Steels can be classified by a variety of different systems depending on:

- The composition, such as carbon, low-alloy or stainless steel.
- The manufacturing methods, such as open hearth, basic oxygen process, or electric furnace methods.
- The finishing method, such as hot rolling or cold rolling.
- The product form, such as bar plate, sheet, strip, tubing or structural shape.
- The de-oxidation practice, such as killed, semi-killed, capped or rimmed steel.
- The microstructure, such as ferritic, pearlitic and martensitic.
- The required strength level, as specified in ASTM standards.
- The heat treatment, such as annealing, quenching and tempering, and thermo mechanical processing.
- Quality descriptors, such as forging quality and commercial quality.

![Classification of Carbon and Low-Alloy Steels Diagram](www.spacersandwashers.com)
Classification of Carbon and Low-Alloy Steels

Carbon Steels:

The American Iron and Steel Institute (AISI) define carbon steel as follows:
Steel is considered to be carbon steel when no minimum content is specified or required for chromium, cobalt, columbium [niobium], molybdenum, nickel, titanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 per cent; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, copper 0.60.

Carbon steel can be classified, according to various de-oxidation practices, as rimmed, capped, semi-killed, or killed steel. De-oxidation practice and the steelmaking process will have an effect on the properties of the steel. However, variations in carbon have the greatest effect on mechanical properties, with increasing carbon content leading to increased hardness and strength. As such, carbon steels are generally categorized according to their carbon content. Generally speaking, carbon steels contain up to 2% total alloying elements and can be subdivided into low-carbon steels, medium-carbon steels, high-carbon steels, and ultrahigh-carbon steels; each of these designations is discussed below.

As a group, carbon steels are by far the most frequently used steels. More than 85% of the steel produced and shipped in the United States is carbon steel.

Low-carbon steels contain up to 0.30% C. The largest category of this class of steel is flat-rolled products (sheet or strip), usually in the cold-rolled and annealed condition. The carbon content for these high-formability steels is very low, less than 0.10% C, with up to 0.4% Mn. Typical uses are in automobile body panels, tin plate, and wire products. For rolled steel structural plates and sections, the carbon content may be increased to approximately 0.30%, with higher manganese content up to 1.5%. These materials may be used for stampings, forgings, seamless tubes, and boiler plate.

Medium-carbon steels are similar to low-carbon steels except that the carbon ranges from 0.30 to 0.60% and the manganese from 0.60 to 1.65%. Increasing the carbon content to approximately 0.5% with an accompanying increase in manganese allows medium carbon steels to be used in the quenched and tempered condition. The uses of medium carbon-manganese steels include shafts, axles, gears, crankshafts, couplings and forgings. Steels in the 0.40 to 0.60% C range are also used for rails, railway wheels and rail axles.

High-carbon steels contain from 0.60 to 1.00% C with manganese contents ranging from 0.30 to 0.90%. High-carbon steels are used for spring materials and high-strength wires.

Ultrahigh-carbon steels are experimental alloys containing 1.25 to 2.0% C. These steels are thermo-mechanically processed to produce microstructures that consist of ultrafine, equiaxed grains of spherical, discontinuous proeutectoid carbide particles.

High-Strength Low-Alloy Steels

High-strength low-alloy (HSLA) steels, or micro alloyed steels, are designed to provide better mechanical properties and/or greater resistance to atmospheric corrosion than conventional carbon steels in the normal sense because they are designed to meet specific mechanical properties rather than a chemical composition. The HSLA steels have low carbon contents (0.05-0.25% C) in order to produce adequate formability and weldability, and they have manganese contents up to 2.0%. Small quantities of chromium, nickel, molybdenum, copper, nitrogen, vanadium, niobium, titanium and zirconium are used in various combinations.

HSLA Classification:

- **Weathering steels**, designated to exhibit superior atmospheric corrosion resistance
- **Control-rolled steels**, hot rolled according to a predetermined rolling schedule, designed to develop a highly deformed austenite structure that will transform to a very fine equiaxed ferrite structure on cooling
- **Pearlite-reduced steels**, strengthened by very fine-grain ferrite and precipitation hardening but with low carbon content and therefore little or no pearlite in the microstructure
- **Micro alloyed steels**, with very small additions of such elements as niobium, vanadium, and/or titanium for refinement of grain size and/or precipitation hardening
Classification of Carbon and Low-Alloy Steels

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• **Acicular ferrite steel**, very low carbon steels with sufficient hardenability to transform on cooling to a very fine high-strength acicular ferrite structure rather than the usual polygonal ferrite structure

• **Dual-phase steels**, processed to a micro-structure of ferrite containing small uniformly distributed regions of high-carbon martensite, resulting in a product with low yield strength and a high rate of work hardening, thus providing a high-strength steel of superior formability.

The various types of HSLA steels may also have small additions of calcium, rare earth elements, or zirconium for sulfide inclusion shape control.

**Low-alloy Steels**

Low-alloy steels constitute a category of ferrous materials that exhibit mechanical properties superior to plain carbon steels as the result of additions of alloying elements such as nickel, chromium, and molybdenum. Total alloy content can range from 2.07% up to levels just below that of stainless steels, which contain a minimum of 10% Cr. For many low-alloy steels, the primary function of the alloying elements is to increase hardenability in order to optimize mechanical properties and toughness after heat treatment. In some cases, however, alloy additions are used to reduce environmental degradation under certain specified service conditions.

As with steels in general, low-alloy steels can be classified according to:

• **Chemical composition**, such as nickel steels, nickel-chromium steels, molybdenum steels, chromium-molybdenum steels

• **Heat treatment**, such as quenched and tempered, normalized and tempered, annealed.

Because of the wide variety of chemical compositions possible and the fact that some steels are used in more than one heat-treated condition, some overlap exists among the alloy steel classifications. In this article, four major groups of alloy steels are addressed: (1) low-carbon quenched and tempered (QT) steels, (2) medium-carbon ultrahigh-strength steels, (3) bearing steels, and (4) heat-resistant chromium-molybdenum steels.

**Low-carbon quenched and tempered steels** combine high yield strength (from 350 to 1035 MPa) and high tensile strength with good notch toughness, ductility, corrosion resistance, or weldability. The various steels have different combinations of these characteristics based on their intended applications. However, a few steels, such as HY-80 and HY-100, are covered by military specifications. The steels listed are used primarily as plate. Some of these steels, as well as other, similar steels, are produced as forgings or castings.

**Medium-carbon ultrahigh-strength steels** are structural steels with yield strengths that can exceed 1380 MPa. Many of these steels are covered by SAE/AISI designations or are proprietary compositions. Product forms include billet, bar, rod, forgings, sheet, tubing, and welding wire.

**Bearing steels** used for ball and roller bearing applications are comprised of low carbon (0.10 to 0.20% C) case-hardened steels and high carbon (-1.0% C) through-hardened steels. Many of these steels are covered by SAE/AISI designations.

**Chromium-molybdenum heat-resistant steels** contain 0.5 to 9% Cr and 0.5 to 1.0% Mo. The carbon content is usually below 0.2%. The chromium provides improved oxidation and corrosion resistance, and the molybdenum increases strength at elevated temperatures. They are generally supplied in the normalized and tempered, quenched and tempered or annealed condition. Chromium-molybdenum steels are widely used in the oil and gas industries and in fossil fuel and nuclear power plants.