

# Sanmac® 316/316L

## Billets

## Datasheet

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

### 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
- ASTM A-314

Suitable for the production of flanges etc. according to ASTM A-182 Grade F316/316L.

### Certificates

Status according to EN 10 204/3.1

### Chemical composition (nominal) %

| C      | Si  | Mn  | P      | S      | Cr   | Ni | Mo  |
|--------|-----|-----|--------|--------|------|----|-----|
| ≤0.030 | 0.6 | 1.8 | ≤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 AISI 304/304L have insufficient corrosion resistance.

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

|                         |                |
|-------------------------|----------------|
| Pulp and paper industry | Couplings      |
| Nuclear industry        | Rings          |
|                         | Seals          |
|                         | Bolts and nuts |
|                         | Shafts         |
|                         | Forgings       |
|                         | Discs          |

## Corrosion resistance

### General corrosion

Sanmac® 316/316L has good resistance in:

- Organic acids at high concentrations and moderate temperatures
- Inorganic acids, e.g. phosphoric and sulphuric acids, at moderate concentrations and temperatures. The steel can also be used in sulphuric acid with concentrations above 90% at low temperature
- Salt solutions, e.g. sulphates, sulphides and sulphites
- 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 comes into contact with certain solutions, particularly those containing chlorides. In applications demanding high resistance to stress corrosion cracking, we recommend the austenitic-ferritic steel Sanmac® SAF 2205.

### Intergranular corrosion

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

### Pitting and crevice corrosion

Resistance to these types of corrosion improves with an 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, 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

### Sizes and tolerances

Round-cornered square, as well as round billets, are produced in a wide range of sizes according to the following tables. Larger sizes offered on request.

### Surface conditions

#### Square billets

Unground, spot ground or fully ground condition.

#### Round billets

Peel turned or black condition.

#### Square billets

| Size<br>mm              | Tolerance<br>mm | Length<br>m |
|-------------------------|-----------------|-------------|
| 80                      | +/-2            | 4 - 6.3     |
| 100, 114, 126, 140, 150 | +/-3            | 4 - 6.3     |
| 160, 180, 195, 200      | +/-4            | 4 - 6.3     |
| >200 - 350              | +/-5            | 3 - 5.3     |

Sizes and tolerances apply to the rolled/forged condition.

#### Peel turned round billets

| Size<br>mm               | Tolerance<br>mm | Length<br>m |
|--------------------------|-----------------|-------------|
| 75 - 200 (5 mm interval) | +/-1            | max 10      |
| >200 - 450               | +/-3            | 3 - 8       |

#### Unground round billets

| Size<br>mm               | Tolerance<br>mm | Length<br>m |
|--------------------------|-----------------|-------------|
| 77 - 112 (5 mm interval) | +/-2            | max 10      |
| 124, 134                 | +/-2            | max 10      |
| 127, 147, 157            | +/-2            | max 10      |
| 142, 152, 163            | +/-2            | max 10      |
| 168, 178, 188            | +/-2            | max 10      |
| 183, 193                 | +/-2            | max 10      |

## Other products

Solid bar (Sanmac)  
Hollow bar (Sanmac)

## Heat treatment

Sanmac® 316/316L billets are delivered in the hot worked condition. If an another heat treatment is needed after further processing, the following is recommended.

## Solution annealing

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

## Mechanical properties

Testing is performed on separately solution annealed and quenched test pieces. The following figures apply to material in the solution annealed and quenched 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              | %        | %      |         |
|                 |                 |                  |          |        | approx. |
| ≥205            | ≥240            | 515-690          | ≥40      | ≥50    | 170     |

#### Imperial units

| Proof strength  |                 | Tensile strength | Elong.   | Contr. | HB      |
|-----------------|-----------------|------------------|----------|--------|---------|
| $R_{p0.2}^{a)}$ | $R_{p1.0}^{a)}$ | $R_m$            | $A^{b)}$ | Z      |         |
| MPa             | MPa             | MPa              | %        | %      |         |
|                 |                 |                  |          |        | approx. |
| ≥29.5           | ≥35             | 74.5-100         | ≥40      | ≥50    | 170     |

1 MPa = 1 N/mm<sup>2</sup>

a)  $R_{p0.2}$  and  $R_{p1.0}$  correspond to 0.2% offset and 1.0% offset yield strengths, respectively.

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

The **impact energy** (Charpy V) at 20°C (68°F) is min 100 J (74 ft-lb).

## At high temperatures

#### Metric units

| Temperature | Proof strength | Tensile strength |
|-------------|----------------|------------------|
|-------------|----------------|------------------|

|     | $R_{p,0.2}$ | $R_{p1.0}$ | $R_m$ |
|-----|-------------|------------|-------|
| °C  | MPa         | MPa        | MPa   |
|     | min.        | min.       | min.  |
| 100 | 155         | 190        | 450   |
| 200 | 127         | 155        | 400   |
| 300 | 110         | 135        | 380   |
| 400 | 98          | 125        | 380   |
| 500 | 92          | 120        | 360   |

#### Imperial units

| Temperature | Proof strength |            | Tensile strength |
|-------------|----------------|------------|------------------|
|             | $R_{p,0.2}$    | $R_{p1.0}$ | $R_m$            |
| °F          | ksi            | ksi        | ksi              |
|             | min.           | min.       | min.             |
| 200         | 23.1           | 28.1       | 66.1             |
| 400         | 18.3           | 22.4       | 57.9             |
| 600         | 15.7           | 19.3       | 55.1             |
| 800         | 14.0           | 17.9       | 54.3             |
| 1000        | 13.1           | 17.4       | 48.9             |

## Physical properties

Density: 7.9 g/cm<sup>3</sup> , 0.29 lb/in<sup>3</sup>

#### 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 1)

| 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   |

1) Mean values in temperature ranges ( $\times 10^{-6}$ )

### Modulus of elasticity 1)

| 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

1) ( $\times 10^3$ )

## 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 should 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.

## 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. Preheating and post-weld heat treatment are normally not necessary.

Since this material is alloyed in such a way to improve machinability, the amount of surface oxides on the welded beads might be higher compared to standard 316/316L steels. This may lead to arc instability during TIG/GTAW welding, especially welding without filler material. However, the welding behavior of this material is the same as for standard 316/316L 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.

## 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

### General

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

Improved machinability is brought about by:

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

### Machining chart

The diagram shows the ranges, within which data should be chosen in order to obtain a tool life of 10 minutes minimum, when machining the austenitic Sanmac® 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 chattering (chipping) increases significantly. The diagram is applicable for short cutting times. For long, continuous cuts, cutting speeds should be reduced.

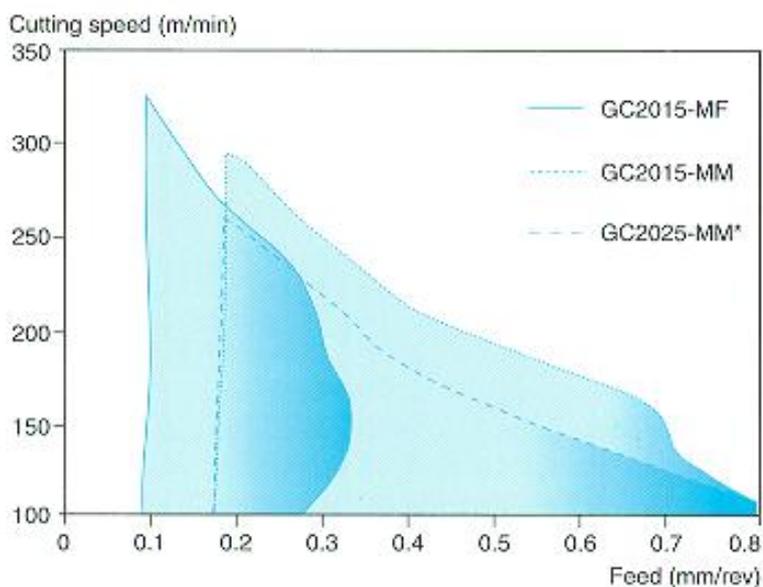


Figure 1. Machining chart for Sanmac® 316/316L.

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 optimize cutting data with the aid of the diagram.

### Turning Sanmac® 316/316L

Recommended insert and cutting data (starting values)

| Insert Geometry | Grade  | Cutting data Feed mm/rev | Cutting speed m/min | Application  |
|-----------------|--------|--------------------------|---------------------|--|
| MF              | GC2015 | 0.15                     | 250                 | Finishing, copy turning                                |
| MM              | GC2015 | 0.30                     | 220                 | Medium machining                                       |
| MM              | GC2025 | 0.30                     | 190                 | Medium-to-rough machining under less stable conditions |

### Drilling Sanmac® 316/316L

The recommended methods for drilling give the most cost effective results for the respective diameter ranges. When producing holes with diameters larger than 58 mm, short hole drilling is used up to 58 mm, followed by internal turning, up to the desired diameter. Cutting data for internal turning should be chosen in accordance with the turning recommendations. The recommendations for drilling are applicable for a tool life of 30 minutes.

### Short hole drilling, diameter 12.7 - 58 mm

Coromant U-drill, R416.2

| Insert Geometry | Grade                      | Cutting data Feed mm/rev | Cutting speed m/min |
|-----------------|----------------------------|--------------------------|---------------------|
| -               |                            |                          |                     |
| -53             | Central insert GC1020      | -                        | -                   |
| -53             | Peripheral insert GC1020*  | 0.04-0.18                | 160                 |
| -53             | Peripheral insert GC3040** | 0.04-0.18                | 200                 |

\* GC1120 for diameters below 17.5 mm

\*\* stable conditions, otherwise use GC1020

### Drilling with Alleima Coromant Delta C drill, diameter 3 - 12.7 mm

Code R415.5. Grade GC1220  
(diameter range 3 - 20 mm)

| Cutting data Feed* mm/rev | Cutting speed m/min |
|---------------------------|---------------------|
| 0.08-0.22                 | 50                  |

\* The lower feed value should be selected for smaller diameters

### Drilling with high speed steel (HSS) drill

(diameter 1-3 mm)

| Cutting data Feed* mm/rev | Cutting speed** m/min |
|---------------------------|-----------------------|
| 0.03-0.09                 | 8-15                  |

\* The lower feed value should be selected for smaller diameters

\*\* The higher cutting speed should be selected for coated drills

### Milling Sanmac® 316/316L

Use of optimum cutting data means that milling can be carried out at cutting speeds above those where there is a risk of built-up edge formation. Dry milling results in long tool life. If coolant is needed (e.g. when the surface cannot be reached in the dry condition), the cutting speed must be reduced by approximately 40-60% to prevent tool wear due to increased thermal load on the inserts.

#### Milling with CoroMill cutters (starting values for dry machining)

| Roughing Geometry/ Grade | Cutting speed m/min | Finishing Geometry/ Grade | Cutting speed m/min |
|--------------------------|---------------------|---------------------------|---------------------|
| MM-2030                  | 185                 | ML-2030                   | 235                 |

## Threading Sanmac® 316/316L

Indexable inserts can be used for external thread cutting of all diameters. Threading with screw-cutting dies or die heads is economical only for small diameters. For internal threading with short and normal cutting lengths, thread cutting with indexable inserts is recommended above a hole diameter of 12 mm. For long cutting lengths, thread cutting with indexable inserts is recommended for hole diameters above 20 mm.

### Thread turning

Due to the tendency of austenitic materials to work harden, radial infeed is recommended. A generous flow of cutting fluid should also be used, partly to obtain a reliable process and partly to guide the chip. The recommendations apply to a tool life of 30 minutes.

| Insert Geometry | Grade  | Cutting speed m/min |
|-----------------|--------|---------------------|
| All-round       | GC1020 | 160                 |

### Thread tapping

Compared with uncoated threading taps, coated threading taps can improve productivity by up to 100%. For the advantages of coated threading taps to be realized, a generous flow of cooling fluid must be used. The recommendations apply to a tool life of 30 minutes.

| Cutting speed m/min |
|---------------------|
| 4-15                |

The higher range of cutting data should be chosen for coated threading taps

## Sawing Sanmac® 316/316L

Cutting with bandsaws or cold saws gives the best cutting economy. If the demand for surface smoothness is great, circular sawing is preferable. Band sawing gives high productivity, is flexible and incurs low investment costs.

When band sawing Sanmac® 316/316L, the Sandflex Cobra type 3851 bimetallic bandsaw blades, which is available from Bahco Group (formerly Sandvik Saws and Tools), is recommended.

Tooth spacing should be selected according to the dimensions of the material to be cut, and stated in TPI (the number of teeth per in.). The TPI should be reduced for thicker dimensions. For a bar dimension of D = 150 mm, 2/3 TPI or 1/2 TPI is recommended.

| Cutting speed m/min |
|---------------------|
| 45-50               |

Feed is regulated to obtain a good chip form.

Disclaimer:

Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when we know the actual service conditions. Continuous development may necessitate changes in technical data without notice. This datasheet is only valid for Alleima materials.