Description

Image

Caption

1. Siemens toaster in brushed austenitic stainless steel (by Porsche Design) © Granta Design 2. Scissors in ferritic stainless steel; it is magnetic, austenitic stainless is not. © Granta Design

The material

Stainless steels are alloys of iron with chromium, nickel, and - often - four of five other elements. The alloying transmutes plain carbon steel that rusts and is prone to brittleness below room temperature into a material that does neither. Indeed, most stainless steels resist corrosion in most normal environments, and they remain ductile to the lowest of temperatures.

Composition (summary)

Fe/<0.25C/16 - 30Cr/3.5 - 37Ni/<10Mn + Si,P,S (+N for 200 series)

General properties

Density	474	-	506	lb/ft^3
Price	* 2.54	-	2.77	USD/lb
Date first used	1915			

Mechanical properties

Young's modulus	27.4	-	30.5	10^6 psi
Shear modulus	10.7	-	12.2	10^6 psi
Bulk modulus	19.4	-	21.9	10^6 psi
Poisson's ratio	0.265	-	0.275	
Yield strength (elastic limit)	24.7	-	145	ksi
Tensile strength	69.6	-	325	ksi
Compressive strength	24.7	-	145	ksi
Elongation	5	-	70	% strain
Hardness - Vickers	130	-	570	HV
Fatigue strength at 10^7 cycles	* 25.4	-	109	ksi

Fracture toughness	56.4	-	137	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 2.9e-4	-	0.00148	

Thermal properties

Melting point	2.51e3	-	2.64e3	°F
Maximum service temperature	1.38e3	-	1.51e3	°F
Minimum service temperature	-458	-	-456	°F
Thermal conductor or insulator?	Poor conductor			
Thermal conductivity	6.93	-	13.9	BTU.ft/h.ft^2.F
Specific heat capacity	0.107	-	0.127	BTU/lb.°F
Thermal expansion coefficient	7.22	-	11.1	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	64	-	107	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	Yes

Processability

Castability	3	-	4
Formability	2	-	3
Machinability	2	-	3
Weldability	5		
Solder/brazability	5		

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Limited use

Hydrofluoric acid (40%)	Limited use
Nitric acid (10%)	Excellent
Nitric acid (70%)	Limited use
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Acceptable
Sulfuric acid (70%)	Limited use

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Acceptable
Benzene	Acceptable
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Acceptable
Toluene	Excellent
Turpentine	Acceptable
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Acceptable
Formaldehyde (40%)	Acceptable
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Excellent
O2 (oxygen gas)	Excellent

Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Excellent
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production, principal component	2.26e9	ton/yr
Reserves, principal component	1.57e11	I. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	8.7e3	-	9.62e3	kcal/lb
CO2 footprint, primary production	*	4.73	-	5.23	lb/lb
Water usage	*	15.5	-	17	gal(US)/lb
Eco-indicator 95		910			millipoints/kg
Eco-indicator 99		308			millipoints/kg

Material processing: energy

Casting energy	*	1.17e3	-	1.29e3	kcal/lb
Extrusion, foil rolling energy	*	1.59e3	-	1.77e3	kcal/lb
Rough rolling, forging energy	*	813	-	898	kcal/lb
Wire drawing energy	*	5.89e3	-	6.51e3	kcal/lb
Metal powder forming energy	*	3.91e3	-	4.48e3	kcal/lb
Vaporization energy	*	1.18e6	-	1.3e6	kcal/lb
Coarse machining energy (per unit wt removed)	*	169	-	186	kcal/lb
Fine machining energy (per unit wt removed)	*	1.22e3	-	1.35e3	kcal/lb
Grinding energy (per unit wt removed)	*	2.39e3	-	2.64e3	kcal/lb
Non-conventional machining energy (per unit wt removed)		1.18e4	-	1.3e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.809	-	0.894	lb/lb
Extrusion, foil rolling CO2	* 1.1	-	1.22	lb/lb
Rough rolling, forging CO2	* 0.562	-	0.621	lb/lb
Wire drawing CO2	* 4.08	-	4.51	lb/lb
Metal powder forming CO2	* 2.89	-	3.31	lb/lb
Vaporization CO2	* 815	-	900	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.117	-	0.129	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.847	-	0.936	lb/lb
Grinding CO2 (per unit wt removed)	* 1.66	-	1.83	lb/lb
Non-conventional machining CO2 (per unit wt removed	8.15	-	9	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 1.82e3	-	2.02e3	kcal/lb
CO2 footprint, recycling	* 1.32	-	1.46	lb/lb
Recycle fraction in current supply	35	-	40	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

Stainless steels are FDA approved -- indeed, they are so inert that they can be implanted in the body, and are widely used in food processing equipment. All can be recycled.

Supporting information

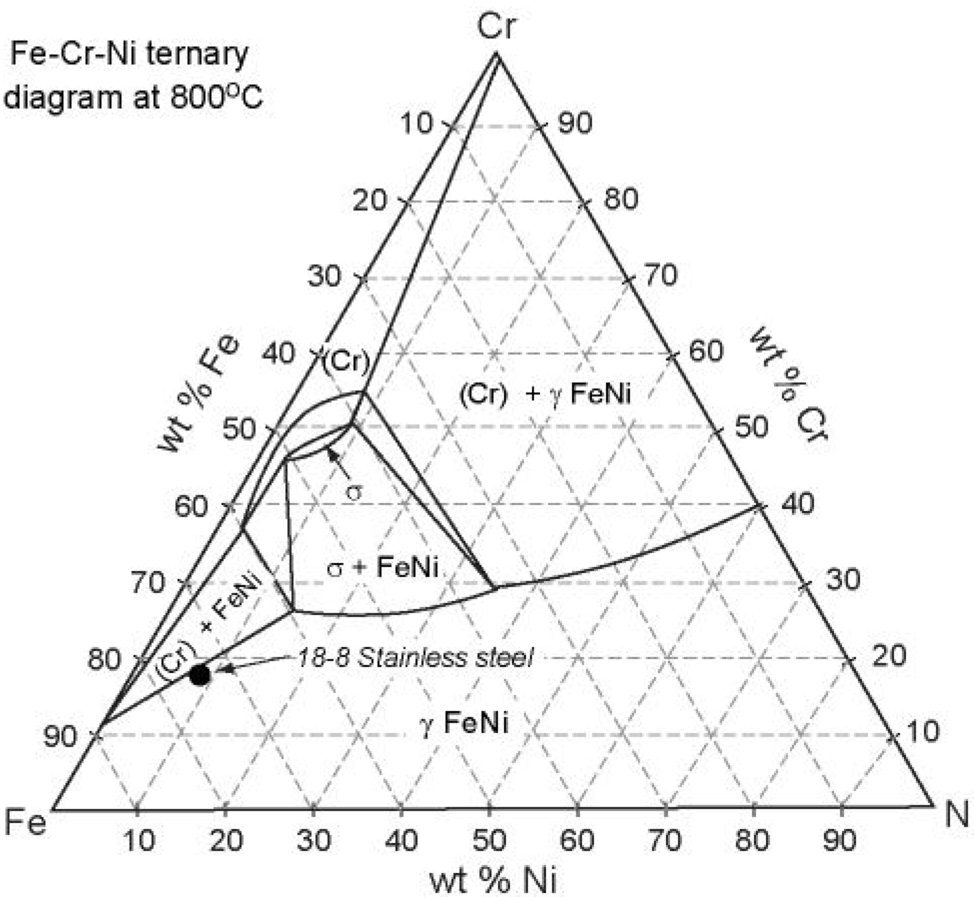
Design guidelines

Stainless steel must be used efficiently to justify its higher costs, exploiting its high strength and corrosion resistance. Economic design uses thin, rolled gauge, simple sections, concealed welds to eliminate refinishing, and grades that are suitable to manufacturing (such as free machining grades when machining is necessary). Surface finish can be controlled by rolling, polishing or blasting. Stainless steels are selected, first, for their corrosion resistance, second, for their strength and third, for their ease of fabrication. Most stainless steels are difficult to bend, draw and cut, requiring slow cutting speeds and special tool geometry. They are available in sheet, strip, plate, bar, wire, tubing and pipe, and can be readily soldered and braised. Welding stainless steel is possible but the filler metal must be selected to ensure an equivalent composition to maintain corrosion resistance. The 300 series are the most weldable; the 400 series are less weldable.

Technical notes

Stainless steels are classified into four categories: the 200and 300 series austenitic (Fe-Cr-Ni-Mn) alloys, the 400 series ferritic (Fe-Cr) alloys, the martensitic (Fe-Cr-C) alloys that also form part of the 400 series, and precipitation hardening or PH (Fe-Cr-Ni-Cu-Nb) alloys with designations starting with S. Typical of the austenitic grades of stainless steel is the grade 304: 74% iron, 18% chromium and 8 % nickel. Here the chromium protects by creating a protective Cr2O3 film on all exposed surfaces, and the nickel stabilizes face-centered cubic austenite, giving ductility and strength both at high and low temperatures; they are non-magnetic (a way of identifying them). The combination of austenitic and ferritic structures (the duplex stainless steels) provide considerably slower growth of stress-induced cracks, they can be hot-rolled or cast and are often heat treated as well. Austenitic stainless steel with high molybdenum content and copper has excellent resistance to pitting and corrosion. High nitrogen content austenitic stainless steel gives higher strength. Superferrites (over 30% chromium) are very resistant to corrosion, even in water containing chlorine. More information on designations and equivalent grades can be found on the Granta Design website at www.grantadesign.com/designations

Phase diagram



Phase diagram description

Most stainless steels are alloys of iron (Fe) with chromium (Cr) and nickel (Ni). This is the ternary phase diagram, at a temperature of 800 C, for those three elements. The position of AISI 302 stainless steel (Fe-18%Cr-8%Ni) is

Typical uses

Railway cars, trucks, trailers, food-processing equipment, sinks, stoves, cooking utensils, cutlery, flatware, scissors and knives, architectural metalwork, laundry equipment, chemical-processing equipment, jet-engine parts, surgical tools, furnace and boiler components, oil-burner parts, petroleum-processing equipment, dairy equipment, heat-treating equipment, automotive trim. Structural uses in corrosive environments, e.g. nuclear plants, ships, offshore oil installations, underwater cables and pipes.

Links

Reference	
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