



Stainless Steel

Properties, Applications and Classifications

Contents

Properties and uses of stainless steel

International classification schemes

Austenitic, Ferritic and Martensitic stainless steel

Superalloys, duplex, precipitation and casting grades

32 selected stainless steels, with properties, applications, and
international equivalent grades

Sheet bend radius tables

Table of available finishes

Stainless Steel

Introduction

Stainless steel is a ferrous alloy containing a minimum 10% Chromium (4% in the US). The steel exhibits a combination of corrosion resistance, strength at high temperatures, and ductility at very low temperatures that cannot be matched by any material of similar cost. It has been crucial in the growth of the food processing, chemical, and energy supply industries. Since its initial development, the basic stainless steel has evolved into several groups of alloys including Ferritic, Martensitic, and Austenitic steels. Applications include human body implants, domestic cutlery, decorative trim, catering equipment, goods vehicle bodies, and car exhausts. It is often more expensive than plain carbon steel. Stainless steels can be soldered (using a phosphoric acid flux), brazed and welded. Stainless steels are relatively poor conductors of heat and electricity. Machinability is good, but slow cutting speeds are required, and rapid work hardening can cause problems. The material is commonly used in sheet form, with its corrosion-resistant surface visible, being supplied ready-polished, wire brushed, or textured by rolling or grit blasting.

- Since it is often left unpainted, features giving rise to unsightly spot-weld marks or sealant residues should be kept away from presentation surfaces.
- Stainless steel forms a tenacious hard oxide film, which provides good adhesion for paint and adhesive. If stainless steel is to be painted, etch primers should be avoided – they make adhesion worse.

Classification

AISI and UNS grade designations are used in the US. AISI groupings for stainless steels are as follows:

AISI GROUP	MEANING
2xx	Low nickel Austenitic grades
3xx	Basic Austenitic grades
4xx	Basic Ferritic and Martensitic grades
6xx	Special treatment grades. 'Superalloys'.
xxxL	Low carbon (<0.03%), provides extra corrosion resistance after welding
xxxH	High carbon (0.04% - 10%), for strength at very high temperatures

The relationship between UNS designations and AISI designations is generally straightforward. For example, AISI grade 316 is equivalent to UNS S31600. The UNS designation may have adjustments to the last 2 digits to indicate minor variants.

In UK/Europe, the preferred stainless steel designations are those given in BS EN 10088 (1995). In addition, heat-resisting grades are described in BS EN 10095. In the UK, the move from British to European standards means that the old BS 970 (1970), BS 1449, and BS 1554 designations (for example BS 970 grade 430S17, the British equivalent of AISI grade 430) are becoming obsolete in favor of European designations (for example 1.4016). This

means that the translation of designations from UK to US grades will no longer be intuitive, and equivalents must be individually identified. Obsolescent BS 970 (1970 onwards) grades are included in the table of stainless steel equivalents, since they are still used by metal suppliers in the UK and elsewhere.

CAUTION:

An older version of BS 970, published in 1955, gives UK steel designations according to their 'En number', which is usually 2 or 3 digits in length, for example 1A, 16, 19A, etc. 'En' numbers (emergency numbers) have absolutely nothing to do with European EN designations. European EN designations (BS EN when published in the UK) take the form of 5 digits separated by a dot, for example 1.4016. There is a risk of confusion since the obsolete BS 970 (1955) 'En' numbers are frequently published alongside their BS 970 (1970 onwards) equivalents.

Austenitic (200/300 series)

This group contains the most commonly used stainless steels, based on 18%Cr and 8%Ni (the origin of the phrase '18-8 stainless steel'), typified by grade 304. They are generally non-magnetic, cannot be hardened by heat treatment, but tend to harden by cold working, after which they appear slightly magnetic. Properties hold up over a wide temperature range, and weldability is excellent. They are the most corrosion resistant of the stainless steels and are used for car exhaust parts, hospital equipment, marine pipes and fittings, components in the food, chemical, gas and oil industries, washing machine drums and domestic appliances.

Ferritic (400 series)

This group of alloys, generally containing only chromium, with the balance mostly Fe, are based upon the type 430 composition of 17% Cr, with a little added molybdenum for improved corrosion resistance. These alloys are slightly less ductile than the austenitic types and again are not generally hardenable by heat treatment, but they can be cold worked and can be annealed. They are magnetic and were developed to resist stress corrosion cracking. Machinability is good and the grades are weldable, although welding brings an increased risk of embrittlement. Corrosion resistance is between that of Austenitic and Martensitic grades. Generally the least expensive grades, they are used for decorative trim on domestic products and vehicles, for car exhausts, catering equipment and pressed metal sinks.

Martensitic (400 series)

The members of this family of stainless steels may be hardened and tempered just like alloy steels. Their basic building block is type 410 which consists of 12% Cr and 0.12% C. They are magnetic and can be hardened and tempered by heat treatment to give tensile strengths in the range 550-1000 N/mm², being used where there is a need for specific hardness and strength combined with wear resistance. Corrosion resistance is good in water, steam and weak acids, but relatively poor in more corrosive environments. They can be formed and welded, but not as readily as the austenitics. Typical applications include cutlery, valves, spindles and shafts, surgical instruments, and fasteners.

Superalloys (600 series)

The Ferrous superalloys (as distinct from Cobalt or Nickel superalloys) were developed for very high temperature applications, retaining strength, creep resistance, corrosion

resistance and wear resistance. Martensitic superalloys are useful up to about 550°C. For higher temperatures, Austenitic superalloys are preferred. Used in high temperature aircraft bearings (rotary and sliding). The alloys can be hot or cold worked, but welding requires care.

Precipitation-Hardening

These alloys generally contain Cr and less than 8% Ni, with other elements in small amounts. As the name implies, they can be hardened by heat treatment.

Duplex

This is a stainless steel alloy with two distinct microstructure phases – ferrite and austenite. The Duplex alloys have greater resistance to chloride stress corrosion cracking and higher strength than the other austenitic or ferritic grades.

Cast

The cast stainless steels, in general, are similar to the equivalent wrought alloys. Most of the cast alloys are direct derivatives of one of the wrought grades. For example C-8 is the cast equivalent of wrought type 304. The C preceding a designation means that the alloy is primarily used for resistance to liquid corrosion. An H designation indicates high temperature applications.

Selected Wrought Stainless Steels

AISI ASTM (USA)	BS970 BS1449 BS1554 (UK)	EN 10088 10095 (Eur)	PROPERTIES	MACHINING	FORMING	WELDING	CORROSION RESISTANCE	APPLICATIONS
AUSTENITIC GRADES (BASED ON BS EN 10088-1 RANGES):								
201 202	202S16	1.4372 1.3965	Low nickel alternatives to 301/302 (produced during Nickel shortage)			G	G	Cookware, cutlery, sinks, domestic appliances, counters, car trim, fasteners, food handling, buses, aircraft.
301	301S21	1.4310	High tensile strength by cold working.		F	G	G	Dishwasher parts. Hub caps. Wiper arms. Springs, cookware, cutlery, sinks
302	302S25		The original '18-8' stainless steel. 302S25 = old En58A.	F/G	G	V	G	Obsolescent. General purpose. Being superseded by 304, which is now the preferred basic grade.
303	303S31	1.4305	'Free machining 18-8'. Corrosion resistance up to 870°C.	V	F			Commonly used. Screw parts, fasteners, valve parts, trim.
304	304S15 304S31	1.4301	Basic Austenitic grade. Atmospheric resistance. Ductile. Better weldability than 302. 'Weldable 18-8'.	F/G	V	V	G	Commonly used. Stoves, pen barrels, fasteners, beer barrels, cryogenic equip, food processing and chemicals. Pressure vessels, sanitary fittings. Spinning and drawing
304L	304S11	1.4306	Extra low carbon for weldability. Good for deep drawing.	F/G	V	E	G	For welded parts, tubes, pressure vessels, boilers.
305	305S19 325S31	1.4303	Ductile. Good corrosion resistance.				G	Deep drawing and spinning. Electronic components. Nuts & bolts, pressure vessels.
309	309S16 309S24	1.4833	Excellent weldability. High temp working. Corrosion resistance.		F/G	E	V	For welded parts. Furnaces, dryers, heaters, pressure vessels.
310	310S24 310S31	1.4845	As 309 but higher corrosion resistance during welding. Atmospheric resistance. High temp working.				E	Aircraft exhaust, jet engines, furnace parts, conveyor parts, mining equipment.
316	316S31 316S33	1.4401 1.4436	High creep strength at high temps. Superior corrosion resistance up to 870°C. Salt resistance.	F/G	G	V	V	Chemical processing, prevents pitting from chemical attack. Paper mills. Storage tanks, kettles, pharmaceutical, photographic equip. Marine trim.
316L	316S11 316S13	1.4307 1.4404 1.4435	As 316 but better weldability	F/G	G	E	V	Recommended for welded parts, flanges, valves, pressure vessels.
317	317S16		As 316L but higher corrosion resistance				V	For use in highly corrosive environments.
317L	317S12	1.4438	As 317 but higher corrosion resistance after welding. Acid resistant.				V	Extra corrosion resistance in welded areas. Cladding plate.

AISI ASTM (USA)	BS970 BS1449 BS1554 (UK)	EN 10088 10095 (Eur)	PROPERTIES	MACHINING	FORMING	WELDING	CORROSION RESISTANCE	APPLICATIONS
321	321S31	1.4541	High temp working, weldability.			V	G	For parts to be welded and used at temps from 425°C to 1010°C. Jet engines, aircraft exhaust, fire walls, pressure tanks
347	347S31	1.4550	High temp working, excellent weldability.			E	V	For parts to be welded and used at temps from 425°C to 1010°C. Furnace exhausts, heat exchangers, jet engines, aircraft exhausts.
FERRITIC GRADES (BASED ON BS EN 10088-1 RANGES):								
403	403S17	1.4000	Good finish. Ductile. Magnetic					Turbine components (especially high pressure steam), pumps, aircraft components.
405	405S17	1.4002	Good finish. Ductile. Magnetic					Heat exchangers, drop forged components.
409	409S19	1.4512	Good finish. Ductile. Magnetic					Cheap. Lowest Cr content. For car exhausts.
430	430S17	1.4016	Basic Ferritic grade. Good finish. Ductile. Magnetic. (The close relative 430S15 was the old En60 grade)		V	F	F/G	General purpose. Domestic appliances, car trim, vending machine parts, cooking utensils, petroleum refinery equip, fasteners, food handling.
434	434S17 434S19	1.4113	Good finish. Ductile. Magnetic. Resistance to atmospheric corrosion				V	Automotive trim and fasteners.
MARTENSITIC and PRECIPITATION HARDENED GRADES (BASED ON BS EN 10088-1 RANGES):								
410	410S21	1.4006	Basic Martensitic grade. Tensile strength 590 MPa. 410S21 = old En 56A.					General purpose, used where strength is important. Fasteners. Pipes, bolts and flanges. Not usually suitable for welding or cold forming.
410S	410S21	1.4000	Good finish. Ductile. Magnetic	F	G	G	F	Gen purpose. Fasteners, gauges, springs, brackets, cutlery, micrometers, valves.
416	416S21 416S37 416S29	1.4005 1.4029 1.4104	Easy machining. Magnetic. The first free machining stainless steel.	V	F	P		Screw fasteners, gears, axles.
420	420S29 420S45	1.4021 1.4028	As 410 but harder.					Dental and surgical instruments. Pump parts, valves, turbine parts.
440A 440B 440C		----- 1.4112 1.4125	High hardness and wear resistance.			F	F/G	Knife-making, cutlery. Ball bearings. Valve parts. Instruments.

E = excellent, V = very good, G = good, F = fair, P = poor

 = HEAT RESISTING GRADES TO BS EN 10095

Note that BS 970 (1991) grades are being gradually transferred to the BS EN series. Stainless and heat resisting grades in BS 970 have been re-designated according to BS EN 10088 (stainless steels) and BS EN 10095 (heat-resisting steels and nickel alloys).

Stainless Steel Finishes

SHEET FINISH	DESCRIPTION
HRAP	Orange peel finish, grey.
2D	Dull, no reflectivity.
2B	Smooth cold rolled, some reflectivity.
#1 BA	Bright and silvery, not fully reflective
#2 BA	Bright and silvery. Mirror in 430 grade.

SHEET FINISH	DESCRIPTION
RIP, RSK	Rolled-in finish, satin-like, short scratches
#3	120 grit satin finish
#4	180 grit satin finish
#6	Tampico brush finish
#7	Semi-mirror, fine grain.
#8	Mirror finish.

Stainless Steel Bend Radii (Cold Bending) – Annealed (Soft) Condition

GRADE	FREE BEND (0<t<6mm) 180° bend	V BLOCK BEND (0<t<6mm) 135° bend
301	R = ½ t	R = ½ t
302		
304		
305		
309		
310		
316		
321		
347	R = t	R = t
405		
410		
430		
442		
446		

Stainless Steel Bend Radii (Cold Bending) – Temper Rolled Condition

Heat treatable stainless can be tempered to $\frac{1}{4}$ $\frac{1}{2}$ $\frac{3}{4}$ or full hard. The table below shows the relationship between minimum recommended bend radius and degree of hardness for 3 selected grades of stainless steel, for thin and thick sheets. Two sets of figures are provided, one for 'free bend,' the other for bends using a V-block. For all other grades consult the supplier.

GRADE	THICKNESS (t)	FREE BEND 180° bend for t < 1.5mm 90° bend for 1.5 < t < 5mm				V BLOCK BEND 135° for 0 < t < 5mm			
		$\frac{1}{4}$ HARD	$\frac{1}{2}$ HARD	$\frac{3}{4}$ HARD	FULL HARD	$\frac{1}{4}$ HARD	$\frac{1}{2}$ HARD	$\frac{3}{4}$ HARD	FULL HARD
301	t < 1.5mm	R = $\frac{1}{2}$ t	R = t	R = $1\frac{1}{2}$ t	R = 2t	R = t	R = 2t	R = 3t	R = 3t
	1.5 < t < 5mm	R = t	R = t	---	---	R = $1\frac{1}{2}$ t	R = 2t	---	---
302	t < 1.5mm	R = $\frac{1}{2}$ t				R = 2t			
	1.5 < t < 5mm	R = t				R = 2t			
316	t < 1.5mm	R = t				R = $2\frac{1}{2}$ t			
	1.5 < t < 5mm	R = t				R = 3t			

Selected Casting Grades of Stainless Steel

ASTM (US)	BS 970 BS 3100 (UK)	Properties
ASTM-A297 HF	302C35	Austenitic. Heat resisting. Excellent ductility. Can be hardened by cold working. Good resistance to corrosion, good weldability and low temperature toughness. Tensile strength 510 MPa.
ASTM-A297 HK	310C40	
ASTM-A297 HT	330C11	
ASTM-A297 HU	331C40 331C60	
ASTM-A297 HC	452C11	Ferritic. Better corrosion resistance than martensitic steels. Heat Resisting. Good ductility. Hardenable by heat treatment. Tensile strength 540 MPa.
ASTM-A743 CA-15	410C21 410C29	Martensitic. Corrosion Resistant. Not usually suitable for welding or cold forming. Moderate machinability. Resistant to tempering at high temperatures. Turbine blades. Tensile strength 590-900 MPa.
ASTM-A743 CA-6NM	425C11	

Note that BS 3100 (steel castings) is to be withdrawn, to be replaced by BS EN 10293.

LINKS and RESOURCES

(W) International Stainless Steel Forum (ISSF): www.worldstainless.org

(W) International Iron & Steel Institute: www.worldsteel.org

(Eur) Euro-Inox (The European Stainless Steel Development Association): www.euro-inox.org For other stainless-related organizations in Europe, follow Home > Other Organizations.

(UK) British Stainless Steel Association: www.bssa.org.uk

(UK) The Stainless Centre: www.stainless-centre.co.uk

(UK) UK Steel Association: www.uksteel.org.uk

(UK) Corus Group (Head Office): www.corusgroup.com/home/index.cfm

(UK) Avesta Polarit (Stainless Products): www.avestapolarit.com

(US) Stainless Steel Fabrication, Allegheny Ludlum Steel Corporation, 1959.

(US) SSINA, Stainless Steel Information Center: www.ssina.com

(US) Stainless Steel World: www.stainless-steel-world.net

For General Design Tips and Resources, visit:

<http://www.design1st.com/Design-Resource-Library/design-resource-center.html>