

Sanmac® 4435

Hollow bar

Datasheet

Sanmac® 4435 is a molybdenum-alloyed austenitic chromium-nickel steel with improved machinability, with a guaranteed minimum molybdenum level of 2.5%.

Standards

- ASTM: MT 316L, MT 316
- UNS: S31603, S31600
- EN Number: 1.4435, 1.4436
- EN Name: X2CrNiMo18-14-3, X3CrNiMo17-13-3
- JIS: SUS316TKA

Product standards

- EN 10216-5*, EN 10297-2
- 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	0.2	1.8	≤0.040	≤0.017	17.5	12.5	2.6

Applications

Sanmac® 4435 is used in a wide range of industrial applications where steels of type ASTM 304/304L have insufficient corrosion resistance. Typical applications are :

- Machines 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

Corrosion resistance

General corrosion

Sanmac[®] 4435 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[®] 4435 has a low carbon content and therefore better resistance to intergranular corrosion than other steels of type ASTM 316.

Pitting and crevice corrosion

Resistance to these types of corrosion improves with molybdenum content. Sanmac[®] 4435, containing approximately 2.6% molybdenum, has substantially higher resistance to attack than steels of type AISI 304 and also better resistance than ordinary ASTM 316/316L steels with 2.1% molybdenum.

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[®] SAF[™] 2205 have higher resistance to stress corrosion cracking than 4435.

Gas corrosion

Sanmac[®] 4435 can be used in:

- Air up to 850°C (1560°)
- 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 Sanmac[®] 4435 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[®] 4435 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, S-029-ENG or S-02909-ENG.

Dimensions are given as outside and inside diameter with guaranteed component sizes after machining for OD<2.5 x OD.

Outside diameter +2 / -0 %, but minimum +1 / -0 mm

Inside diameter +0 / -2 %, but minimum +0 / -1 mm

Straightness +/-1.5mm/m

Better tolerances can be supplied to special order.

Other forms of supply

Bar

Steel with improved machinability, Sanmac[®], is also available in round bar and billet.

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)

Solution annealing

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

Mechanical properties

For hollow bar with wall thickness greater than 10 mm (0.4 in.) the proof strength may fall short of the stated values by approximately 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 = 1 N/mm²

- a) $R_{p0.2}$ and $R_{p1.0}$ correspond to 0.2% offset and 1.0% offset yield strength, respectively.
- b) Based on $L_0 = 5.65 \sqrt{S_0}$ where L_0 is the original gauge length and S_0 the original cross-section area.

Impact strength

Due to its austenitic micro structure, Sanmac[®] 4435 has very good impact strength both at room temperature and at cryogenic temperatures.

Tests have demonstrated that the steel fulfils the requirements according to the European standards EN 13445-2 (UFPV-2) (min. 60 J (44 ft-lb) at -270 °C (-455 °F) and EN 10216-5 (min. 60 J (44 ft-lb) at -196 °C (-320 °F).

At high temperatures

Temperature	Proof strength	
°C	$R_{p0.2}$	$R_{p1.0}$
	MPa	MPa
	min.	min.
50	200	230
100	180	215
150	165	195
200	150	180
250	140	170
300	135	160
350	130	155
400	125	150
450	120	145
500	120	145
550	115	140
600	110	135

Imperial units

Temperature	Proof strength	
°F	$R_{p0.2}$	$R_{p1.0}$
	ksi	ksi
	min.	min.
200	26	31
400	21	26
600	19	23
800	18	21
1000	17	20

Physical properties

Density: 8.0 g/cm³, 0.29 lb/in³

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
30-600	18.5	86-1200	10.5
30-700	18.5	86-1400	10.5

Modulus of elasticity, (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

Welding

The weldability of Sanmac® 4435 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.

Due to 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 welded beads compared to standard 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 316L steels when welding with filler material.

For Sanmac® 4435, 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 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-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® 4435 (316L min. 2.5% Molybdenum / EN 1.4435)

[bild]

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 optimise cutting data with the aid of the diagram.

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.