Stainless Steel Material Properties

1. ISO 3506 specifications apply to fasteners (primarily bolts, screws and nuts) made from austenitic grades of corrosion-resistant stainless steels with sizes from 1.6 up to and including 39mm, metric (ISO) thread and also to nuts with widths across flats or outside diameters ≥ 1.45 d and an effective thread engagement of at least 0.6 d.

This International Standard does not define corrosion or oxidation resistance in particular environments. It does specify grades for fasteners made from corrosion-resistant stainless steels. Some have mechanical properties allowing use at temperatures down to -200°C or up to +800°C in air. Acceptable corrosion and oxidation performances and use at elevated or sub-zero temperatures must be subject of agreement between user and manufacturer appropriate to the proposed service environment.

2. Choice of Material

"STAINLESS" steel contains a great number of variants, all with at least 12% chromium (Cr) and mostly also other alloying elements, nickel (Ni) and molybdenum (Mo) being the most important. This extensive field has been divided for fasteners into 3 MATERIAL GROUPS based on their metallurgical structure:

austenitic (A) | martensitic (C) | ferritic (F)

The martensitic and ferritic groups are hardly of any importance to commercial fasteners. They are not available from stock and are only manufactured on order in great quantities.

The austenitic material group (also called chromium-nickel steels) is the most used for fasteners and is further subdivided into 3 steel grades, each with a different resistance to corrosion and a specific field of application.

A1 = a free-cutting quality, having a superior machinability due to a higher phosphorus and sulphur percentage. As a consequence, however, the general corrosion resistance is decreased. This "automatic lathe" stainless steel is seldom used for mass production fasteners.

A2 = the most current steel grade – also called 18/8 (18% Cr, 8% Ni) – with outstanding corrosion resistance under normal atmospheric conditions, in wet surroundings, oxidizing and organic acids, many alkalic and salt solutions.

A4 = the most corrosion resistant steel grade – also called "acid proof" – with an increased nickel percentage and addition of molybdenum. Better resistance to aggressive media such as sea climate (chlorides), industrial atmosphere (sulphur dioxide), oxidizing acids and there where pitting may occur.

Unless otherwise specified fasteners from austenitic stainless steel shall be clean and bright. For maximum corrosion resistance passivation is recommended.

3. Chemical Composition

Below is the table of chemical composition for different stainless steel grades in accordance with ISO 3506-1:1997.

Group	Grade	Chemical Composition, % (m/m) [1)								Notes
		C	Si	Mn	P	S	Cr	Mo	Ni	Cu	
Austenitic	A1	0.12	1	6.5	0.2	0.15 to 0.35	16 to 19	0.7	5 to 10	1.75 to 2.25	2) 3) 4)
	A2	0.1	1	2	0.05	0.03	15 to 20	- 5)	8 to 19	4	7) 8)
	A3	0.08	1	2	0.045	0.03	17 to 19	- 5)	9 to 12	1	9)
	A4	0.08	1	2	0.045	0.03	16 to 18.5	2 to 3	10 to 15	1	8) 10)
	A5	0.08	1	2	0.045	0.03	16 to 18.5	2 to 3	10.5 to 14	1	9) 10)
Martensitic	C1	0.09 to 0.15	1	1	0.05	0.03	11.5 to 14	-	1	-	10)
	C3	0.17 to 0.25	1	1	0.04	0.03	16 to 18	-	1.5 to 2.5	-	
	C4	0.08 to 0.15	1	1.5	0.06	0.15 to 0.35	12 to 14	0.6	1	-	2) 10)
Ferritic	F1	0.12	1	1	0.04	0.03	15 to 18	- 6)	1	-	11) 12)

NOTES
1 A description of the groups and grades of stainless steel also entering into their specific properties and application is given in annex B.
2 Examples for stainless steels which are standardized in ISO 683-13 and in ISO 4954 are given in annexes C and D respectively.
3 Certain materials for specific application are given in annex E.

1) Values are maximum unless otherwise indicated.
2) Sulfur may be replaced by selenium.
3) If the nickel content is below 8%, the minimum manganese content must be 5%.
4) There is no minimum limit to the copper content provided that the nickel content is greater than 8%.
5) Molybdenum may be present at the discretion of the manufacturer. However, if for some applications limiting of the molybdenum content is essential, this must be stated at the time of ordering by the purchaser.
6) Molybdenum may be present at the discretion of the manufacturer.
7) If the chromium content is below 17%, the minimum nickel content should be 12%.
8) For austenitic stainless steels having a maximum carbon content of 0.03%, nitrogen may be present to a maximum of 0.22%.
9) Must contain titanium ≥ 5 x C up to 0.8% maximum for stabilization and be marked appropriately in accordance with this table, or must contain niobium (columbium) and/or tantalum ≥ 10 x C up to 1.0% maximum for stabilization and be marked appropriately in accordance with this table.
10) At the discretion of the manufacturer the carbon content may be higher where required to obtain the specified mechanical properties at larger diameters, but shall not exceed 0.12% for austenitic steels.
11) May contain titanium ≥ 5 x C up to 0.8% maximum.
12) May contain niobium (columbium) and/or tantalum ≥ 10 x C up to 1% maximum.

4. Performance under Different Kinds of Corrosion

4.1 Atmospheric (Chemical) Corrosion

This kind of general corrosion is caused by chemical attack from the atmosphere or aggressive media and is mostly defined as the loss of surface material in µm/year. The attack passes evenly and gradually, mostly visibly and it is checkable. Sudden collapse does not occur, so this type of corrosion is not dangerous.

Generally grade A2 is very satisfactory, but under more aggressive conditions A4 is recommended.

4.2 Contact (Galvanic) Corrosion

When two metals in the presence of an electrolyte create a difference of electrical potential, a galvanic action occurs which causes the lesser noble metal (anode) to corrode and to sacrifice itself, protecting the nobler metal (cathode). The higher the difference in electrical potentials and the larger the contacting area of the nobler metal relative to that of the lesser noble, the more severely this contact corrosion will attack the anode. Passive austenitic stainless steel is relatively noble, whereas fasteners generally have a comparatively small surface in relation to the construction.

Aluminium performs very well, as practice has proven, because of the formation of an insulating layer of aluminium oxide.
Steel and cast iron have to be covered with a closed protective layer e.g. zinc or lacquer.

Copper and brass are applicable, when the fasteners are relatively small. Generally this combination can only be advised when an adequate insulation is applied.

Dry wood will not cause problems. In socked condition pitting corrosion may occur on the long run, however the time of resistance is much longer than with plated steel.

Plastic performs well, although deformation of washers, for example, may cause crevice corrosion.

Asbestos cement and concrete are permissable, given the good experience with, for instance, stainless steel anchors in concrete.

For further information see the contact corrosion table in the next page. In all cases contact corrosion cannot be avoided, the contact areas have to be insulated with, for example, non-acid fat, insulating lacquers or pastes, plastic bushes or washers, insulating tape.

4.3 Intercrystalline Corrosion

Austenitic stainless steel grades A2 and A4 shall not show chromium carbides between 400ºC and 800ºC causing an attack between the material crystals at the grain boundaries. This is achieved by the choice of the right steel type with, for example, either a lower carbon content, or by addition of stabilizing elements e.g. Titanium. For fasteners the first method is the most used.

4.4 Pitting Corrosion

Local pore-like holes may form, growing fast and deep into the material causing the product to be attacked suddenly and severely. This type of corrosion appears especially in halogen (chloride) environments e.g. sea climate and brackish water. A4 offers the best resistance to pitting due to the addition of molybdenum.

4.5 Crevice Corrosion

In presence of an aqueous environment corrosion may occur in crevices, for example, of spring washers and under sediments or layers of paint where insufficient air (oxygen) can circulate to restore the passivity of the stainless steel.

5. Magnetic Properties

Austenitic stainless steel fasteners are normally non-magnetic. The right choice of steel type will limit the permeability (that is the rate of penetration in a magnetic field) to below 1.05 G/Oe.
However after cold working some ability to be magnetized may be evident. In this respect A4 is less sensible than A2 and A1 is the most unfavorable.

Some special applications like for electrotechnical equipment, and in the marine and nuclear industry, require a permeability as close as possible to 1.0. Fasteners on stock are not suitable for these purposes and special non-magnetizable steel types have to be applied in agreement.

Contact Corrosion Table

S = heavy corrosion of the metal given in the horizontal column
G = little or no corrosion of the metal given in the horizontal column
M = moderate corrosion (in very humid atmosphere) of the metal given in the horizontal column

Metal	Surface*	Magnesium alloy	Zinc	Hot dip galv. steel	Aluminium alloy	Cadmium layers	Mild steel	Low alloyed steel	Malleable steel	Chromium steel	Lead	Tin	Copper	Stainless steel
Magnesium-alloy	small		S	S	S	S	S	S	S	S	S	S	S	S
	large		M	M	M	M	S	S	S	S	S	S	S	S
Zinc	small	M		G	S	S	S	S	S	S	S	S	S	S
	large	G		G	G	G	G	G	G	G	G	G	G	G
Hot dip galvanised steel	small	M	G		M	M	S	S	S	S	S	S	S	S
	large	G	G		G	G	G	G	G	G	G	G	G	G
Aluminium alloy	small	M	G	G		G	S		S		S		S	S
	large	G	G	M		G	G	G	M	M	S	S	S	S
Cadmium-layers	small	G	G	G	G		S	S	S	S	S	S	S	S
	large	M	G	M	G		G	G	G	G	G	G	G	G
Mild steel	small	G	G	G	G	G		M	S	S	S	S	S	S
	large	G	G	G	G	G		G	G	G	G	G	G	G
Low alloyed steel	small	G	G	G	G	G	G		G	S	S	S	S	S
	large	G	G	G	G	G	G		G	G	G	G	G	G
Malleable steel	small	G	G	G	G	G	G	M		S	S	S	S	S
	large	G	G	G	G	G	G	G		G	G	G		
Chromium steel	small	G	G	G	G	G	G	G			M	M	S	S
	large	G	G	G	G	G	G	G			G	G		G
Lead	small	G	G	G	G	G	G	G	G	G		G	G	
	large	G	G	G	G	G	G	G	M	G		G		G
Tin	small	G	G	G	G	G	G	G		G		G		
	large	G	G	G	G	G	G	G	G	M		G		
Copper	small	G	G	G	G	G	G	G		M	M	S		
	large	G	G	G	G	G	G	G	G		G	M		G
Stainless steel	small	G	G	G	G	G		G	G		G	G		
	large	G	G	M	G	G	G	G	G	M	M	M	G	

* Relative relationship of the area of this metal surface with respect to the area of the metals given in the adjacent columns.

Chemical Corrosion Table

CHEMICAL AGENT	Hot dip galv. steel	Stainless steel A2	Stainless steel A4	Brass
Acetates		0-1	0	1-2
Acetone		0	0	0
Acetylene		0	0	3
Alcohols	3	0	0	0
Alum		2	1	2
Ammonia gas		0	0	3
Ammonia	3	0	0	3
Benzene/Toluene/Xylene	0	0	0	0
Carbonic acid		0	0	2
Chlorides				
– sodium-/potassium chloride	0	1	1	2
– Ammonia-/zinc chloride		2	1	2
– Iron chloride		3	3	3
Chlorine gas		1	1	1
Chlorine water		1	1	
Citric acid		1	0	2
Formic acid		1	0	2
Glycerol	0	0	0	0-1
Glycol		0	0	1
Hydrogen chloride		2-3	2-3	3
Hydrocarbons	0	0	0	0-1
– Butane, petrol, tar				
hydrocarbons chlorided				
– Trichlore ethylene	0	0	0	0-1
– Tetrachloride	0	0	0	0-1
Hydrogen sulphide		0-1	0	2
Lacquers	0	0	0	1
Nitric acid		1	0-1	3
– Sodium/Ammonia nitrate	0	0	2-3	0
Oil-fuel/vegetable	1	0	0	0
Palmatin/stearin acid		1	0	2
Phosphates	0	1	0	2
Phosphoric acid		2-3	0-1	3
Resins	2-3	1	1	2-3
Sodium carbonate		0	0	1-2
Sulphur dioxide dry		0	0	0-1
Sulphur dioxide wet		1	0	3
Sulphuric acid	3	3	2-3	3
– Sodium/Ammonia-sulphate	1	0	0	1
– Nickel/Copper sulphate		0-1	0	2-3
Water				
– drinking water		0	0	2
– acid water	1-2			3
– salt water	0	1	1	2

0 = GOOD RESISTANCE
1 = MODERATE RESISTANCE
2 = POOR RESISTANCE
3 = NO RESISTANCE

Stainless Steel Mechanical Properties

1. Designation of Property Classes

A characteristic property of austenitic stainless steel is that - contrary to the heat treated steels, which are used for the property classes 8.8, 10.9 and 12.9 - this material cannot be hardened and tempered, but can only be strengthened by cold-working, increasing the mechanical properties considerably.

The 3 austenitic steel grades A1, A2 and A4 are divided into 3 property classes 50, 70 and 80 depending on the method of manufacturing and on sizes. The number of the property class corresponds with 1/10 of the tensile strength in N/mm^2, e.g. class 80 has a minimum tensile strength: 80 x 10 = 800 N/mm^2.

50 = the soft condition of turned and hot-pressed fasteners. This is seldom used for current fasteners.

70 = the most universal and applied property class for all cold-formed fasteners. This class is the standard class and is delivered when no other class is ordered.

80 = the highest property class, having obtained mechanical values by extra cold deformation to the level of the 8.8 heat-treated steel bolts. Exchange does not require a new strength calculation or adaptation of the construction.

2. **Mechanical Properties of Bolts, Screws and Studs for Different Stainless Steel Grades in accordance with ISO3506-1:1997 are given below.**

Group	Grade	Property class	Thread diameter range	Tensile strength R_m 1) min. N/mm^2	Stress at 0.2% permanent strain $R_{p\,0.2}$ 1) min. N/mm^2	Elongation after fracture A 2) min. mm
Austenitic	A1, A2	50	≤ M39	500	210	0.6 d
	A3, A4	70	≤ M24 3)	700	450	0.4 d
	A5	80	≤ M24 3)	800	600	0.3 d

1) The tensile stress is calculated on the stress area (see annex A).
2) To be determined according to 6.2.4 on the actual screw length and not on a prepared test piece; d is the nominal thread diameter.
3) For fasteners with nominal thread diameters d > 24mm the mechanical properties shall be agreed upon between user and manufacturer and marked with grade and property class according to this table.

Group	Grade	Property class	Tensile strength R_m 1) min. N/mm^2	Stress at 0.2 % permanent strain $R_{p\,0.2}$ 1) min. N/mm^2	Elongation after fracture A 2) min. mm	Hardness		
						HB	HRC	HV
Martensitic	C1	50	500	250	0.2 d	147 to 209	-	155 to 220
		70	700	410	0.2 d	209 to 314	20 to 34	220 to 330
		110 3)	1100	820	0.2 d	-	36 to 45	350 to 440
	C3	80	800	640	0.2 d	228 to 323	21 to 35	240 to 340
	C4	50	500	250	0.2 d	147 to 209	-	155 to 220
		70	700	410	0.2 d	209 to 314	20 to 34	220 to 330
Ferritic	F1 4)	45	450	250	0.2 d	128 to 209	-	135 to 220
		60	600	410	0.2 d	171 to 271	-	180 to 285

1) The tensile stress is calculated on the stress area (see annex A).
2) To be determined according to 6.2.4 on the actual screw length and not on a prepared test piece. d is the nominal thread diameter.
3) Hardened and tempered at a minimum tempering temperature of 275°C.
4) Nominal thread diameter d ≤ 24mm.

3. **Mechanical Properties of Nuts for Different Stainless Steel Grades in accordance with ISO 3506-2:1997 are given below.**

Group	Grade	Property class		Range of thread diameter d mm	Stress under proof load S_p min. N/mm^2	
		Nuts style 1 (m ≥ 0.8 d)	Thin nuts (0.5 d ≤ m < 0.8 d)		Nuts style 1 (m ≥ 0.8 d)	Thin nuts (0.5 d ≤ m < 0.8 d)
Austenitic	A1	50	025	≤ 39	500	250
	A2, A3	70	035	≤ 24 1)	700	350
	A4, A5	80	040	≤ 24 1)	800	400

1) For fasteners with nominal thread diameters d > 24 mm the mechanical properties shall be agreed upon between user and manufacturer and marked with grade and property class according to this table.

Group	Grade	Property class		Stress under proof load S_p min. N/mm^2		Hardness		
		Nuts style 1 (m ≥ 0.8 d)	Thin nuts (0.5 d ≤ m < 0.8 d)	Nuts style 1 (m ≥ 0.8 d)	Thin nuts (0.5 d ≤ m < 0.8 d)	HB	HRC	HV
Martensitic	C1	50	025	500	250	147 to 209	-	155 to 220
		70	-	700	-	209 to 314	20 to 34	220 to 330
		110 1)	055 1)	1100	550	-	36 to 45	350 to 440
	C3	80	040	800	400	228 to 323	21 to 35	240 to 340
	C4	50	-	500	-	147 to 209	-	155 to 220
		70	035	700	350	209 to 314	20 to 34	220 to 330
Ferritic	F1 2)	45	020	450	200	128 to 209	-	135 to 220
		60	030	600	300	171 to 271	-	180 to 285

1) Hardened and tempered at a minimum tempering temperature of 275 °C.
2) Nominal thread diameter d ≤ 24 mm.

4. **Marking:**

Stainless steel hexagon head bolts and nuts, socket cap screws of size M5 and greater and all packaging shall be marked with the manufacturer's identification mark and the steel grade followed by the two digits of the property class or in the case of turned nuts on the alternative way of groove marking, see examples below. Marking of studs and other fasteners shall be agreed on by user and manufacturer.