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Glossary of Metallurgical Terms

Alloying Elements

ALUMINUM - Al
is used to deoxidize steel and control grain size. Grain size control is affected by forming a fine dispersion with nitrogen and oxygen which restricts austenite grain growth. Aluminum is also an extremely effective nitride former in nitriding steels.

BORON - B
is usually added between .0005-.003% to significantly increase the hardenability, especially for low carbon alloys. It does not affect the strength of ferrite, therefore not sacrificing ductility, formability or machinability in the annealed state.

CALCIUM - Ca
is used in certain steels to control the shape, size and distribution of oxide and/or sulfide inclusions. Benefits may include improved ductility, impact strength and machinability.

CARBON - C
is the most important alloying element which is essential for the formation of cementite, pearlite, spheriodite, bainite, and iron-carbon martensite. Compared to steels with similar microstructures, strength, hardness, hardenability, and ductile-to-brittle transition temperature are increased with increasing carbon content up to approximately .60%. Toughness and ductility of pearlitic steels are decreased with increasing carbon content.

CHROMIUM - Cr
is used in low alloy steels to increase 1) resistance to corrosion and oxidation, 2) high temperature strength, 3) hardenability, and 4) abrasion resistance in high carbon alloys. Straight chromium steels are susceptible to temper embrittlement and can be brittle.

COPPER - Cu
is detrimental to hot workability and subsequent surface quality. It is used in certain steels to improve resistance to atmospheric corrosion.

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LEAD - Pb
improves machinability. It does not dissolve in steel but stays as globules. Environmental concerns are resulting in a decreased usage of lead in the steel industry.

MANGANESE - Mn
is important because it deoxidizes the melt and facilitates hot working of the steel by reducing the susceptibility to hot shortness. It combines with sulfur to form MnS stringers which increases machinability. Manganese contributes to the effectiveness of normalizing for strengthening, to the formation of fine pearlite, and lowers the Ms temperature, therefore increasing the probability of retained austenite.

MOLYBDENUM - Mo
increases hardenability of steels and helps maintain a specified hardenability. It increases high temperature tensile and creep strengths. Molybdenum hardened steels require higher tempering temperatures for softening purposes.

NICKEL - Ni
is used in low alloy steels to reduce the sensitivity of the steel to variations in heat treatment and distortion and cracking on quenching. It also improves low temperature toughness and hardenability.

NIOBIUM - Nb (Columbium - Cb)
lowers transition temperature and raises the strength of low carbon steel. Niobium increases strength at elevated temperatures, results in finer grain size and forms stable carbides, lowering the hardenability of the steel.

NITROGEN - N
increases the strength, hardness and machinability of steel, but it decreases the ductility and toughness. In aluminum killed steels, nitrogen combines with the aluminum to provide grain size control, thereby improving both toughness and strength. Nitrogen can reduce the effect of boron on the hardenability of steels.

PHOSPHORUS - P
is generally restricted to below 0.04 weight percent to minimize its detrimental effect on ductility and toughness. Certain steels may contain higher levels to enhance machinability, strength and/or atmospheric corrosion resistance.

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SILICON - Si
is one of the principal deoxidizers with the amount used dependent on the deoxidization practice. It slightly increases the strength of ferrite without a serious loss of ductility. In larger quantities, it aids the resistance to scaling up to 500°F in air and decreases magnetic hysteresis loss.

SULFUR - S
is detrimental to transverse strength and impact resistance. It affects longitudinal properties to a lesser degree. Existing primarily in the form of manganese sulfide stringers, sulfur is typically added to improve machinability.

TITANIUM - Ti
is added to boron steels because it combines with oxygen and nitrogen, thus increasing the effectiveness of boron. Titanium, as titanium nitride, also provides grain size control at elevated temperatures in microalloy steels. In excess, titanium is detrimental to machinability and internal cleanness.

TELLURIUM - Te
is added to steel to modify sulfide type inclusion size, morphology and distribution. The resulting sulfide type inclusions are finer and remain ellipsoidal in shape following hot working, thereby improving transverse properties.

VANADIUM - V
inhibits grain growth during heat treating while improving strength and toughness of hardened and tempered steels. Additions up to .05% increase hardenability whereas larger amounts tend to reduce hardenability because of carbide formation. Vanadium is also utilized in ferrite/pearlite microalloy steels to increase hardness through carbonitride precipitation strengthening of the matrix.

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Standard Mill Terminology

ANNEALING
A treatment consisting of heating uniformly to a temperature, within or above the critical range, and cooling at a controlled rate to a temperature under the critical range. This treatment is used to produce a definite microstructure, usually one designed for best machinability, and/or to remove stresses, induce softness, and alter ductility, toughness or other mechanical properties.

BILLET
A solid semifinished round or square that has been hot worked usually smaller than a bloom. Also a general term for wrought starting stock for forgings or extrusions.

BLOOM
A semifinished hot rolled rectangular product. The width of the bloom is no more than twice the thickness and the cross-sectional area is usually not less that 36 square inches.

CAPPED STEEL
A type of steel similar to rimmed steel, usually cast in a bottle top ingot, in which the application of a mechanical or chemical cap renders the rimming action incomplete by causing the top metal to solidify.

DI (Ideal Diameter)
The diameter of a round steel bar that will harden at the center to a given percent of martensite when subjected to an ideal quench (i.e., Grossman quench severity H=infinity)

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

END-QUENCH HARDENABILITY TEST (Jominy Test)
A laboratory procedure for determining the hardenability of a steel or other ferrous alloy. Hardenability is determined by heating a standard specimen above the upper critical temperature, placing the hot specimen in a fixture so that a stream of cold water impinges on one end, and, after cooling to room temperature is completed, measuring the hardness near the surface of the specimen at regularly spaced intervals

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along its length. The data are normally plotted as hardness versus distance from the quenched end.

HARDNESS
Resistance of a metal to plastic deformation, usually by indentation. However, this may also refer to stiffness or temper, or to resistance to scratching, abrasion, or cutting.

IMPACT TEST
A test to determine the behavior of materials when subjected to high rates of loading, usually in bending, tension or torsion. The quantity measured is the energy absorbed in breaking the specimen by a single blow, as in the Charpy or Izod tests.

INGOT
A casting of a simple shape which can be used for hot working or remelting.

KILLED STEEL
Steel treated with a strong deoxidizer to reduce oxygen to a level where no reaction occurs between carbon and oxygen during solidification.

LAP
A surface imperfection which appears as a seam. It is caused by the folding over of hot metal, fins, or sharp corners and then rolling or forging them into the surface but not welding them. Laps on tubes can form from seams on piercing mill billets.

MACHINABILITY
This is a generic term for describing the ability of a material to be machined. To be meaningful, machinability must be qualified in terms of tool wear, tool life, chip control, and/or surface finish and integrity. Overall machining performance is affected by a myriad of variables relating to the machining operation and the workpiece. An overall review is provided in the ASM Metals Handbook: Machinability, Ninth Edition, Volume 16, 1989.

NORMALIZING
A treatment consisting of heating uniformly to temperature at least 100 °F above the critical range and cooling in still air at room temperature. The treatment produces a recrystallization and refinement of the grain structure and gives uniformity in hardness and structure to the product.

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PICKLING
An operation by which surface oxide (scale) is removed by chemical action. Sulfuric acid is typically used for carbon and low-alloy steels. After the acid bath, the steel is rinsed in water.

QUENCHING
A treatment consisting of heating uniformly to a predetermined temperature and cooling rapidly in air or liquid medium to produce a desired crystalline structure.

REDUCTION OF AREA
The difference, expressed as a percentage of original area, between the original cross-sectional area of a tensile test specimen and the minimum cross-sectional area measured after complete separation.

RIMMED STEEL
A low carbon steel having enough iron oxide to give a continuous evolution of carbon monoxide during solidification giving a rim of material virtually free of voids.

SCAB
An imperfection which is a flat piece of metal rolled into the steel surface.

SEAM
A defect on the surface of a metal which appears as a crack. Experience indicates that most seams are created during the cooling or reheating of cast structures.

SEMI-KILLED STEEL
Incompletely deoxidized steel which contains enough dissolved oxygen to react with the carbon to form carbon monoxide to offset solidification shrinkage.

SPHEROIDIZE ANNEAL
A special type of annealing that requires an extremely long cycle. This treatment is used to produce globular carbides and maximum softness for best machinability in some analyses, or to improve cold formability.

STRAND CASTING (Continuous Casting)
Operation in which a cast shape is continuously drawn through the bottom of the mold as it solidifies. The length is not determined by mold dimensions.

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STRESS RELIEVE TEMPER
A thermal treatment to restore elastic properties and to minimize distortion on subsequent machining or hardening operations. This treatment is usually applied to material that has been heat treated (quenched and tempered). Normal practice would be to heat to a temperature 100°F lower than the tempering temperatures used to establish mechanical properties and hardness. Ordinarily, no straightening is performed after the stress relieve temper.

TEMPERING
A treatment consisting of heating uniformly to some predetermined temperature under the critical range, holding at that temperature a designated period of time and cooling in air or liquid. This treatment is used to produce one or more of the following end results: A) to soften material for subsequent machining or cold working, B) to improve ductility and relieve stresses resulting from prior treatment or cold working, and C) to produce the desired mechanical properties or structure in the second step of a double treatment.

TENSILE STRENGTH
In tensile testing, the ratio of maximum load to original cross-sectional area.

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. 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 .2% is commonly used.

Information adapted from ASM and/or SAE publications and is for reference only.