

Metals and Alloys Glossary

Aging - A change in the properties of certain metals and alloys that occurs at ambient or moderately elevated temperatures after a hot-working operation or a heat-treatment (quench aging in ferrous alloys, natural or artificial aging in ferrous and nonferrous alloys) or after a cold-working operation (strain aging). The change in properties is often, but not always, due to a phase change (precipitation), but never involves a change in chemical composition of the metal or alloy.

Al₂O₃ - aluminum oxide - Abrasive material for grinding tools, Al₂O₃ also is the base for ceramics and is used to coat tools.

Alloy - A substance having metallic properties and being composed of two or more chemical elements of which at least one is a metal.

Alloying element - An element that is added to a metal to change the metal's properties.

Alpha iron - The body-centered cubic form of pure iron, stable below 910° C.

Aluminizing - Formation of an aluminum or aluminum-alloy coating on a metal by hot dipping, hot spraying, or diffusion.

Amorphous - Not having a crystal structure; noncrystalline.

Atmospheric corrosion - The gradual degradation or alteration of a material by contact with substances present in the atmosphere, such as oxygen, carbon dioxide, water vapor, and sulfur and chlorine compounds.

Austenite - Metallurgical term for a material that forms when carbon steel is heated above 735° C and the iron-carbide compounds within the steel dissolve. Quenching the carbon steel at this point replaces the austenite with martensite, which has an angular molecular structure and high hardness.

Bainite - A metastable aggregate of ferrite and cementite resulting from the transformation of austenite at temperatures below the pearlite range. Its appearance is feathery if formed in the upper part of the bainite transformation range; acicular, resembling tempered martensite, if formed in the lower part.

Black oxide - A black finish on a metal produced by immersing it in hot oxidizing salts or salt solutions.

Carbide - Compound of carbon and one or more metallic elements. For cutting tools, tungsten carbide, or a combination of these in a cobalt or nickel matrix provides hardness, wear resistance, and heat resistance. Other elements added to carbide include vanadium, niobium, silicon, boron, and hafnium.

Carbon steel - Steel combined with varying amounts of carbon. Has no specified minimum quantity for any alloying element (other than the commonly accepted amounts of manganese, silicon, and copper) and contains only an incidental amount of any element other than carbon, silicon, manganese, copper, sulfur, and phosphorus.

Cast alloy - Alloy cast from the molten state; most high-speed steel is melted in an electric-arc furnace and cast into ingots.

Cast iron - A generic term for a large family of cast ferrous alloys in which the carbon content exceeds the solubility of carbon in austenite at the eutectic temperature. Most cast irons contain at least 2% carbon, plus silicon and sulfur, and may or may not contain other alloying elements. For the various forms--gray cast iron, white cast iron, malleable cast iron and ductile cast iron--the word "cast" is often left out.

Ceramic - Made from finely powdered aluminum oxide sintered into the desired form. Ceramics operate at higher speeds than carbides, plus they wear longer, provide smoother finishes, and can machine harder materials. They are, however, less shock-resistant. Typically used for high-speed turning.

Cementite - Fe₃C also known as Iron Carbide.

Cold working - Deforming metal plastically under conditions of temperature and strain rate that induce strain hardening. Working below the recrystallization temperature, which is usually, but not necessarily, above room temperature.

Commercial-grade tool steel - Low-grade tool steel; not controlled for hardenability.

Composites - Materials composed of different elements, with one element normally embedded in another, held together by a compatible binder.

Continuous casting - A casting technique in which a cast shape is continuously withdrawn through the bottom of the mold as it solidifies, so that its length is not determined by mold dimensions. Used chiefly to produce semifinished mill products such as billets, blooms, ingots, slabs, and tubes.

Corrosion - The chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties.

Corrosion fatigue - The process in which a metal fractures prematurely under conditions of simultaneous corrosion and repeated cyclic loading at lower stress levels or fewer cycles than would be required in the absence of the corrosive environment.

Corrosion resistance - Ability of an alloy or material to withstand rust and corrosion; properties fostered by nickel and chromium in alloys such as stainless steel.

Cutting tool materials - Include cast cobalt-base alloys, ceramics, cemented carbides, cubic boron nitride, diamond, high-speed steels, and carbon steels.

Diamond - Cubic crystalline form of carbon produced under extreme pressures at elevated temperatures. The hardest natural substance, it has approximately five times the indentation hardness of carbide. Its extreme hardness, though makes it susceptible to fracturing.

Die casting - 1. A casting made in a die. 2. A casting process wherein molten metal is forced under high pressure into the cavity of a metal mold.

Diffusion - 1. Spreading of a consistent in a gas, liquid, or solid, tending to make the composition of all parts uniform. 2. The spontaneous movement of atoms or molecules to new sites within a material.

Ductile cast iron - A cast iron that has been treated while molten with an element such as magnesium or cerium to induce the formation of free graphite as nodules or spherulites, which imparts a measurable degree of ductility to the cast metal. Also known as nodular cast iron, spherulitic graphite cast iron, or SG iron.

Ductility - The ability of a material to be bent, formed, or stretched without rupturing. Measured by elongation or reduction of area in a tensile test or by other means.

Elastic limit - The maximum stress that a material can sustain without deforming.

Elasticity - The property of a material to deform under stress and recover its original shape and dimensions after release of stress.

Elongation - In tensile testing, the increase in the gage length, measured after fracture of the specimen within the gage length, usually expressed as a percentage of the original gage length.

Embrittlement - Reduction in the normal ductility of a metal due to a physical or chemical change. Examples include blue brittleness, hydrogen embrittlement, and temper brittleness.

Endurance limit - The maximum stress below which a material can presumably endure an infinite number of stress cycles.

Extrusion - Conversion of an ingot or billet into lengths of uniform cross section by forcing metal to flow plastically through a die or orifice.

Fatigue - The phenomenon leading to fracture under repeated or fluctuating stresses having a maximum value less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of the fluctuating stress.

Fatigue life - The number of cycles of stress that can be sustained prior to failure under a stated test condition.

Fatigue resistance - Ability of a tool or component to be flexed repeatedly without cracking; important for bandsaw-blade backing.

Fatigue strength - The maximum stress that can be sustained for a specified number of cycles without failure, the stress being completely reversed within each cycle unless otherwise stated.

Ferrite - A solid solution of one or more elements in body-centered cubic iron. Unless otherwise designated (for instance, as chromium ferrite), the solute is generally assumed to be carbon. On some equilibrium diagrams, there are two ferrite regions separated by an austenite area. The lower area is alpha ferrite; the upper, delta ferrite. If there is no designation, alpha ferrite is assumed.

Fracture stress - 1. The maximum principal true stress at fracture. Usually refers to un-notched tensile specimens. 2. The (hypothetical) true stress that will cause fracture without further deformation at any given strain.

Free-machining steels - Carbon and alloy steels that contain lead, sulfur, or other elements that improve machinability.

Galling - A condition whereby excessive friction between high spots results in localized welding with subsequent spalling and further roughening of the rubbing surface(s) of one or both of two mating parts.

Gray cast iron - A cast iron that gives a gray fracture due to the presence of flake graphite. Often called gray iron.

Hard chromium - Chromium electrodeposited for engineering purposes (such as to increase the wear resistance of sliding metal surfaces) rather than as a decorative coating. It is usually applied directly to basis metal and is customarily thicker than a decorative deposit, but not necessarily harder.

Hardenability - The ability of a ferrous alloy to form martensite when quenched from a temperature above the upper critical temperature. Hardenability is commonly measured as the distance below a quenched surface at which the metal exhibits a specific hardness ($R_c 50$, for example) or a specific percentage of martensite in the microstructure.

Hardness - Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper, or to resistance to scratching, abrasion, or cutting. Indentation hardness may be measured by various hardness tests, such as Brinell, Rockwell, and Vickers.

Hot working - Deforming a metal plastically at a temperature and strain rate such that the recrystallization temperature is exceeded and recrystallization takes place simultaneously with the deformation, thus avoiding any strain hardening.

HSS, high-speed steel - Tool steel alloyed with tungsten and molybdenum. Permits cutting at higher speeds and feeds than carbon-steel tools because an HSS tool's cutting edges don't soften at temperatures that soften carbon steel.

Induction hardening - A surface-hardening process in which only the surface layer of a suitable ferrous workpiece is heated by electromagnetic induction to above the upper critical temperature and immediately quenched.

Inhibitor - A chemical substance or combination of substances that, when present in the environment, prevents or reduces corrosion without significant reaction with the components of the environment.

Investment casting - 1. Casting metal into a mold produced by surrounding (investing) an expendable pattern with a refractory slurry that sets at room temperature, after which the wax, plastic, or frozen-mercury pattern is removed through the use of heat. Also called precision casting or lost-wax process. 2. A part made by the investment-casting process.

Killed steel - Steel treated with a strong deoxidizing agent such as silicon or aluminum to reduce the oxygen content so that no reaction occurs between carbon and oxygen during solidification.

Knoop hardness - Hardness rating for very thin materials and plated surfaces.

Machinability, machinability rating - Determines acceptability of a tool for the workpiece to be machined. Indicates workpiece's hardness, chemical composition and qualities, microstructure, propensity to workharden, elasticity, and propensity to be worked cold. In general, the harder a material, the higher its machinability rating. A material's machinability also is impacted by the type and age of machine, its power and rigidity, and the cutting tool used.

Malleable cast iron - A cast iron made by prolonged annealing of white cast iron in which decarburization or graphitization, or both, take place to eliminate some or all of the cementite. The graphite is in the form of temper carbon.

Martensite - A generic term for microstructures formed by diffusionless phase transformation in which the parent and product phases have a specific crystallographic relationship. Martensite is characterized by an acicular pattern in the microstructure in both ferrous and nonferrous alloys. In alloys where the solute atoms occupy interstitial positions in the martensitic lattice (such as carbon in iron), the structure is hard and highly strained; but where the solute atoms occupy substitutional positions (such as nickel in iron), the martensite is soft and ductile. The amount of high-temperature

phase that transforms to martensite on cooling depends to a large extent on the lowest temperature attained, there being a rather distinct beginning temperature (M_s) and a temperature at which the transformation is essentially complete (M_f).

Mechanical properties - The properties of a material that reveal its elastic and inelastic behavior when force is applied, thereby indicating its suitability for mechanical applications; for example, modulus of elasticity, tensile strength, elongation, hardness, and fatigue limit. Compare with physical properties.

Microhardness - The hardness of a material as determined by forcing an indenter such as a Vickers or Knoop indenter into the surface of the material under very light load; usually, the indentations are so small that they must be measured with a microscope. Capable of determining hardness of different microconstituents within a structure, or measuring steep hardness gradients such as those encountered in casehardening.

Microstructure - The structure of a metal as revealed by microscopic examination of the etched surface of a polished specimen.

Mild steel - Carbon steel with a maximum of about 0.25% carbon.

Oxidation - 1. A reaction in which there is an increase in valence resulting from a loss of electrons. Contrast with reduction. 2. A corrosion reaction in which the corroded metal forms an oxide; usually applied to a reaction with a gas containing elemental oxygen, such as air.

Peening - Mechanical working of a metal by hammer blows or shot impingement.

Pearlite - A lamellar aggregate of ferrite and cementite. Softer than most other microstructures. Formed from austenite during air cooling from austenite.

Physical properties - Properties of a metal or alloy that are relatively insensitive to structure and can be measured without the application of force; for example, density, electrical conductivity, coefficient of thermal expansion, magnetic permeability, and lattice parameter. Does not include chemical reactivity. Compare with mechanical properties.

Pitting - Localized corrosion of a metal surface, confined to a point or small area, that takes the form of cavities.

PM, powder metallurgy - Processes in which metallic particles are fused under various combinations of heat and pressure to create solid metals.

Rockwell hardness - Various scales for determining material hardness. Rockwell C, A, and D scales measure metal hardness. The Rockwell C, or R_C , scale, and the Brinell hardness (Bhn) scale are used most often in connection with cutting tools and machining.

Shear strength - The stress required to produce fracture in the plane of cross section, the conditions of loading being such that the directions of force and of resistance are parallel and opposite although their path are offset a specified minimum amount. The maximum load divided by the original cross-sectional area of a section separated by shear.

Sintering - The bonding of adjacent surfaces in a mass of particles by molecular or atomic attraction on heating at high temperatures below the melting temperature of any constituent in the material. Sintering strengthens and increases the density of a powder mass and recrystallizes powder metals.

Steel - Basically pure iron in combination with carbon and other elements. There are two types of steel: carbon steel, or a combination of iron and carbon; and alloy steel, which is carbon steel plus manganese, molybdenum, chromium, nickel, or other alloying elements. A steel's quality depends on how it is refined and produced. See *alloy*; *alloy steel*; *alloying element*; *carbon steel*.

Steel-specification number - A system of numbers developed by the AISI (American Iron and Steel Institute) and SAE (Society of Automotive Engineers) to identify steel. The first two digits in the code indicate the family and basic alloying elements. The final two digits indicate the approximate carbon content in hundredths of a percent. For steels with a carbon content above 1.00%, five digits are used. Numbers with L or S added indicate alloys incorporating lead or sulfur for improved machinability. A number of steels and alloys are identified under different codes, including tool steel, carbon tool steel, high-speed steel, die steel, stainless steel, strain-hardenable or workhardening steel, and nickel-base superalloys.

Stress - Force per unit area, often thought of as force acting through a small area within a plane. It can be divided into components, normal and parallel to the plane, called normal stress and shear stress, respectively. True stress denotes the stress where force and area are measured at the same time. Conventional stress, as applied to tension and compression tests, is force divided by original area. Nominal stress is the stress computed by simple elasticity formulas, ignoring stress raisers and disregarding plastic flow; in a notch bend test, for example, it is bending moment divided by minimum section modulus.

Tensile strength - In tensile testing, the ratio of maximum load to original cross-sectional area. Also called ultimate strength. Compare with yield strength.

Tool Steel - Any of a class of carbon and alloy steels commonly used to make tools. Tool steels are characterized by high hardness and resistance to abrasion, often accompanied by high toughness and resistance to softening at elevated temperatures. These attributes are generally attained with high carbon and alloy contents.

Wear resistance - Ability of the tool to withstand stresses that cause it to wear during cutting; an attribute linked to alloy composition, base material, thermal conditions, type of tooling and operation, and other variables.

Yield point - The first stress in a material, usually less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress. Only certain metals exhibit a yield point. If there is a decrease in stress after yielding, a distinction may be made between upper and lower yield points.

Yield strength - The stress at which a material exhibits a specified deviation from proportionality of stress and strain. An offset of 0.2 percent is used for many metals. Compare with tensile strength.