# Sanmac® 316/316L

## Bar

## Datasheet

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.

Typical applications for Sanmac® 316/316L are machined parts as fittings and flanges and components for valves and pumps.

## Standards

- 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

- EN 10088-3, EN 10088-5 (dimensions up to 250 mm)
- EN 10272, EN 10222-5 (dimensions ≥ 180 mm)
- ASTM A479, A276
- Chemical composition and mechanical properties acc. ASTM A182

### Approvals

- TÜV AD-Merkblatt W0/TRD 100
- Pressure Equipment Directive (2014/68/EU)
- DNV, dimensions up to 450 mm
- Pre approval for PMA

Datasheet last updated 2/28/2024 11:26:22 AM (supersedes all previous editions)

### Certificate

– Status according to EN 10 204/3.1

## 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.

| Industrial categories | Typical applications |
|---|---|
| Chemical industry | Flanges |
| Food industry | Valves |
| Petrochemical industry | Fittings |
| Pulp & paper industry | 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

### 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, 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® 316L/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 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

**Finishes and dimensions**
Sanmac® 316/316L bar steel is stocked in a large number of sizes. The standard size range for stock comprises 40-450 mm.
Round bar is supplied in solution annealed and peel turned condition.

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

**Straightness**

| Diameter<br>mm | Height of arch, mm/m<br>Typical value |
|---|---|
| 20 - 70 | 1 |
| > 70 | 2 |

**Tolerances, mm sizes**

| Diameter, mm | Tolerances, mm |
|---|---|
| 40-45 | -0/+0.16 |
| 50-70 | -0/+0.19 |
| 75-95 | -0/+1.00 |

| | |
|---|---|
| 100-285 | -0/+1.50 |
| 290-350 | -0/+2.00 |
| 360-450 | -0/+3.00 |

**Surface conditions**

| Surface conditions | Ra, µm Typical value | Size, diameter, mm |
|---|---|---|
| Peeled and burnished | 1 | 20-285 |
| Peel turned | 2 | >285 - 350 |
| Rough machined | 5 | >350 |

## Heat treatment

Sanmac® 316/316L bars are delivered in solution annealed condition.

**Solution annealing**
1040–1100°C (1900–2010°F), rapid cooling in air or water.

## Mechanical properties

Bar steel is tested in delivery condition.

### At 20°C (68°F)

**Metric units**

| Proof strength | | Tensile strength | Elong. | Contr. | HB |
|---|---|---|---|---|---|
| $R_{p0.2}$ [a)] | $R_{p1.0}$ [a)] | $R_m$ | A [b)] | Z | |
| MPa | MPa | MPa | % | % | |
| ≥205 | ≥240 | 515-690 | ≥40 | ≥50 | ≤215 |

**Imperial units**

| Proof strength | | Tensile strength | Elong. | Contr. | HB |
|---|---|---|---|---|---|
| $R_{p0.2}$ [a)] | $R_{p1.0}$ [a)] | $R_m$ | A [b)] | Z | |
| ksi | ksi | ksi | % | % | |
| ≥29.5 | ≥35 | 74.5-100 | ≥40 | ≥50 | ≤215 |

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.
b) Based on $L_0 = 5.65\ddot{O}S_0$ , where $L_0$ is the original gauge length and $S_0$ the original cross-section area.

### 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 prEN13445-2(UFPV-2) and EN 10272.

### At high temperatures

**Metric units**

| Temperature | Proof strength | | Tensile strength |
|---|---|---|---|
| °C | $R_{p.02}$ | $R_{p1.0}$ | $R_m$ |
| | MPa | MPa | MPa |
| | min. | min. | min. |
| 100 | 165 | 200 | 430 |
| 200 | 137 | 165 | 390 |
| 300 | 119 | 145 | 380 |
| 400 | 108 | 135 | 380 |
| 500 | 100 | 128 | 360 |

**Imperial units**

| Temperature | Proof strength | | Tensile strength |
|---|---|---|---|
| °F | $R_{p.02}$ | $R_{p1.0}$ | $R_m$ |
| | ksi | ksi | ksi |
| | min. | min. | min. |
| 200 | 24.0 | 29.0 | 62.4 |
| 400 | 19.8 | 23.9 | 56.6 |
| 600 | 17.3 | 21.0 | 55.1 |
| 800 | 15.7 | 19.6 | 55.1 |
| 1000 | 14.5 | 18.6 | 52.2 |

## 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

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
- optimal chemical composition
- optimised 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-029-ENG. Figure 1 shows the ranges within data should be chosen in order to obtain a tool life of minimum 10 minutes when machining austenitic SANMAC materials (304/304L, 316/316L). 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.

[bild] Figure 1. Machining chart SANMAC® 316/316L.

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 optimise cutting data with the aid of the diagram.

### Turning of SANMAC® 304/304L, 316/316L

Recommended insert and cutting data (starting values)

| Insert Geometry | Grade | Cutting data Feed | Cutting speed | Application |
|---|---|---|---|---|
| | | mm/rev | m/min | |
| MF | GC2015 | 0.15 | 250 | Finishing, copy turning |
| MM | GC2015 | 0.30 | 225 | Medium machining |
| MM | GC2025 | 0.30 | 195 | Medium-to-rough machining under less stable conditions |

## 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)



Datasheet last updated 2/28/2024 11:26:22 AM (supersedes all previous editions)