

2. RUST AND ACID-RESISTANT FASTENERS

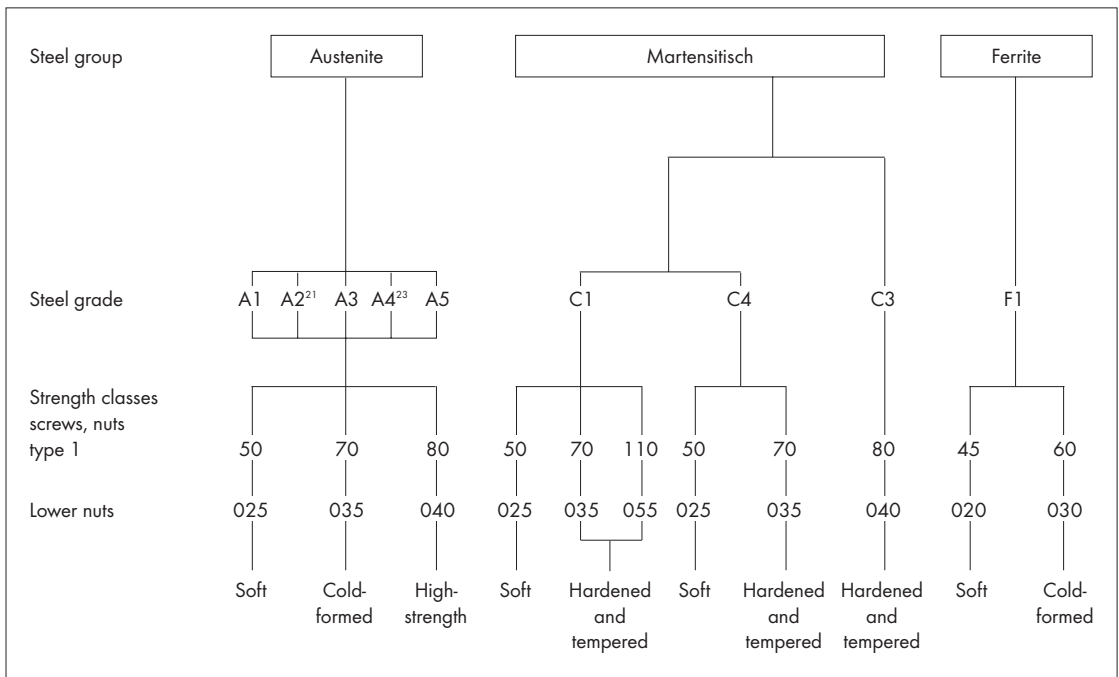
2.1 Mechanical properties

DIN EN ISO 3506 applies to screws and nuts made of stainless steel. There are a great number of stainless steels, which are classified in the three steel groups austenite, ferrite and martensite, whereby austenite steel is the most widespread.

Example:

A2-70
 A Austenite steel
 2 Alloy type in group A
 70 Tensile strength not less than 700 MPa, strain-hardened

The steel groups and the strength classes are designated with a four-character sequence of letters and digits.



Differentiation characteristics of austenite steel grades (in accordance with ISO 3506)

Steel group	Chemical composition in % (maximum values, unless other details provided)								
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu
A1	0.12	1	6.5	0.2	0.15-0.35	16-19	0.7	5-10	1.75-2.25
A2	0.1	1	2	0.05	0.03	15-20	-	8-19	4
A3	0.08	1	2	0.045	0.03	17-19	-	9-12	1
A4	0.08	1	2	0.045	0.03	16-18.5	2-3	10-15	4
A5	0.08	1	2	0.045	0.03	16-18.5	2-3	10.5-14	1

A3 and A5 stabilised against intercrystalline corrosion through adding titanium, niobium or tantalum.

Chemical composition of austenite steels (in accordance with ISO 3506)

The most important stainless steels and their composition

	Material name	Material no.	C %	Si ≤ %	Mn ≤ %	Cr %	Mo %	Ni %	Altri %
A1	X 8 Cr Ni S 18-9	1.4305	≤ 0.10	1.0	2.0	17.0 ÷ 19.0	-	8 ÷ 10	S 0.15 ÷ 0.35
A2	X 5 Cr Ni 1810	1.4301	≤ 0.07	1.0	2.0	17.0 ÷ 20.0	-	8.5 ÷ 10	-
	X 2 Cr Ni 1811	1.4306	≤ 0.03	1.0	2.0	17.0 ÷ 20.0	-	10 ÷ 12.5	-
	X 8 Cr Ni Ti 19/10	1.4303	≤ 0.07	1.0	2.0	17.0 ÷ 20.0	-	10.5 ÷ 12	-
A3	X 6 Cr Ni Ti 1811	1.4541	≤ 0.10	1.0	2.0	17.0 ÷ 19.0	-	9.0 ÷ 11.5	Ti ≥ 5 X % C
A4	X 5 Cr Ni Mo 1712	1.4401	≤ 0.07	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	10.5 ÷ 13.5	-
	X 2 Cr Ni Mo 1712	1.4404	≤ 0.03	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	11 ÷ 14	-
A5	X 6 Cr Ni Mo Ti 1712	1.4571	≤ 0.10	1.0	2.0	16.5 ÷ 18.5	2.0 ÷ 2.5	10.5 ÷ 13.5	Ti ≥ 5 X % C

Tab. 15: Common stainless steels and their chemical composition

Steel grade A1

Steel grade A1 is intended in particular for metal-cutting. Because of the high sulphur content, steels of this grade have lower corrosion resistance than corresponding steels with a normal sulphur content.

Steel grade A2

Grade A2 steels are the more commonly used stainless steels. They are used for kitchen equipment and for apparatus for the chemical industry. Steels of this steel grade are not suitable for use in non-oxidising acids and media containing chloride, e.g. in swimming pools and in sea water.

Steel grade A3

Grade A3 steels are stainless steels stabilised through the addition of titanium, possibly niobium, tantalum, with the properties of A2 steels (stabilised against intercrystalline corrosion, e.g. after welding).

Steel grade A4

Grade A4 steels are "acid-resistant steels" that are molybdenum alloyed and have much better corrosion resistance. A4 steels are used in large volumes in the cellulose industry, because this steel grade was developed for boiling sulphuric acids (which is the reason for the designation "acid-resistant"), and are suitable to a certain extent for environments containing chloride. A4 steels are also used frequently in the food industry and in ship building.

Steel grade A5

Grade A5 steels are stabilised "acid-resistant steels" with properties of grade A4 steels (see A3 as well).

2.1.1 Strength classification of stainless steel screws

DIN EN ISO 3506 puts together the steel grades that are recommended for fasteners. Austenitic steels in grade A2 are used primarily. In contrast, in case of increased corrosion loads chromium-nickel steels from steel grade A4 are used. The mechanical strength values in Table 17 below are to be used for the construction of screw assemblies made of austenitic steel.

Mechanical properties of screws in the austenitic steel groups

Steel group	Steel grade	Strength class	Diameter range	Screws		
				Tensile strength $R_{m}^{1)}$ MPa min.	0.2% offset yield point $R_{p0.2}^{1)}$ MPa min.	Elongation at fracture $A^{2)}$ mm min.
Austenitic	A1, A2, A3, A4 and A5	50	≤ M39	500	210	0.6 d
		70	< M24 ³⁾	700	450	0.4 d
		80	< M24 ³⁾	800	600	0.3 d

¹⁾ The tensile stress is calculated in relation to the tension cross-section (see annex A or DIN EN ISO 3506-1).
²⁾ According to 6.2.4, the elongation at fracture is to be determined at the respective length of the screw and not on turned off specimens. d is the nominal diameter.
³⁾ In case of fasteners with a nominal thread diameter $d > 24$ mm the mechanical properties must be agreed between the user and the manufacturer. They must be marked with the steel grade and strength class in accordance with this table.

Tab. 16: Extract from DIN EN ISO 3506-1

The yield point $R_{p0.2}$ is determined in accordance with DIN EN ISO 3506-1 in the tensile test of whole screws because the strength properties are achieved in part through cold forming.

2.1.2 Apparent yielding point loads for set screws

Austenitic chromium-nickel steels cannot be hardened. A higher yield point can only be achieved through strain hardening that arises as a consequence of cold forming (e.g. round die thread rolling). Table 17 shows apparent yielding point loads for set screws in accordance with DIN EN ISO 3506.

Nominal diameter	Apparent yielding point loads for austenitic steels in accordance with DIN EN ISO 3506 A2 and A4 in N	
	50	70
M5	2,980	6,390
M6	4,220	9,045
M8	7,685	16,470
M10	12,180	26,100
M12	17,700	37,935
M16	32,970	70,650
M20	51,450	110,250
M24	74,130	88,250
M27	96,390	114,750
M30	117,810	140,250

Tab. 17: Apparent yielding point loads for set screws in accordance with DIN EN ISO 3506

2.1.3 Reference values for tightening torques for screws, cf. chapter 6.6

2.2 Corrosion resistance of A2 and A4

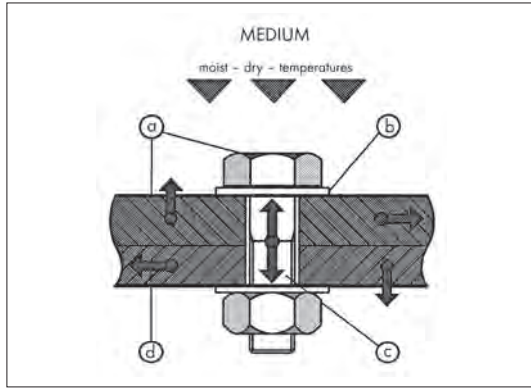
Stainless steels and acid-resistant steels such as A2 and A4 come in the category of "active" corrosion protection.

Stainless steels contain at least 16% chromium (Cr) and are resistant to aggressive oxidising media. Higher Cr contents and additional alloy components, such as nickel (Ni), molybdenum (Mo), titanium (Ti) or niobium (Nb), improve the corrosion resistance. These additives also influence the mechanical properties. Other alloy components are added only to improve the mechanical properties, e.g. nitrogen (N), or the machining capability, e.g. sulphur (S).

Fasteners made of austenitic steels are generally not magnetisable, but a certain amount of magnetisability may be present after the cold forming. However, this does not affect the corrosion resistance. Magnetisation through strain hardening can go so far that the steel part sticks to a magnet.

Under the effect of oxygen stainless steel forms a stable oxide layer (passive layer). This passive layer protects the metal from corrosion.

It should be noted that in practice there are a number of different types of corrosion. The more frequent types of corrosion involving stainless steel are shown below and in the following Fig. J as examples:



- a Surface degrading corrosion, pitting
- b Contact corrosion
- c Stress corrosion cracking
- d Mechanical effects

Fig. K: The most frequent corrosion types with screw assemblies

2.2.1 Surface and degrading corrosion

With uniform surface corrosion, also known as degrading corrosion, the surface is degraded evenly. This type of corrosion can be prevented through a careful selection of the material.

On the basis of laboratory experiments manufacturers have published resistance tables that provide information on the behaviour of the steel grades at different temperatures and concentrations in the individual media (see chapter 2.2.5).

2.2.2 Pitting

Pitting is seen through surface corrosion degrading with the additional formation of cavities and holes. The passive layer is penetrated locally here.

In case of stainless steel in contact with active media containing chloride there is also pitting by itself with pinhole notches in the material. Deposits and rust can also

be the starting point for pitting. For this reason, residues and deposits must be cleaned regularly from all fasteners.

Austenitic steels such as A2 and A4 are more resistant to pitting than ferrite chromium steels.

Classification of the degree of resistance into different groups

Degree of resistance	Assessment	Weight loss in g/m ² h
A	Fully resistant	< 0.1
B	Practically resistant	0.1 - 1.0
C	Less resistant	1.0 - 10
D	Not resistant	> 10

Tab. 22

2.2.3 Contact corrosion

Contact corrosion occurs when two components with different compositions are in metallic contact with each other and there is moisture in the form of an electrolyte. The baser element is attacked and destroyed.

The following points should be observed to prevent contact corrosion:

- Insulating the metals at the contact point, e.g. through rubber, plastics or coatings, so that a contact current cannot flow.
- Where possible, avoid unequal material pairings. As an example, screws, nuts and washers should be matched to the connecting components.
- Make sure that the connection is not in contact with electrolytic active means.
→ cf. chapter 6.8 as well

2.2.4 Stress corrosion cracking

This type of corrosion usually occurs in components used in industrial atmospheres that are under heavy mechanical tensile and bending loads. Internal stresses created by welding can also lead to stress corrosion cracking.

Austenite steels in atmospheres containing chloride are particularly sensitive to stress corrosion cracking. The influence of the temperature is considerable here. The critical temperature is 50 °C.

2.2.5 A2 and A4 in combination with corrosive media

The following table provides an overview of the resistance of A2 and A4 in combination with various corrosive media. The values shown are intended only as reference points but still provide good possibilities for comparisons.

Overview of the chemical resistance of A2 and A4 screws

Corrosive agent	Concentration	Temperature in °C	Degree of resistance A2	Degree of resistance A4
Acetic acid	10%	20 boiling	A A	A A
Acetone	all	all	A	A
Ammoniac	all	20 boiling	A A	A A
Beer	-	all	A	A
Benzene, all types	-	all	A	A
Benzoic acid	all	all	A	A
Benzol	-	all	A	A
Blood	-	20	A	A
Bonderising solution	-	98	A	A
Carbon dioxide	-	-	A	A
Chloride: dry gas, damp gas	-	20 all	A D	A D
Chloroform	all	all	A	A
Chromic acid	10% pure 50% pure	20 boiling 20 boiling	A C B D	A B B D
Citric acid	to 10% 50%	all 20 boiling	A A C	A A B
Copper acetate	-	all	A	A
Copper nitrate	-	-	A	A
Copper sulphate	all	all	A	A
Developer (photogr.)	-	20	A	A
Ethyl alcohol	all	20	A	A
Ethyl ether	-	all	A	A
Fatty acid	technical	150 180 200-235	A B C	A A A
Formic acid	10%	20 boiling	A B	A A
Fruit juices	-	all	A	A
Glycerine	conc.	all	A	A
Hydrochloric acid	0.2% 2% to 10%	20 50 20 50 20	B C D D D	B B D D D

Corrosive agent	Concentration	Temperature in °C	Degree of resistance A2	Degree of resistance A4
Hydrocyanic acid	-	20	A	A
Industrial air	-	-	A	A
Lactic acid	1.5% 10%	all 20 boiling	A A C	A A A
Lemon juice	-	20	A	A
Magnesium sulphate	approx. 26%	all	A	A
Mercury	-	to 50	A	A
Mercury nitrate	-	all	A	A
Methyl alcohol	all	all	A	A
Milk of lime	-	all	A	A
Nitric acid	to 40% 50% 90%	all 20 boiling 20 boiling	A A B A C	A A B A C
Oils (mineral and vegetable)	-	all	A	A
Oxalic acid	10% 50%	20 boiling boiling	B C D	A C C
Petroleum	-	all	A	A
Phenol	pure	boiling	B	A
Phosphoric acid	10% 50% 80% conc.	boiling 20 boiling 20 boiling 20 boiling	A A C B D B D	A A B A C A D
Potassium permanganate	10%	all	A	A
Salicylic acid	-	20	A	A
Seawater	-	20	A	A
Sodium carbonate	cold saturated	all	A	A
Sodium hydroxide	20% 50%	20 boiling 120	A B C	A B C
Sodium nitrate	-	all	A	A
Sodium perchlorate	10%	all	A	A
Sugar solution	-	all	A	A
Sulphur dioxide	-	100-500 900	C D	A C
Sulphuric acid. 1%	to 70% 2.5% 5% 10% 60%	B boiling to 70 boiling 20 > 70 20 70 all	A B B C B B C C D	B A C A B B C D
Sulphurous acid	aqueous solution	20	A	A
Tannic acid	all	all	A	A

Corrosive agent	Concentration	Temperature in °C	Degree of resistance A2	Degree of resistance A4
Tar	-	hot	A	A
Tartaric acid	to 10%	20 boiling	A B	A A
	over 100%	20	A	A
	to 50%	boiling	C	C
75%	boiling	C	C	
Wine	-	20 and hot	A	A

2.2.6 Creation of extraneous rust

Extraneous rust consists of adherent particles of a carbon steel ("normal steel") on the stainless steel surface that turn into rust through the effect of oxygen. If these places are not cleaned and removed, the rust can cause electrochemical pitting corrosion even in stainless steel.

Extraneous rust can be caused by:

- Contact of objects that rust with a stainless steel surface.
- Flying sparks during work with a right angle grinder, or grinding dust. or during welding work.
- Water containing rust dripping onto a stainless steel surface.
- Use of tools that were previously used to work on carbon steel.

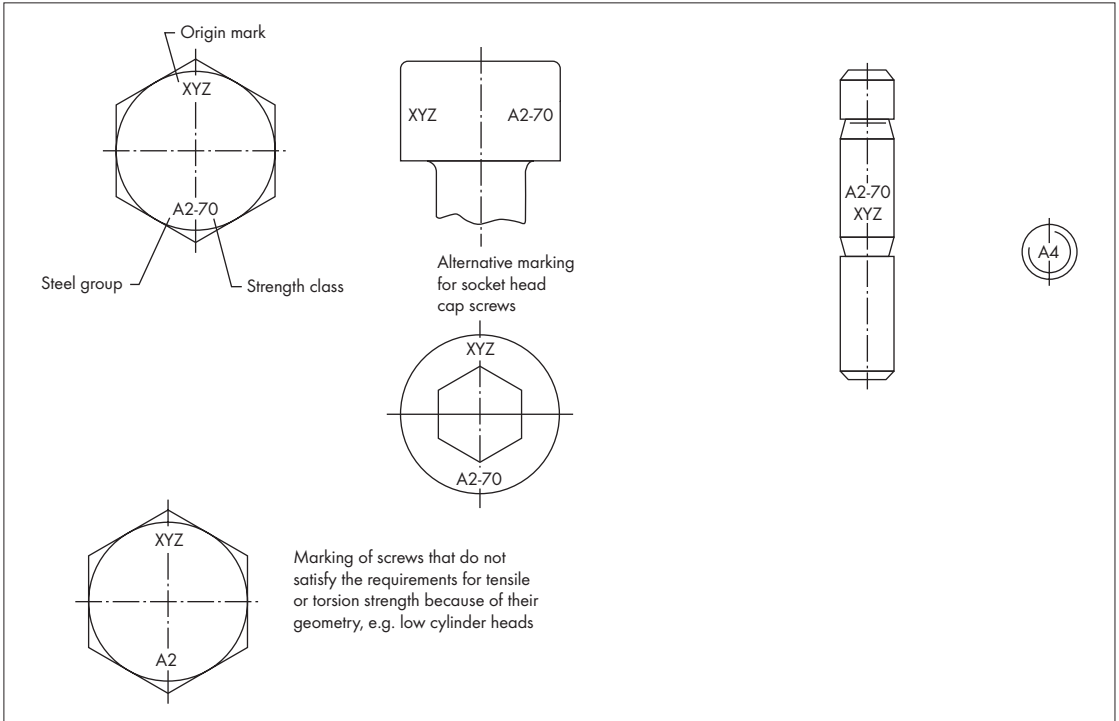


Fig. L: Extract from DIN EN ISO 3506-1

2.3 Marking corrosion-resistant screws and nuts

The marking of corrosion-resistant screws and nuts must contain the steel group, the strength class and the manufacturer's mark.

Marking screws in accordance with DIN EN ISO 3506-1

Hexagon head screws and socket head cap screws from nominal diameter M5 must be clearly marked in accordance with the classification system. Where possible, the marking should be on the screw head.

Marking nuts in accordance with DIN EN ISO 3506-2

Nuts with a nominal thread diameter from 5 mm must be clearly marked in accordance with the classification system. Marking on a single flat is permissible and may only be recessed. Marking on the flats is also permissible as an option.

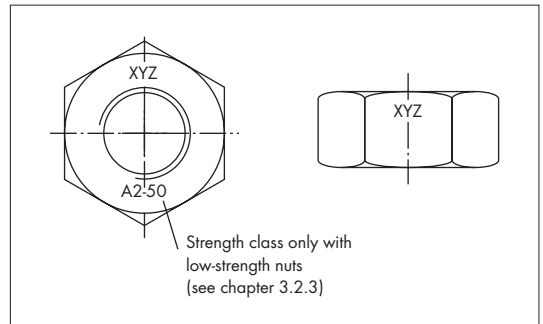


Fig. M: Extract from DIN EN ISO 3506-2