Description

Image

Caption

Ductile or malleable cast irons are used for heavily loaded parts such as gears and automotive suspension

The material

The foundations of modern industrial society are set, so to speak, in cast iron: it is the material that made the industrial revolution possible. Today it holds a second honor: that of being the cheapest of all engineering metals. Cast iron contains at least 2% carbon -- most have 3 to 4% -- and from 1-3% silicon. The carbon makes the iron very fluid when molten, allowing it to be cast to intricate shapes. There are five classes of cast iron: gray, white, ductile (or nodular), malleable and alloy; details are given under Design Guidelines, below. The two that are most used are gray and ductile. This record is for ductile cast iron.

Composition (summary)

Fe/3.2-4.1%C/1.8-2.8%Si/<0.8%Mn/<0.1%P/<0.03%S

General properties

Density	440	-	453	lb/ft^3
Price	* 0.254	-	0.277	USD/lb
Date first used	1948			

Mechanical properties

Young's modulus	23.9	-	26.1	10^6 psi
Shear modulus	9.28	-	10.3	10^6 psi
Bulk modulus	17.3	-	19.9	10^6 psi
Poisson's ratio	0.26	-	0.28	
Yield strength (elastic limit)	36.3	-	98.6	ksi
Tensile strength	59.5	-	120	ksi
Compressive strength	36.3	-	115	ksi
Elongation	3	-	18	% strain
Hardness - Vickers	115	-	320	HV

Fatigue strength at 10^7 cycles	26.1	-	47.9	ksi
Fracture toughness	20	-	49.1	ksi.in^0.5
Mechanical loss coefficient (tan delta)	0.002	-	0.009	

Thermal properties

Melting point	2.07e3	-	2.28e3	°F
Maximum service temperature	662	-	842	°F
Minimum service temperature	-145	-	-36.7	°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	16.8	-	25.4	BTU.ft/h.ft^2.F
Specific heat capacity	0.11	-	0.118	BTU/lb.°F
Thermal expansion coefficient	5.56	-	6.94	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	49	-	56	µohm.cm

Optical properties

Transparency	Opaque

Processability

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

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)	Limited use
Citric acid (10%)	Limited use
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%)	Acceptable
Sulfuric acid (70%)	Acceptable

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%)	Limited use
Glycerol	Excellent
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

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

Durability: built environments

Industrial atmosphere	Acceptable
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)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production	2.26e9	ton/yr
Reserves	1.57e11	l. ton

Primary material production: eco-costs, energy, CO2 and water

Eco-costs (global trade mix)		0.136	-	0.15	USD/lb
Embodied energy, primary production	*	1.95e3	-	2.38e3	kcal/lb
CO2 footprint, primary production	*	1.7	-	1.8	lb/lb
Water usage	*	5.1	-	5.64	gal(US)/lb
Eco-indicator 95		40			millipoints/kg
Eco-indicator 99		112			millipoints/kg

Material processing: eco-costs

Casting eco-costs	0.0717	-	0.0798	USD/lb
Coarse machining eco-costs	0.00726	-	0.00816	USD/lb
Fine machining eco-costs	0.0417	-	0.0458	USD/lb
Grinding eco-costs	0.0796	-	0.0882	USD/lb
Metal powder forming eco-costs	0.215	-	0.247	USD/lb
Non-conventional machining eco-costs (per unit wt removed)	1.72	-	1.9	
Vaporisation eco-costs	78.2	-	86.1	USD/lb

Material processing: energy

Casting energy	*	1.08e3	-	1.2e3	kcal/lb
Metal powder forming energy	*	3.24e3	-	3.72e3	kcal/lb

Vaporization energy	* 1.18e6	-	1.3e6	kcal/lb
Coarse machining energy (per unit wt removed)	* 109	-	120	kcal/lb
Fine machining energy (per unit wt removed)	* 628	-	694	kcal/lb
Grinding energy (per unit wt removed)	* 1.2e3	-	1.33e3	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.18e4	-	1.3e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.751	-	0.83	lb/lb
Metal powder forming CO2	* 2.39	-	2.75	lb/lb
Vaporization CO2	* 815	-	901	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0756	-	0.0835	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.435	-	0.481	lb/lb
Grinding CO2 (per unit wt removed)	* 0.835	-	0.923	lb/lb
Non-conventional machining CO2 (per unit wt removed)	8.15	-	9.01	lb/lb

Material recycling: energy, CO2 and recycle fraction

Eco-costs, (credit) upcycling	-0.0315	-	-0.0285	USD/lb
Eco-costs, landfill	0.0781			USD/lb
Recycle	✔			
Embodied energy, recycling	* 849	-	939	kcal/lb
CO2 footprint, recycling	* 0.616	-	0.681	lb/lb
Recycle fraction in current supply	60	-	80	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

As metals go, it takes relatively little energy to make cast iron; it's exceptionally durable, and easily recycled. The pollution caused by blast furnaces in which it is made was at one time a major problem; but modern technology has totally overcome this.

Supporting information

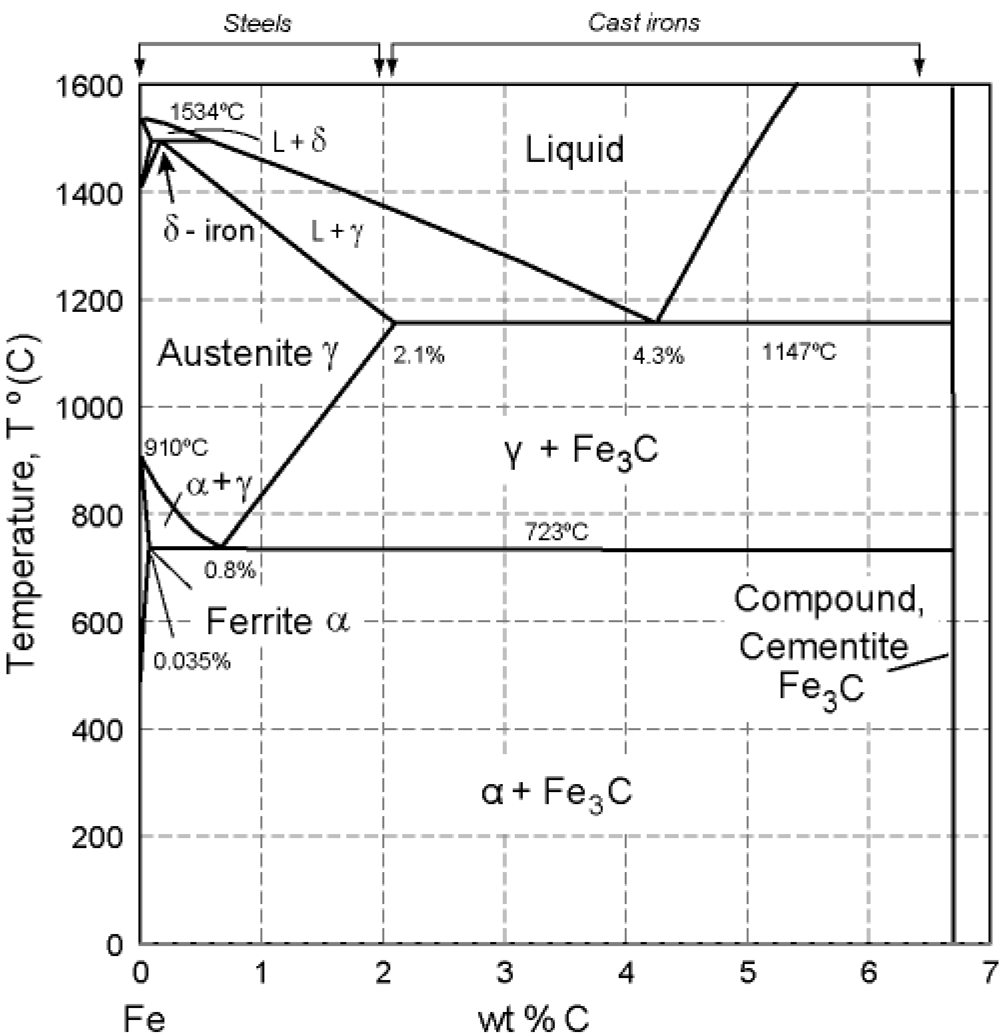
Design guidelines

There are five kinds of cast iron. Gray cast iron machines easily, damps vibration well, is relatively brittle and has low tensile strength; it is the material of automotive cylinder blocks, exhaust manifolds, break disks and drums, gears and flywheels. White cast iron, made by chill casting to give a high cooling rate at the surface, is much harder than gray; it is used when wear resistance is wanted, as in rolls for rolling mills, blades for crushers and mixers. Nodular (ductile) cast iron contains additions that cause the flakes of graphite that are present in gray iron to spherodize, giving higher toughness and strength but at the loss of damping-ability; it is used for crank shafts and heavy duty gears. Malleable cast iron, made by heat-treating white cast iron, is ductile and easily machined; it is used for heavy-duty parts of cars, trucks, and railway rolling stock. Finally, alloy cast irons contain up to 35% of chromium or nickel; they are corrosion resistant and have high strength, but are much more expensive.

Technical notes

There is no single systematic numbering system for cast irons. The UNS and the AISI systems are widely used, particularly in the US. Ductile cast irons are generally described using the ASTM system, a set of three numbers separated by colons, like this: ASTM 60:40:18. The first number is the tensile strength in ksi, the second is the yield strength in ksi and the third is the elongation in % (to convert ksi to MPa, multiply by 6.89).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

Grey cast irons are based on iron (Fe) with 3 - 4.1% carbon (C), for which this is the phase diagram. Ductile cast irons have small additions of magnesium or cerium that cause the graphite to form spherical nodules rather than flakes.

Typical uses

Brake discs and drums; bearings; camshafts; cylinder liners; piston rings; machine tool structural parts; engine blocks, gears, crankshafts; heavy-duty gear cases; pipe joints; pump casings; components in rock crushers.

Links

Reference

ProcessUniverse

Producers