Low alloy steel

Description

Image

Caption

Low alloy steel wrench. © Granta Design

The material

Pure iron is soft stuff. Add carbon and heat-treat it right, and you can get a material that is almost as hard and brittle as glass, or as ductile and tough as boiler plate. 'Heat treat' means heating the steel to about 800 C to dissolve the carbon, then quenching (rapid cooling, often by dropping into cold water) and tempering - reheating it to a lower temperature and holding it there. Quenching turns the steel into hard, brittle 'martensite'; tempering slowly restores the toughness and brings the hardness down. Control of tempering time and temperature gives control of properties. It's wonderful what 1% of carbon can do. But (the inevitable 'but') the cooling rate in that initial quench has to be fast - more than 200 C/second for plain carbon steels. There is no difficulty in transforming the surface of a component to martensite, but the interior cools more slowly because heat has to be conducted out. If the component is more than a few millimeters thick, there is a problem - the inside doesn't cool fast enough. The problem is overcome by alloying. Add a little manganese (Mn), nickel (Ni), molybdenum (Mo), or chromium (Cr), and the critical cooling rate comes down, allowing thick sections to be hardened and then tempered. Adding some vanadium, V, as well allows a dispersion of carbides giving strength while retaining toughness and ductility. Chrome-molybdenum steels such as AIS 4140 are used for aircraft tubing and other high strength parts. Chrome-vanadium steels are used for crank and propeller shafts and high quality tools. Steels alloyed for this purpose are called low alloy steels, and the property they have is called 'hardenability'.

Composition (summary)

Fe/<1.0 C/<2.5 Cr/<2.5 Ni/<2.5 Mo/<2.5 V

General properties

Density		487	-	493	lb/ft^3
Price	*	0.254	-	0.281	USD/lb
Date first used		1930			

Mechanical properties

Young's modulus		29.7	-	31.5	10^6 psi
Shear modulus		11.2	-	12.3	10^6 psi
Bulk modulus		23.2	-	25.5	10^6 psi
Poisson's ratio		0.285	-	0.295	
Yield strength (elastic limit)		58	-	218	ksi
Tensile strength		79.8	-	255	ksi
Compressive strength		58	-	218	ksi
Elongation		3	-	38	% strain
Hardness - Vickers		140	-	693	HV
Fatigue strength at 10^7 cycles	*	36	-	102	ksi

Fracture toughness	12.7 - 182	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 1.8e-4 - 0.00116	

Thermal properties

Melting point	2.52e3 - 2.78e3	°F
Maximum service temperature	* 932 - 1.02e3	°F
Minimum service temperature	* -99.7 - -45.7	°F
Thermal conductor or insulator?	Good conductor	
Thermal conductivity	19.6 - 31.8	BTU.ft/h.ft^2.F
Specific heat capacity	0.0979 - 0.127	BTU/lb.°F
Thermal expansion coefficient	5.83 - 7.5	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor	
Electrical resistivity	* 15 - 35	µohm.cm

Optical properties

Transparency	Opaque	

Processability

Castability	1 - 2	
Formability	3 - 4	
Machinability	3 - 4	
Weldability	5	
Solder/brazability	5	

Eco properties

Embodied energy, primary production	* 3.11e3 - 3.43e3	kcal/lb
CO2 footprint, primary production	* 1.93 - 2.13	lb/lb
Recycle	✓	

Supporting information

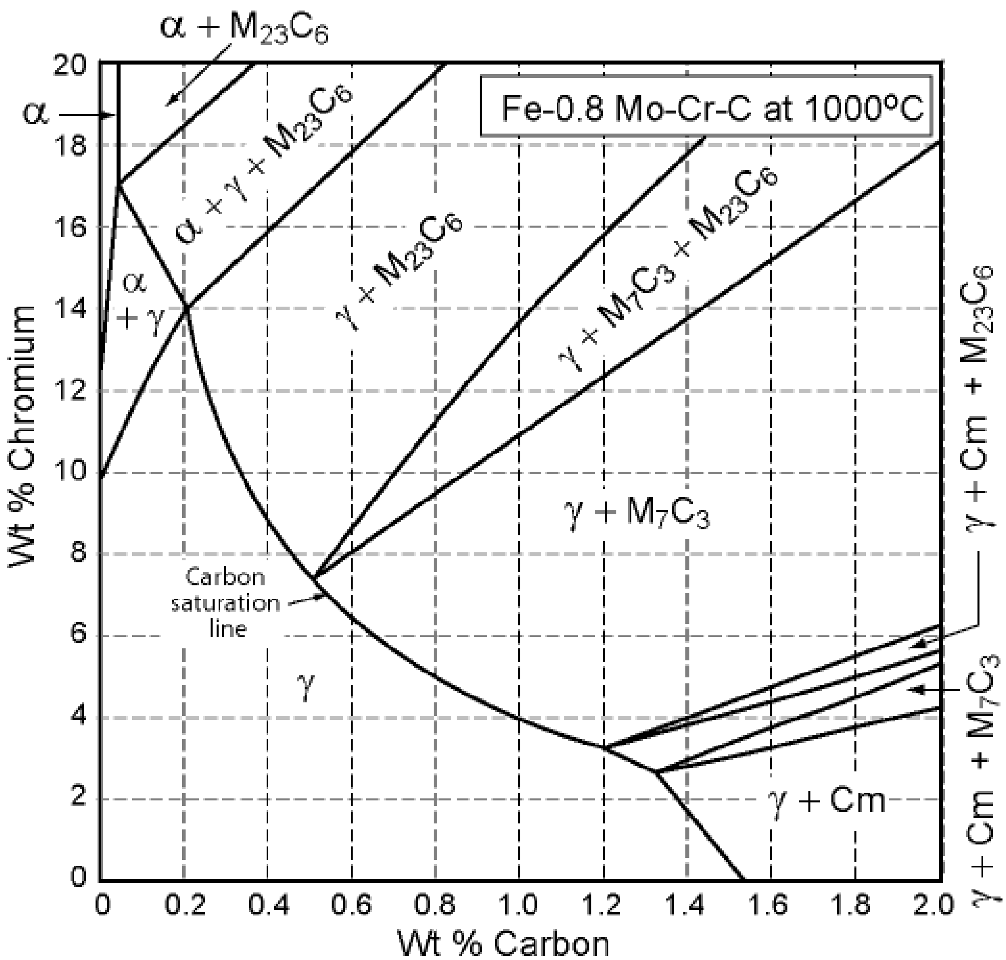
Design guidelines

Low alloy steels are heat treatable - most other carbon steels are not - and so are used for applications where hardness or strength is an important feature, particularly in large sections. They have greater abrasion resistance, higher toughness and better strength at high temperatures than plain carbon steels. Alloy steels with carbon content of 0.30 to 0.37 % are used for moderate strength and great toughness; 0.40 - 0.42% for higher strength and good toughness; 0.45 - 0.50% for high hardness and strength with moderate toughness; 0.50-0.62% for hardness (springs and tools); 1% for high hardness and abrasion resistance (ball bearings or rollers).

Technical notes

The SAE-AISI system for low alloy steels works the same way as that for plain carbon steels. 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. Typical are the nickel-chrome-molybdenum steels with the designation 43xx, but the alloying elements can include any of the following: more than 2% silicon, more than 0.4% copper, more than 0.1% molybdenum, more than 0.5% nickel, more than 0.5% chromium. 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 strength low alloy steels contain small (<5%) additions of chromium (Cr), molybdenum (Mo), nickel (Ni) and carbon (C).

Typical uses

Springs, tools, ball bearings, rollers; crankshafts, gears, connecting rods, knives and scissors, pressure vessels.

Links

Reference

ProcessUniverse

Producers