Standard Cr-Ni Stainless Steels

Steel grades

Outokumpu	EN	ASTM
4318	1.4318	301LN
4301	1.4301	304
4307	1.4307	304L
4311	1.4311	304LN
4541	1.4541	321
4306	1.4306	304L

Characteristic properties

- All-purpose grades
- Good corrosion resistance
- Excellent formability
- Excellent weldability
- Excellent impact strength
- Supplied with a range of functional and aesthetic surface finishes

Chemical composition

The chemical composition of specific steel grades may vary slightly between different product standards.

The required standard will be fully met as specified on the order.

General characteristics

This group of steels includes the most widely used stainless chromium-nickel steels. They are general-purpose grades with good resistance to atmospheric corrosion and to many organic and inorganic chemicals.

They are suitable for processing, storing and transporting foodstuffs and beverages. This, together with their good formability and that they are supplied with a wide range of functional and aesthetic surfaces, makes them suitable for use in a variety of applications.

Non-titanium-stabilised grades generally have a better surface finish than titanium-stabilised grades.

These grades are non-magnetic in the annealed condition but may become slightly magnetic as a result of phase transformation to martensite or ferrite after cold working and welding respectively. Some of these grades have higher structural stability than others. This is utilized for grade 4318, which is easily partly transformed to martensite during cold working operations, resulting in an increase of strenght and hardness of the material. On the other hand, if transformations are undesirable grade 4306, which has a slightly higher nickel content making transformations more unlikely, is preferable.

Chemical composition Table 1

AvestaPolarit steel name	International steel no.		Typical composition, %						National steel designations, superseded by EN			
	EN	ASTM	C	N	Cr	Ni	Mo	Others	BS	DIN	NF	SS
4318	1.4318	301LN	0.02	0.14	17.7	6.5	–	–	–	–	Z3 CN 18-07 Az	–
4301	1.4301	304	0.04	–	18.1	8.3	–	–	304S31	1,4301	Z7 CN 18-09	2333
4307	1.4307	304L	0.02	–	18.1	8.3	–	–	304S11	–	Z3 CN 18-10	2352
4311	1.4311	304LN	0.02	0.14	18.5	10.5	–	–	304S61	1.4311	Z3 CN 18-10 Az	2371
4541	1.4541	321	0,04	–	17.3	9.1	–	Ti	321S31	1.4541	Z6 CNT 18-10	2337
4306	1.4306	304L	0.02	–	18.2	10.1	–	–	304S11	1.4306	Z3 CN 18-10	2352
4401	1.4401	316	0.04	–	17.2	10.2	2.1	–	S316S31	1.4401	Z7 CND 17-11-02	2347
4436	1.4436	316	0.04	–	16.9	10.7	2.6	–	316S33	1.4436	Z7 CND 18-12-03	2343
904L	1.4539	904L	0.01	–	20	25	4.3	1.5 Cu	904S13	1.4539	Z2 NCDU 25-20	2562
LDX 2101®	1.4162	S32101	0.03	0.22	21.5	1.5	0.3	5 Mn	–	–	–	–
2304	1.4362	S32304	0.02	0.10	23	4.8	0.3	–	–	1.4362	Z3 CN 23-04 Az	2327
2205	1.4462	S32205*	0.02	0.17	22	5.7	3.1	–	318S13	1.4462	Z3 CND 22-05 Az	2377

* Also available as S31803

Mechanical properties

Outokumpu Stainless uses the European Standard EN10088 where applicable. The permitted design values may vary between product forms, see the relevant specification for the correct value.

The values in Table 2 refer to hot rolled plate/cold rolled strip and sheet. For hot rolled strip, the proof strength corresponds to that of hot rolled plate, and thetensile strength and elongation to that of cold rolled strip.

Mechanical properties. Hot rolled plate/cold rolled strip and sheet, minimum values at 20°C Table 2

Steel grade	Proof strength $R_{p0.2}$ MPa	Proof strength $R_{p1.0}$ MPa	Tensile strength R_m MPa	Elongation A_5 %	Impact value KV J
4318	330/350	370/380	630/650	35/40	60
4307	200/220	240/250	500/520	45/45	60
4301	210/230	250/260	520/540	45/45	60
4311	270/290	310/320	550/550	40/40	60
4541	200/220	240/250	500/520	40/40	60
4306	200/220	240/250	500/520	45/45	60

Mechanical properties. Hot rolled plate/cold rolled strip and sheet, typical values at 20°C Table 3

Steel grade	Proof strength $R_{p0.2}$ MPa	Proof strength $R_{p1.0}$ MPa	Tensile strength R_m MPa	Elongation A_5 %	Hardness HB
4318					
4301	290/300	330/330	600/600	55/55	165/175
4307	280/300	320/330	580/600	55/55	165/175
4311	320/	360/	640/	55/	–/–
4541	250/270	290/310	570/590	55/55	165/160
4306	280/280	320/310	580/580	55/55	165/155

Tensile properties at elevated temperatures.
Proof strength $R_{p0.2}$, MPa, minimum values Table 4a

Steel grade	Temperature, °C 100	200	300	400	500
4318	265	185	170	–	–
4307	147	118	100	89	81
4301	157	127	110	98	92
4311	205	157	136	125	119
4541	176	157	136	125	119
4306	147	118	100	89	81

Tensile properties at elevated temperatures.
Proof strength $R_{p1.0}$, MPa, minimum values Table 4b

Steel grade	Temperature, °C 100	200	300	400	500
4318	300	215	200	–	–
4307	181	147	127	116	109
4301	191	157	135	125	120
4311	240	187	167	156	149
4541	208	186	167	156	149
4306	181	147	127	116	109

Tensile properties at elevated temperatures.
Proof strength R_m, MPa, minimum values Table 4c

Steel grade	Temperature, °C 100	200	300	400	500
4404	530	460	440	–	–
4307	410	360	340	–	–
4301	450	400	380	380	360
4311	490	430	410	–	–
4541	440	390	375	375	360
4306	410	360	340	–	–

Mechanical properties at low temperatures.
Proof strength R_m, MPa, minimum values Table 5

Steel grade	Temp °C	$R_{p0.2}$ MPa	$R_{p1.0}$ MPa	R_m MPa	A_5 %
4307	-80	220	290	830	35
4301	-80	270	350	860	35
4311	-80	350	420	850	40
4541	-80	200	240	855	35
4307	-196	300	400	1200	30
4301	-196	300	400	1250	30
4311	-196	550	650	1250	35
4541	-196	200	240	1200	30

Values from EN 10028-7 (Annex F-informative).

Physical properties

The physical properties are the same for all of these steel grades.

Data according to EN 10088.

Physical properties, typical values at 20°C Table 6

Density	kg/dm³	7.9
Modulus of elasticity	GPa	200
Poissons ratio		0.3
Thermal conductivity	W/m°C	15
Heat capacity	J/kg°C	500
Electrical resistivity	µΩm	0.73

Physical properties at elevated temperatures. Linear expansion (RT→T) x 10^{-6}/°C Table 7a

Steel grade	Temperature, °C				
	100	200	300	400	500
All grades	16.0	16.5	17.0	17.5	18.0

Physical properties at elevated temperatures. Modulus of elasticity, GPa Table 7b

Steel grade	Temperature, °C				
	100	200	300	400	500
All grades	194	186	179	172	165

Corrosion Resistance

The Cr-Ni standard stainless steels have a versatile corrosion resistance and are suitable for a wide range of general-purpose applications. A brief description of their resistance to different types of corrosion follows below. For a more detailed description of their corrosion resistance properties in different environments, please refer to our Corrosion Handbook.

Uniform corrosion

Uniform corrosion is characterised by a uniform attack on the steel surface that has come into contact with a corrosive medium. The corrosion resistance is generally considered good if the corrosion rate is less than 0.1 mm/year. This group of Cr-Ni grades have a good resistance in many organic and inorganic chemicals. Examples of isocorrosion diagrams are shown in figures 1 and 2.

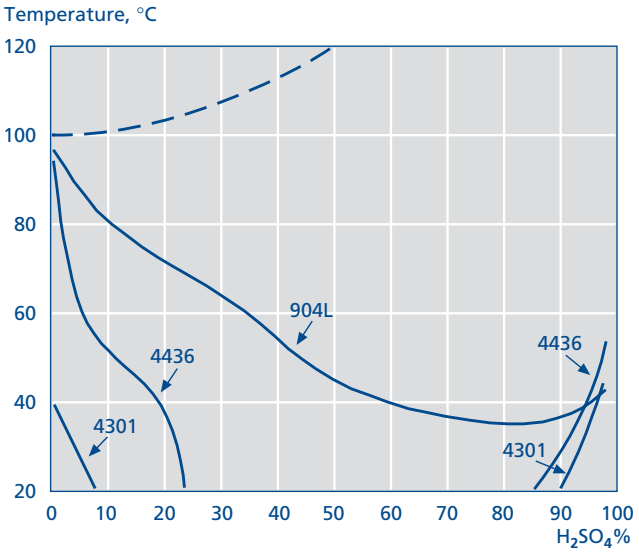

Fig. 1. Isocorrosion diagram for 4301, 4436 and 904L in stagnantsulphuric acid. The curves represent a corrosion rate of 0.1 mm/y. The dashed line represents the boiling point.

Atmospheric corrosion

The resistance to atmospheric corrosion provided by these grades is good. From an appearance point of view, these grades are usually sufficiently resistant in most environments, with the exception of marine and coastal, where 4401 or higher alloyed grades should be used.

In heavy industrial or polluted areas, washing is important to prevent the formation of deposits, which can cause corrosion.

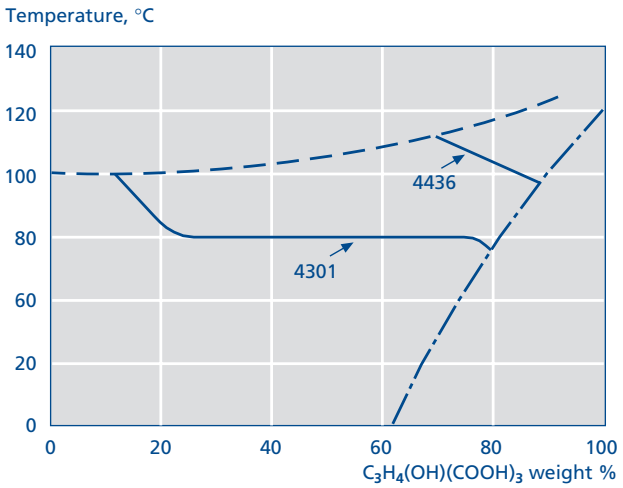

Fig. 2. Isocorrosion diagram, 0.1 mm/year, for stainless steels in citric acid. The dashed line represents the boiling point, the dot-dashed line solubility.

Pitting and crevice corrosion

These corrosion forms typically occur in acidic, neutral or slightly alkaline chloride solutions. The resistance to pitting and crevice corrosion provided by these grades is moderate compared to that offered by other, more highly alloyed stainless steels. They may also be sensitive to these types of corrosion in media with a low chloride content. For better resistance, molybdenum alloyed grades such as 4401 are recommended. The corrosion resistance can be enhanced by increasing the content of chromium, molybdenum and nitrogen.

Figure 3 shows up to which approximate temperatures standard stainless steel can be used in oxygen-saturated solutions of varying chloride content. There is an additional risk of stress corrosion cracking at temperatures above 50°C.

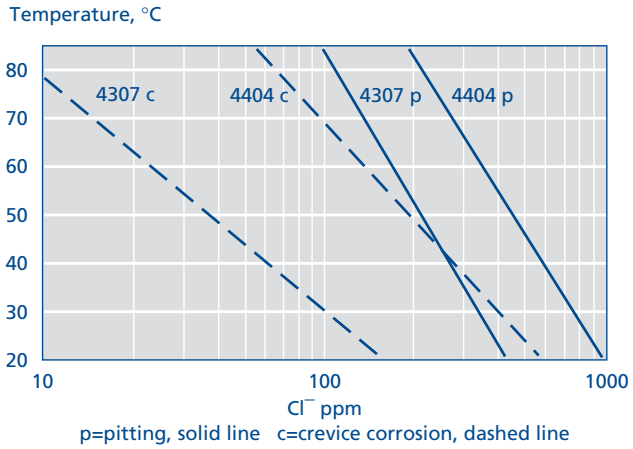

Fig. 3. Risk of pitting and crevice corrosion on conventional stainless steel in water of different chloride content or temperature.

Stress corrosion cracking

This group of austenitic standard Cr-Ni grades are susceptible to stress corrosion cracking (SCC). Critical service conditions, i.e. applications subjected to combinations of tensile stresses, temperatures above about 50°C and solutions containing chlorides, should be avoided.

For applications demanding high resistance to SCC, the duplex grades 2205, 2304 and LDX 201 are more suitable.

Stress corrosion cracking may also occur in hot alkaline solutions (above 110°C).

Intergranular corrosion

Intergranular corrosion is not a common problem for modern stainless steels since the carbon content is generally kept at a low level.

Operations that increase the risk for intergranular corrosion are welding of heavy gauges, heat treatment operations within the critical temperature interval (550 – 850°C) and slow cooling after heat treatment or hot forming. Ti-stabilised steels and steels with low carbon content (0.02%) have better resistance towards intergranular corrosion after such operation conditions.

Fabrication

Hot forming

Hot working can be carried out in the 850 – 1150°C range. For maximum corrosion resistance, forgings should be annealed at 1050°C and rapidly cooled in air or water after hot working operations.

Cold forming

These grades can be readily formed and fabricated by a full range of cold working operations. They can be used in heading, drawing and bending. Any cold working operations will increase the strength and hardness of the material and may leave it slightly magnetic (see Figure 4). Work hardening is aaccentuated by the partial transformation of the austenite phase of the material to hard martensite. At lower contents of alloying elements, the stability of the austenite decreases; more martensite is formed during cold working, which may make the cold working operation more difficult and lead to embrittlement of the product. In many cases, a grade with a more stable austenitic structure is preferable for cold working purposes, e.g. 4306. For more information on deep drawing, contact Avesta Research Centre.

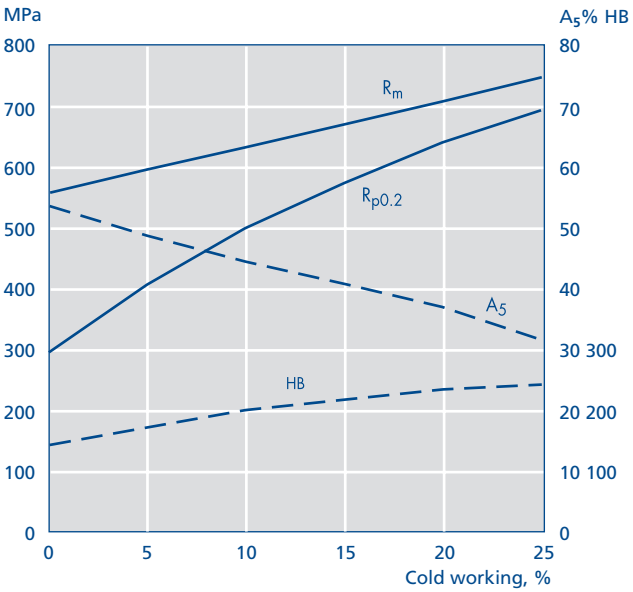

Fig. 4. 4301 work-hardening at cold working

Heat tratment

Annealing

Quench annealing should be performed at 1000 – 1100°C and followed by rapid cooling in water or air. For Ti-stabilised grades, annealing temperatures above 1070°C may impair the resistance to intergranular corrosion.

Ti-stabilised grades may also be given a stabilising treatment at lower temperatures. However, temperatures below 980°C should only be used after due consideration of the intended service environment.

In applications where high residual stresses cannot be accepted, stress relief treatment may be necessary. This can be performed by annealing as outlined above, but may also be performed at lower temperatures. Please contact Outokumpu Stainless for further information.

Hardening
These grades cannot be hardened by heat treatment. However, they can be hardened by cold working.

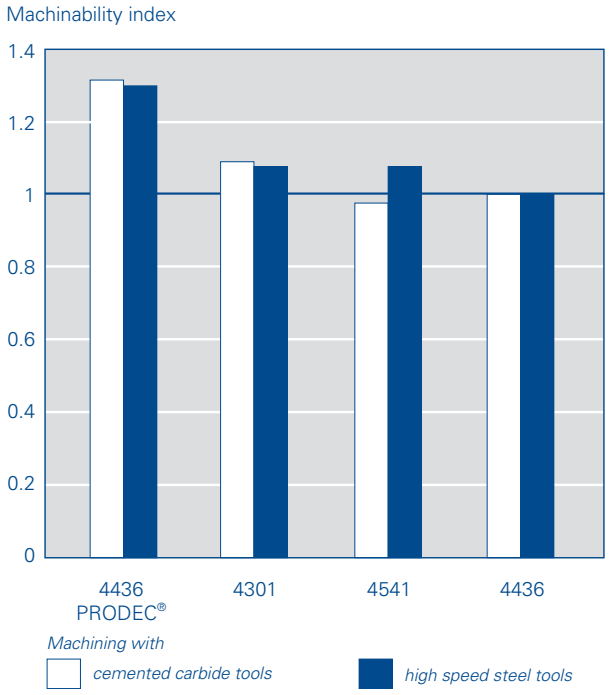

Fig. 5. Relative machinability for som stainless steel grades

Machining

These austenitic grades are more difficult to machine than ordinary carbon steels but are still comparatively easy to machine compared to more highly alloyed stainless grades. Unless modified for improved machinability, they require higher cutting forces than carbon steels, show resistance to chip breaking and a high tendency to built-up edge formation. The best machining results are obtained by using high-power equipment, sharp tooling and a rigid set-up.

The machinability of these grades in relation to other stainless steels is indicated by the machinability index given in Figure 5. This index, which rises with increased machinability, is based on a compounded evaluation of test data from several different machining operations. It gives an indication of the machinability of different stainless steel grades compared to that of grade 4436. It should be noted that it does not describe the relative difficulty of machining with cemented carbide and high speed steel tools. Nitrogen alloyed stainless steels are more difficult to machine.

Better machinability performance is given by PRODEC versions, which have been modified for improved machinability. PRODEC is available as hot rolled plate and bar in 4301 and 4307.

For more information, contact Avesta Research Centre.

Welding

These grades can be readily welded by a full range of conventional welding methods such as:

- Shielded metal arc welding (SMAW)
- Gas tungsten arc welding, TIG (GTAW)
- Gas metal arc welding, MIG (GMAW)
- Flux-cored arc welding (FCAW)
- Plasma arc welding (PAW)
- Submerged arc welding (SAW)

The following welding filler metals from Avesta Welding are recommended:

Table 8

Steelgrade	Filler
4318	308L/MVR
4301	308L/MVR
4307	308L/MVR
4311	308L/MVR
4541	347L/MVNb, 308L/MVR
4306	308L/MVR

Molybdenum containing austenitic stainless steel filler metals may also be suitable for some applications. For further information, contact Avesta Welding or see www.avestawelding.com

Products

- Hot rolled plate, sheet and strip
- Cold rolled plate, sheet and coil
- Cold rolled narrow strip
- Welded tube and pipe
- Bar
- Rod
- Billet
- Welding consumables

Material Standards

Table 9

EN 10088-1	Stainless steels – List of stainless steels (Not for ordering)
EN 10088-2	Stainless steels – Sheet/plate and strip for general purposes
EN 10088-3	Stainless steels – Semi-finished products, bars, rods, sections for general purposes
EN 10028-7	Flat products for pressure purposes – Stainless steels
EN 10272	Stainless steel bars for pressure purposes
ASTM A480	General requirements for flat-rolled stainless and heat resisting steel
ASTM A959	Harmonized standard grade compositions for wrought stainless
ASTM A240/ASME SA-240	Heat-resisting Cr and Cr-Ni stainless steel plate, sheet and strip for pressure vessels
ASTM A666/ASME SA-666	Austenitic stainless steel sheet, strip, plate, bar for structural and architectural applications

1197EN-GB:3. Centrum Tryck AB, Avesta, Sweden. March 2006.

Outokumpu is a dynamic metals and technology group with a clear target to become the number one in stainless steel. Customer in a wide range of industries use our metal products, technologies and services worldwide. We are dedicated to helping our customers gain competitive advantage. We call this promise the Outokumpu factor.

Outokumpu Stainless AB, Avesta Research Centre
Box 74, SE-774 22 Avesta, Sweden
Tel. +46 (0)226 810 00, Fax +46 (0)226 810 77