

Solid Bar

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

The grade is used for a wide range of industrial applications where steels of types ASTM 304/304L have insufficient corrosion resistance.

Material designations

- ASTM: 316, 316L
- UNS: S31600, S31603
- EN Number: 1.4401, 1.4404
- EN Name: X 5 CrNiMo 17-12-2, X 2 CrNiMo 17-12-2
- W.Nr.: 1.4401, 1.4404

Product standards

- ASTM A-479 / ASME SA-479
- ASTM A-276 / ASME SA-276
- EN 10088-3
- EN 10088-5 (D≤250 mm)
- EN 10272
- NORSOK M-630 2020 Rev.7, MDS S17 Rev.1
- AMS 5648 (D≥70 mm)
- AMS 5653 (D≥70 mm)
- ANSI/NACE MR0175 / ISO 15156-3
- ANSI/NACE MR0103 / ISO 17945-1
- ISO 14067:2018 (CO2e)

Chemical composition and mechanical properties only

- ASTM A-182 / ASME SA-182
- EN 10222-5 (dimensions ≥ 180 mm)

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Approvals

- TÜV AD-Merkblatt W0/TRD 100
- Pressure Equipment Directive / PED (2014/68/EU)
- Pre-approval for PMA, D≤450 mm
- DNV approved manufacturer, D≤450 mm

Climate change impact

Carbon footprint / CO2e data (kg/ton) and Life Cycle Assessment report is available for these products in the range of D 75-450 mm (D3.00”-17.7”).

Material Test Certificate

- According to EN 10204/3.1

Chemical composition (nominal)

Chemical composition (nominal) %

C	Si	Mn	P	S	Cr	Ni	Mo
≤0.030	0.3	1.8	≤0.040	≤0.030	17	10	2.1

Applications

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

Typical examples are machined parts for tube and pipe fittings, valves, components for 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.

Industries

- Chemical industry
- Food industry
- Petrochemical industry
- Pulp & paper industry

Components

- Flanges
- Valves
- Fittings
- Couplings
- Rings
- Seals
- Bolts and Nuts
- Shafts
- Discs

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

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 come into contact with certain solutions, particularly those containing chlorides.

In applications demanding high resistance to stress corrosion cracking, austenitic- ferritic steels, e.g Sanmac®2205+ or SAF®2507+, 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.

The PRE number for Sanmac®316/316L is 24.

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Gas corrosion

Sanmac®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 sulphur, 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

Dimensions and finishes

Sanmac®316/316L is stocked in a number of sizes.

The standard size range for stock comprises 20-450mm.

Solid round bar is supplied in solution annealed, quenched and peel-turned condition.

Lengths

Bars are delivered in random lengths of 3-7 m, depending on diameter.

Tolerances

Diameter, mm	Tolerances, mm
20-30	0/+0.13
>30-50	0/+0.16
>50-70	0/+0.19
>70-95	0/+1.00
>95-285	0/+1.50
>285-350	0/+2.00
>350	0/+3.00

Straightness

	Height of arch, mm/m
Diameter, mm	
Typical value	
20-75	1
>75	2

Surface condition

Diameter, mm	Condition	Typical finish (Ra)
20-200	Burnished	1 µm
>200-350	Peel turned	2 µm
>350	Peel turned	5 µm

Manufacturing

All products are made at the Alleima Tube AB integrated production facility in Sandviken, Sweden.

From raw materials, melting, hot working, heat treatment to finishing and testing.

Heat treatment

Sanmac®316/316L bars are delivered in solution annealed or in-process annealed condition, depending on dimension.

Diameter, mm	HT process
D≤35	Solution annealing at 1050°C (1920°F), followed by water quenching.
D>35-150	In-process annealing acc. to ASTM A-484 above 1010°C (1850°F) and cooled in air.
D>150-350	Solution annealing at 1065°C (1949°F), followed by water quenching.
D>350	Solution annealing at 1050°C (1920°F), followed by water quenching.

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Mechanical properties

Tensile strength at 20°C (68°F)

The following values apply to bar material in both the solution annealed/water quenched and in-process annealed/air quenched conditions.

Proof/Yield strength (min.)		Ultimate tensile strength
$R_{p0.2}$ [a] min.	$R_{p1.0}$ [a] min.	R_m
205 MPa	240 MPa	515-690 MPa
29.5 Ksi	35 Ksi	74.5-100 Ksi

Elongation: ≥40%

1 MPa = 1 N/mm^2
a) $R_{p0.2}$ and $R_{p1.0}$ corresponds to 0.2% offset and 1.0% offset yield strength, respectively.

Impact strength

Due to its austenitic microstructure, Sanmac®316/316L has very good impact strength both at room temperature and at cryogenic temperatures.

The Alleima bar stock program guarantees the following impact strength (Charpy-V longitudinal) at “RT” 20°C / 68°F.

Longitudinal	D≤160 mm	100J average / 70J single
Transversal	D>160 mm	66J average / 42J single

Hardness

Max. 215 HBW

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Physical properties

Relativ magnetic permeability < 2,1
Density: 8.0 g/cm^3 , 0.29 lb/in^3

Thermal conductivity

Temperature		Temperature	
°C	W/m °C	°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		Temperature	
°C	J/kg °C	°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		Temperature	
°C	Per °C	°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		Temperature	
°C	MPa	°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

Hot working

Hot working should be carried out at a material temperature of 900-1200°C (1650-2190°F).
Hot-working of SANMAC® 316/316L shall be followed by rapid cooling in air or in water. If additional heat treatment is needed it should be carried out in accordance with the recommendations given for heat treatment.

Machining

General

Machining is an expression used for a number of subtractive manufacturing methods.

Mainly turning, milling, drilling. But also other operations like cutting, boring, grinding, reaming and tapping.

For solid bars the initial operations primarily are cutting and external turning to prepare a blank for component manufacturing.

Sanmac®

Sanmac® is our trademark for the Alleima machinability concept.

In Sanmac® materials, machinability has been improved without jeopardising properties such as corrosion resistance and mechanical strength.

The improved machinability is owing to optimised:

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

Stainless steels

Materials within the ISO-M material area can be challenging to machine.

The materials vary a lot within the ISO-M group, but in general presents difficult chip control, high cutting forces and tool wear.

In order to get as efficient function and tool life as possible, dedicated cutting tools and strategies to be used.

Getting started

To get it right, the first thing is to know the material to be machined.

As the material properties are input to the selection of start values.

- ISO material group
- Condition/heat treatment
- Actual hardness of the material lot

Consult your cutting tool supplier for start recommendations, since the choice of cutting tools and machine tool set the direction for which start values to use.

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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

IG/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)

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