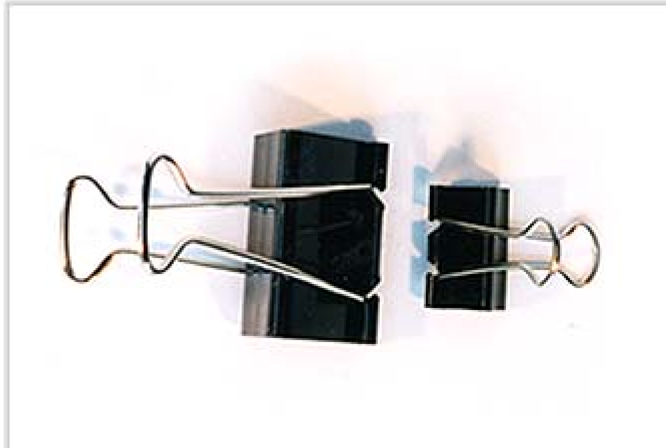
Description

Image



Caption

1. Bearing made of high carbon steel. © Granta Design 2. Drawing board clips made of high carbon steel. © Granta Design

The material

High carbon steels (0.5-1.7% carbon) harden when quenched - a quality that gives great control over properties. High carbon steels achieve hardness sufficient for them to be used as cutting tools, chisels and cables, and "piano wire" - the metal strings of pianos and violins.

Compositional summary

Fe/0.7 - 1.7%C

General properties

Density	487	-	493	lb/ft^3
Price	* 0.263	-	0.268	USD/lb
Date first used	1610			

Mechanical properties

Young's modulus	29	-	31.2	10^6 psi
Shear modulus	11.2	-	12.2	10^6 psi
Bulk modulus	22.5	-	25.4	10^6 psi
Poisson's ratio	0.285	-	0.295	
Yield strength (elastic limit)	58	-	168	ksi
Tensile strength	79.8	-	238	ksi
Compressive strength	48.6	-	168	ksi
Elongation	7	-	30	% strain
Hardness - Vickers	160	-	650	HV
Fatigue strength at 10^7 cycles	* 40.8	-	87.9	ksi
Fracture toughness	24.6	-	83.7	ksi.in^0.5

Mechanical loss coefficient (tan delta)	* 3e-4	-	9.8e-4	

Thermal properties

Melting point	2.35e3	-	2.69e3	°F
Maximum service temperature	* 662	-	752	°F
Minimum service temperature	* -99.7	-	-27.7	°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	27.2	-	30.6	BTU.ft/h.ft^2.F
Specific heat capacity	0.105	-	0.122	BTU/lb.°F
Thermal expansion coefficient	6.11	-	7.5	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	17	-	20	µohm.cm

Optical properties

Transparency	Opaque

Processability

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

Durability: water and aqueous solutions

Water (fresh)	Acceptable
Water (salt)	Limited use
Soils, acidic (peat)	Acceptable
Soils, alkaline (clay)	Acceptable
Wine	Unacceptable

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Unacceptable
Hydrochloric acid (10%)	Unacceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Unacceptable

Phosphoric acid (10%)	Unacceptable
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Unacceptable
Sulfuric acid (70%)	Limited use

Durability: alkalis

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

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Acceptable
Fluorine (gas)	Excellent
O2 (oxygen gas)	Limited use
Sulfur dioxide (gas)	Acceptable

Durability: built environments

Industrial atmosphere	Limited use			
Rural atmosphere	Acceptable			
Marine atmosphere	Limited use			
UV radiation (sunlight)	Excellent			

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Acceptable
Tolerance up to 850 C (1562 F)	Unacceptable
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	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 2.74e3	-	3.03e3	kcal/lb
CO2 footprint, primary production	* 1.71	-	1.89	lb/lb
Water usage	* 5.21	-	5.76	gal(US)/lb
Eco-indicator 95	89			millipoints/kg
Eco-indicator 99	106			millipoints/kg

Material processing: energy

Casting energy	* 1.17e3	-	1.29e3	kcal/lb
Extrusion, foil rolling energy	* 683	-	754	kcal/lb
Rough rolling, forging energy	* 356	-	394	kcal/lb
Wire drawing energy	* 2.47e3	-	2.74e3	kcal/lb
Metal powder forming energy	* 3.66e3	-	4.43e3	kcal/lb
Vaporization energy	* 1.18e6	-	1.3e6	kcal/lb
Coarse machining energy (per unit wt removed)	* 100	-	111	kcal/lb
Fine machining energy (per unit wt removed)	* 541	-	597	kcal/lb
Grinding energy (per unit wt removed)	* 1.03e3	-	1.14e3	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.18e4	-	1.3e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.807	-	0.892	lb/lb
Extrusion, foil rolling CO2				

	* 0.473	-	0.522	lb/lb
Rough rolling, forging CO2	* 0.247	-	0.273	lb/lb
Wire drawing CO2	* 1.71	-	1.89	lb/lb
Metal powder forming CO2	* 2.7	-	3.27	lb/lb
Vaporization CO2	* 815	-	901	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0695	-	0.0768	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.374	-	0.413	lb/lb
Grinding CO2 (per unit wt removed)	* 0.712	-	0.787	lb/lb
Non-conventional machining CO2 (per unit wt removed)	8.15	-	9.01	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 758	-	837	kcal/lb
CO2 footprint, recycling	* 0.55	-	0.608	lb/lb
Recycle fraction in current supply	40	-	44	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

The production energy of steel is comparatively low - per unit weight, about a half that of polymers; per unit volume, though, twice as much. Carbon steels are easy to recycle, and the energy to do so is small.

Supporting information

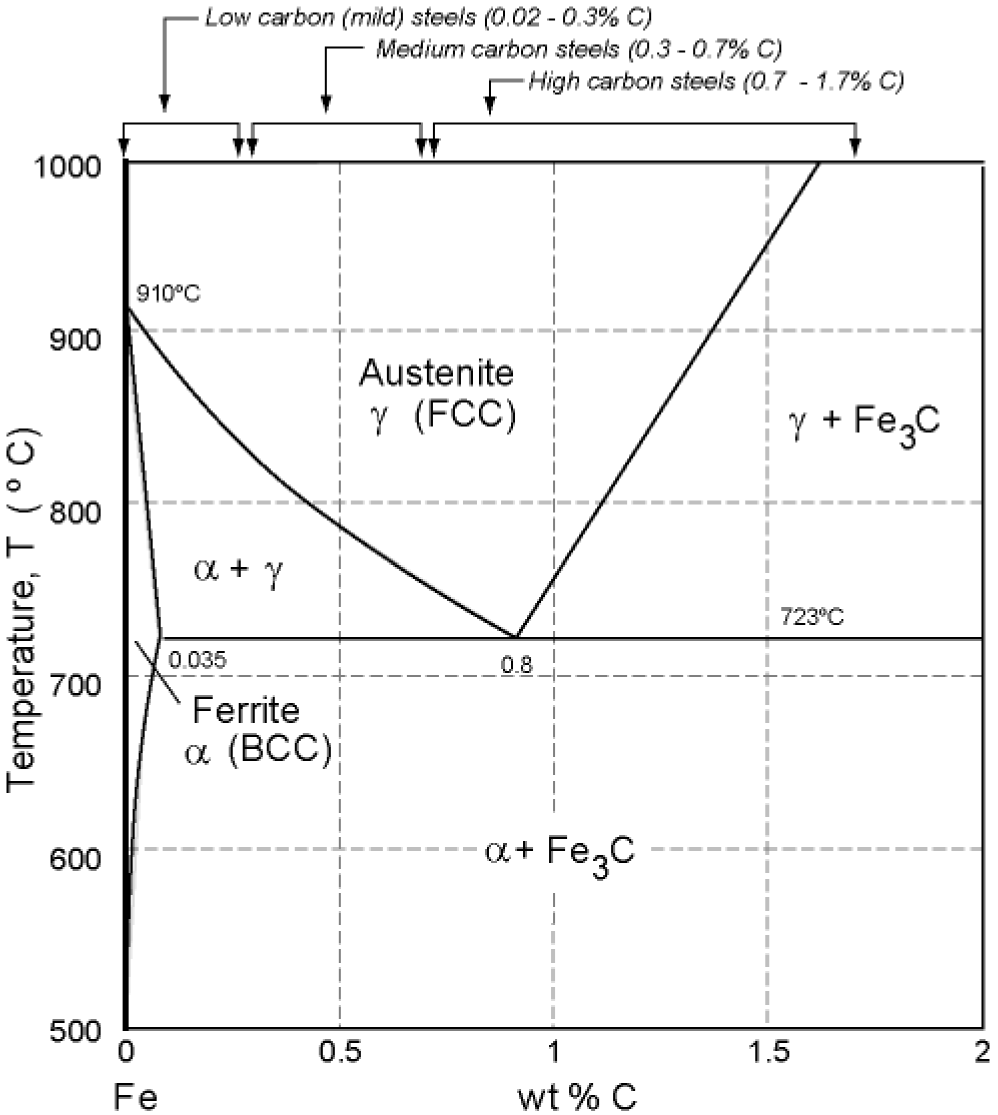
Design guidelines

Hardenability measures the degree to which it can be hardened in thick sections; plain carbon steels have poor hardenability - additional alloying elements are used to increase it (see Low alloy steels).

Technical notes

The two standard classifications for steels, the AISI and the SAE standards, have now been merged. In the SAE-AISI system, each steel has a four-digit code. The first two digits indicate the major alloying elements. The second two give the amount of carbon, in hundredths of a percent. Thus the plain carbon steels have designations starting 10xx, 11xx, 12xx or 14xxx, depending on how much manganese, sulfur and phosphorus they contain. The common low-carbon steels have the designations 1015,1020, 1022, 1117,1118; the common medium carbon steels are 1030,1040, 1050, 1060, 1137, 1141, 1144 and 1340; the common high alloy steels are 1080and 1095. 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

High carbon steels are alloys of iron (Fe) with 0.7 - 1.7% carbon (C), for which this is the phase

Typical uses

Cutting tools; high performance bearings, cranks and shafts, springs, knives and scissors, rail

Links

Reference

ProcessUniverse

Producers