Stainless Steel – Specifications, Grades and Properties

The name stainless steel covers a variety of corrosion resistant steels that contain a minimum of 11% Chromium. Changing the Chromium content and adding other elements like Nickel, Molybdenum, Titanium and Niobium changes the mechanical and physical properties of the steel.

This results in hundreds of different grades of stainless steel that are covered by a range of national and international standards.

Grade Families

Each one of the grades is grouped into one of five stainless steel families. These families are named after their metallurgical microstructure. The five groups are austenitic, ferritic, duplex, martensitic and precipitation hardening.

Ferritic Stainless Steels

The lack of other alloying elements means ferritic stainless steels are known as plain Chromium steels. They have a Chromium content between 12 and 18%. The carbon content in ferritic stainless steels is very low.

Ferritic stainless steels:

- Have moderate corrosion resistance
- Are not susceptible to stress corrosion
- Are magnetic
- Cannot be hardened by heat treatment
- Are always used in the annealed condition
- Poor weldability for most grades

Common ferritic grades include the proprietary grade 430 stainless steel and the cheapest stainless steel, grade 409 stainless steel. 409 stainless steel is the material of choice for automotive exhausts due to its combination of low price, corrosion resistance and excellent formability.

Austenitic Stainless Steels

Adding nickel to stainless steel in sufficient amounts, changes the microstructure to “austenite”.

70% of commercially produced stainless steels are austenitic. The most common grade of austenitic stainless steel is 304 (1.4301). Globally, 304 accounts for more than 50% of stainless steel consumed. A common name for 304 stainless is 18/8. This name refers to the average composition, 18% chromium and 8% nickel. It is sometimes used generically for austenitic stainless steels other than 304, even if the actual composition is vastly different.

Some of the features of austenitic stainless steels include:

- Excellent corrosion resistance
- Non-magnetic when annealed
- Rapidly work harden with cold work
- Not hardenable by heat treatment
- Ductile and readily formable
- Excellent weldability
- Hygienic with excellent cleanability
- Good performance at high temperatures
- Excellent performance at low temperatures

Other than 304 stainless steel, other common austenitic grades include the popular marine grade, 316 stainless steel and the machining bar grade, 303 stainless steel.

Martensitic Stainless Steels

The first stainless steels to be developed for commercial applications were martensitic stainless steels. These steels were used for cutlery. When compared with other stainless steels, the martensitic stainless group have a relatively high carbon content (0.1 - 1.2%). Like ferritic stainless steels, they are plain chromium steels containing between 12 and 18% chromium.

Features of martensitic stainless steels include:

Martensitic Stainless Steels continued…

- Moderate corrosion resistance
- Heat treatable
- Magnetic
- Inability to be cold formed
- Poor weldability

Martensitic grades include 420 stainless steel, which is used in engineering applications like shafts and 440C stainless steel – the hardest and most abrasion resistant of all the stainless steels.

Duplex Stainless Steels

Duplex stainless steels get their name from the fact that they contain both a ferritic and austenitic microstructure. They have a relatively high chromium content of between 18 and 28%. Nickel content is moderate at 4.5 to 8%.

At this level, the nickel content is too low to generate a fully austenitic structure. This results in a duplex microstructure containing both ferritic and austenitic phases.

Duplex stainless steels also tend to contain 2.5-4% molybdenum.

The prime advantage of duplex stainless is the combination of properties derived from both austenitic and ferritic stainless steels.

Duplex stainless steels have:

- Excellent corrosion resistance
- Increased resistance to chloride attack
- Good resistance to stress corrosion cracking
- Tensile and yield strength higher than austenitic or ferritic grades
- Good weldability
- Good formability

With excellent corrosion resistance the common duplex grade, 2205 stainless steel, is used in heat exchangers, chemical tanks and refineries.

Precipitation Hardening Grades

Precipitation hardening stainless steels can be martensitic, semi-austenitic or austenitic. They offer the combined properties of corrosion resistance from austenitic grades with the heat treatability of martensitic grades.

Precipitation hardening grades, like 17-4 PH (also known as 630 stainless steel), are supplied as solution treated bars. They can then be machined before hardening.

The hardening process is a single, low temperature, ageing step.

Properties of precipitation hardening grades include:

- Good to moderate corrosion resistance
- Good weldability
- Very high strength
- Magnetic

Specifications

Grade compositions, mechanical properties and production specifications are governed by a range of international and national standards for stainless steel. While the old AISI three digit stainless steel numbering system (e.g. 304 and 316) is still commonly used for the classification of stainless steel grades, new classification systems have been developed.

These systems include a 1-letter + 5-digit UNS number, like S30400, as defined by SAE and ASTM. European countries are adopting unified Euronorm standards. These countries are either replacing or adapting their own country specific standards to mirror the Euronorm standards. Other designations being replaced include old BS and EN numbers like 304S31 and 58E.

Some grades are not covered by standard numbers and could be proprietary grades or be named using standards for specialist products like welding wire.

Stainless steel standards are explained in detail in the British Stainless Steel Association “Guide to Stainless Steel Specifications”, also known as the BSSA “Blue Guide”.

The following table lists a range of stainless steel grades, their old BS designation, new UNS number and new EN designation. ▶

Specifications continued...

Grade	UNS No	BS	Euronorm No.
301	S30100	301S21	1.4310
302	S30200	302S25	1.4319
303	S30300	303S31	1.4305
304	S30400	304S31	1.4301
304L	S30403	304S11	1.4306
304H	S30409	-	1.4948
(302HQ)	S30430	394S17	1.4567
305	S30500	305S19	1.4303
309S	S30908	309S24	1.4833
310	S31000	310S24	1.4840
310S	S31008	310S16	1.4845
314	S31400	314S25	1.4841
316	S31600	316S31	1.4401
316L	S31603	316S11	1.4404
316H	S31609	316S51	-
316Ti	S31635	320S31	1.4571
321	S32100	321S31	1.4541
347	S34700	347S31	1.4550
403	S40300	403S17	1.4000
405	S40500	405S17	1.4002
409	S40900	409S19	1.4512
410	S41000	410S21	1.4006
416	S41600	416S21	1.4005
420	S42000	420S37	1.4021
430	S43000	430S17	1.4016
440C	S44004	-	1.4125
444	S44400	-	1.4521
630	S17400	-	1.4542
(904L)	N08904	904S13	1.4539
(253MA)	S30815	-	1.4835
(2205)	S31803	318S13	1.4462
(3CR12)	S41003	-	1.4003
(4565S)	S34565	-	1.4565
(Zeron100)	S32760	-	1.4501
(UR52N+)	S32520	-	1.4507

ASTM does not recognise the designations in brackets. Many other grades and specifications are available.

Material supplied by Aalco has been manufactured to comply with a number of standards depending upon the product. Standards also cover the finish of the material.

Mechanical Properties

Required mechanical properties are normally given in purchase specifications for stainless steels. Minimum mechanical properties are also given by the various standards relevant to the material and product form. Meeting these standard mechanical properties indicates that the material has been properly manufactured to an appropriate quality system. Engineers can then confidently utilise the material in structures that meet safe working loads and pressures.

Mechanical properties specified for flat rolled products are normally tensile strength, yield stress (or proof stress), elongation and Brinell or Rockwell hardness. Property requirements for bar, tube, pipe and fittings typically state tensile strength and yield stress.

Yield Strength

Unlike mild steels, the yield strength of annealed austenitic stainless steels is a very low proportion of the tensile strength. Mild steel yield strength is typically 65-70% of the tensile strength. This figure tends to only be 40-45% in the austenitic stainless family.

Cold working rapidly and greatly increases the yield strength. Some forms of stainless steel, like spring tempered wire, can be cold worked to lift the yield strength to 80-95% of the tensile strength.

Tensile Strength

Tensile strength is generally the only mechanical property required to define bar and wire products. Identical material grades may be used at various tensile strengths for completely different applications. The supplied tensile strength of bar and wire products directly relates to the final use after fabrication.

Spring wire tends to have the highest tensile strength after fabrication. The high strength is imparted by cold working into coiled springs. Without this high strength the wire would not function properly as a spring.

Such high tensile strengths are not required for wire to be used in forming or weaving processes. Wire or bar used as raw material for fasteners, like bolts and screws, needs to be soft enough for a head and thread to be formed but still strong enough to perform adequately in service.

The different families of stainless steels tend to have different tensile and yield strengths. These typical strengths for annealed material are outlined in the following table:

	Tensile Strength	Yield Strength
Austenitic	600	250
Duplex	700	450
Ferritic	500	280
Martensitic	650	350
Precipitation Hardening	1100	1000

Ductility

The combination of high work hardening rates and high elongation / ductility makes stainless steels very easy to fabricate. With this property combination, stainless steel can be severely deformed in operations like deep drawing.

Ductility is normally measured as the % elongation before fracture during tensile testing. Annealed austenitic stainless steels have exceptionally high elongations. Typical figures are 60-70%.

Hardness

Hardness is the resistance to penetration of the material surface. Hardness testers measure the depth that a very hard indenter can be pushed into the surface of a material. Brinell, Rockwell and Vickers machines are used. Each of these has a different shaped indenter and method of applying the known force. Conversions between the different scales are therefore only approximate.

Martensitic and precipitation hardening grades can be hardened by heat treatment. Other grades can be hardened through cold working.

Physical Properties

The reason for choosing stainless steel is normally due to advantages given by physical properties such as corrosion resistance.

In addition to corrosion resistance, the advantageous physical properties of stainless steel include:

- High and low temperature resistance
- Ease of fabrication
- High Strength
- Aesthetic appeal
- Hygiene and ease of cleaning
- Long life cycle
- Recyclable
- Low magnetic permeability

Corrosion Resistance

Good corrosion resistance is a feature of all stainless steels. Low alloy grades can resist corrosion in normal conditions. Higher alloys resist corrosion by most acids, alkaline solutions and chloride environments.

The corrosion resistance of stainless steels is due to their chromium content. In general, stainless steels contain a minimum of around 10.5% chromium. The chromium in the alloy forms a self-healing protective clear oxide layer that forms spontaneously in air. The self healing nature of the oxide layer means the corrosion resistance remains intact regardless of fabrication methods. Even if the material surface is cut or damaged, it will self heal and corrosion resistance will be maintained.

Extreme Temperature Resistance

Some stainless steel grades can resist scaling and retain high strength at very high temperatures. Other grades maintain high mechanical properties at cryogenic temperatures.

Simple Fabrication

Most grades of stainless steel can be cut, welded, formed, machined and fabricated using standard methods and equipment used for other types of steel.

High Strength

Component designs and fabrication methods can be altered to take advantage of the work hardening of stainless steels that occurs when they are cold worked. The resultant high strengths can allow the use of thinner material, leading to lower weights and costs.

Other stainless steels can be heat treated to increase strength.

Aesthetic Appeal

Stainless steel can be supplied with a range of surface finishes. It can also be polished after fabrication to give the desired finish. The finish of stainless steel is easy to clean and maintain.

Hygiene and Ease of Cleaning

Stainless steel is non-toxic and readily cleaned. This makes stainless steel the material of choice for use in hospitals, kitchens, food, drink and pharmaceutical processing plants.

Long Life Cycle

The durability and corrosion resistance of stainless steel means it will outlast many competing products. The low maintenance characteristics also add to stainless steel often being the lowest cost choice in a life cycle cost comparison.

Recyclable

Stainless steel is fully recyclable. New stainless steel normally contains between 50 and 80% recycled material. Scrap stainless steel can be stored without degradation to its value as a raw material.

Magnetic Permeability

Magnetic permeability is the ability of a material to attract a magnet. The austenitic grades are the only stainless steel grades that are not magnetic. Cold working can induce a limited degree of magnetism in austenitic grades other than 310 and 316 stainless steels.