Steel

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For other uses, see Steel (disambiguation).

"Steel worker" redirects here. For other uses, see Steel worker (disambiguation).

The steel cable of a colliery winding tower

Steels and other iron–carbon alloy phases

• Ferrite • Austenite • Cementite • Graphite • Martensite
Microstructures
• Spheroidite • Pearlite • Bainite • Ledeburite • Tempered martensite • Widmanstatten structures
Classes
• Crucible steel • Carbon steel • Spring steel

- Alloy steel
- Maraging steel
- Stainless steel
- Weathering steel
- Tool steel

Other iron-based materials

- Cast iron
- Gray iron
- White iron
- Ductile iron
- Malleable iron
- Wrought iron

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Steel is an alloy of iron and other elements, primarily carbon, widely used in construction and other applications because of its high tensile strength and low cost. The base metal, iron, is able to take on two crystalline forms (allotropic forms), body centered cubic (BCC) and face centered cubic (FCC), depending on its temperature. It is the interaction of those allotropes with the alloying elements, primarily carbon, that gives steel and cast iron their range of unique properties. In the body-centred cubic arrangement, there is an additional iron atom in the centre of each cube, and in the face-centred cubic, there is one at the center of each of the six faces of the cube. Carbon, other elements, and inclusions within iron act as hardening agents that prevent the movement of dislocations that otherwise occur in the crystal lattices of iron atoms.

The carbon in typical steel alloys may contribute up to 2.1% of its weight. Varying the amount of alloying elements, their presence in the steel either as solute elements, or as precipitated phases, retards the movement of those dislocations that make iron comparatively ductile and weak, and thus controls its qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel's strength compared to pure iron is only possible at the expense of iron's ductility, of which iron has an excess.

Although steel had been produced in bloomery furnaces for thousands of years, steel's use expanded extensively after more efficient production methods were devised in the 17th century with the production of blister steel and then crucible steel. With the invention of the Bessemer process in the mid-19th century, a new era of mass-produced steel began. This was followed by Siemens-Martin process and then Gilchrist-Thomas process that refined the quality of steel. With their introductions, mild steel replaced wrought iron.

Further refinements in the process, such as basic oxygen steelmaking (BOS), largely replaced earlier methods by further lowering the cost of production and increasing the quality of the product. Today, steel is one of the most common materials in the world, with more than 1.3 billion tons produced annually. It is a major component in buildings, infrastructure, tools, ships, automobiles, machines, appliances, and weapons. Modern steel is generally identified by various grades defined by assorted standards organizations.

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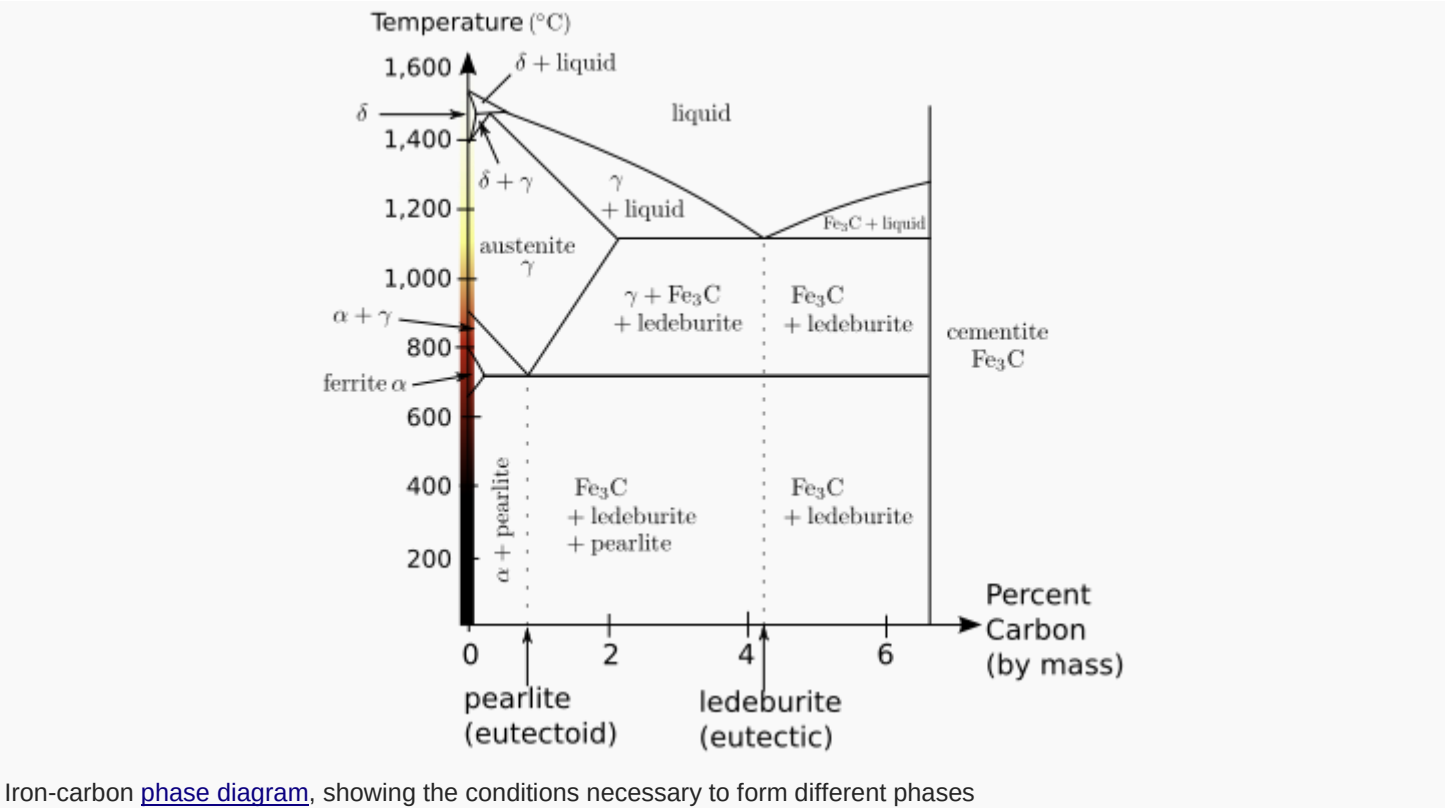
Definitions and related materials[edit]

The noun *steel* originates from the Proto-Germanic adjective *stakhlijan* (*made of steel*), which is related to *stakhla* (*standing firm*).[1]

The carbon content of steel is between 0.002% and 2.1% by weight for plain iron-carbon alloys. These values vary depending on alloying elements such asmanganese, chromium, nickel, iron, tungsten, carbon and so on. Basically, steel is an iron-carbon alloy that does not undergo eutectic reaction. In contrast, cast irondoes undergo eutectic reaction. Too little carbon content leaves (pure) iron quite soft, ductile, and weak. Carbon contents higher than those of steel make an alloy, commonly called pig iron, that is brittle (not malleable). While iron alloyed with carbon is called carbon steel, alloy steel is steel to which other alloying elements have been intentionally added to modify the characteristics of steel. Common alloying elements include: manganese, nickel, chromium, molybdenum, boron, titanium,vanadium, tungsten, cobalt, and niobium.[2] Additional elements are also important in steel: phosphorus, sulfur, silicon, and traces of oxygen, nitrogen, and copper, that are most frequently considered undesirable.

Alloys with a higher than 2.1% carbon content, depending on other element content and possibly on processing, are known as cast iron. Cast iron is not malleable even when hot, but it can be formed by casting as it has a lower melting point than steel and good castability properties.[2] Certain compositions of cast iron, while retaining the economies of melting and casting, can be heat treated after casting to make malleable iron or ductile iron objects. Steel is also distinguishable fromwrought iron (now largely obsolete), which may contain a small amount of carbon but large amounts of slag.

Material properties[edit]



Iron-carbon phase diagram, showing the conditions necessary to form different phases

Iron is commonly found in the Earth's crust in the form of an ore, usually an iron oxide, such as magnetite, hematite etc. Iron is extracted from iron ore by removing the oxygen through combination with a preferred chemical partner such as carbon that is lost to the atmosphere as carbon dioxide. This process, known as smelting, was first applied to metals with lowermelting points, such as tin, which melts at about 250 °C (482 °F) and copper, which melts at about 1,100 °C (2,010 °F) and the combination, bronze, which is liquid at less than 1,083 °C (1,981 °F). In comparison, cast iron melts at about 1,375 °C (2,507 °F).[3] Small quantities of iron were smelted in ancient times, in the solid state, by heating the ore buried in a charcoalfire and welding the clumps together with a hammer, squeezing out the impurities. With care, the carbon content could be controlled by moving it around in the fire.

All of these temperatures could be reached with ancient methods that have been used since the Bronze Age. Since the oxidation rate of iron increases rapidly beyond 800 °C (1,470 °F), it is important that smelting take place in a low-oxygen environment. Unlike copper and tin, liquid or solid iron dissolves carbon quite readily. Smelting, using carbon to reduce iron oxides, results in an alloy (pig iron) that retains too much carbon to be called steel.[3] The excess carbon and other impurities are removed in a subsequent step.

Other materials are often added to the iron/carbon mixture to produce steel with desired properties. Nickel and manganese in steel add to its tensile strength and make the austeniteform of the iron-carbon solution more stable, chromium increases hardness and melting temperature, and vanadium also increases hardness while making it less prone to metal