Technical Bulletin

Industrial Blade Solutions

The Basics of Steel

Metal Basics

The five most used metals are:

- Iron
- Aluminum
- Copper
- Zinc
- Magnesium

General physical properties of metals include:

- They are strong and hard
- They are solids at room temperature (except Mercury, the only metal to be liquid at room temperature)
- They have a shiny appearance when polished
- They make good heat conductors and electrical conductors
- They are dense
- They produce a deep, resonant sound when struck
- They have high melting points
- They are malleable

Certain properties make certain metals suitable for a variety of uses in daily life:

- Copper is a good conductor of electricity and is ductile, and is used for electrical cables.
- Gold and silver are very malleable, ductile and very nonreactive. Gold and silver are popular for making intricate jewelry. Gold is also very suitable for oxidation-free electrical connections.
- Iron and steel are both hard and strong, and are commonly found in construction (i.e. bridges and buildings). A disadvantage of iron is that it tends to rust. Although most steels will also rust, they can be formulated to be rust free.
- Aluminum is a good conductor of heat and is malleable, and is used to make saucepans, foils, etc. It is also very light, making it very popular for use in aerospace.

Steel

By definition, steel is a combination of iron and no more that 2% carbon. Steel may be alloyed with various other elements that combine to produce special properties.

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Alloying Steel

Pure elemental metals are often too soft to be of practical use which is why much of metallurgy focuses on formulating useful alloys. Common engineering metals include aluminum, chromium, copper, magnesium, nickel, titanium and zinc. These are most often used as alloys combined with iron.

- Plain carbon steels and cast irons are used in low cost, high strength applications where weight and corrosion are not a problem.
- Stainless steel or galvanized steel are used where resistance to corrosion is important.
- Aluminum alloys and magnesium alloys are used for applications where strength and lightness are required.
- Cupro-nickel alloys such as Monel are used in highly corrosive environments and for non-magnetic applications.
- Nickel-based superalloys like Inconel are used in high temperature applications such as turbochargers, pressure vessels, and heat exchangers.

Engineering Steels

In the production of steels, metallurgy is concerned with the production of metallic components for use in consumer or engineering products. This involves the production of alloys, and also the shaping, heat treatment and surface treatment of the product. The task of metallurgy is to achieve the right balance between material properties such as cost, weight, strength, toughness, hardness, corrosion and fatigue resistance, and performance in temperature extremes.

To achieve this balance, the operating environment of the finished product must be carefully considered. For example, in a saltwater environment, ferrous metals and some aluminum alloys corrode quickly. Metals exposed to cold or cryogenic conditions may undergo a ductile to brittle transition, losing their toughness and becoming more brittle and prone to cracking. Metals under continual cyclic loading can suffer from metal fatigue. And metals under constant stress at elevated temperatures can creep.

The Metal-working Process

Metals are shaped by processes such as casting, forging, flow forming, rolling, extrusion, sintering, metalworking, machining and fabrication.

- Casting - molten metal is poured into a shaped mold
- Forging - a red-hot billet is hammered into shape
- Rolling - a billet is passed through successively narrower rollers to create a sheet
- Extrusion - hot and malleable metal is forced under pressure through a die, which shapes it before it cools
- Sintering - a powdered metal is compressed into a die at high temperature
- Machining - lathes, milling machines, and drills work the cold metal to shape
- Fabrication - sheets of metal are cut by a variety of methods and bent into shape

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"Cold working" processes, where the product's shape is altered by rolling, fabrication or other processes while the product is cold, can increase the strength of the product by a process called work hardening. Work hardening creates microscopic defects in the metal, which resist further changes of shape.

Various forms of casting exist in industry, including sand casting, investment casting (also called the "lost wax method"), die casting and continuous casting.

Heat Treatment

Metals can be heat treated to alter their properties of strength, ductility, toughness, hardness or resistance to corrosion. Common heat treatment processes include annealing, precipitation strengthening, quenching, and tempering. The annealing process softens the metal by allowing recovery of cold work and grain growth. Quenching hardens alloy steels. Tempering causes the dissolved alloying elements to "precipitate", improving impact strength and ductile properties.

Surface Treatment

Plating

Electroplating is a common surface-treatment technique, involving bonding a thin layer of another metal, such as gold, silver, chromium or zinc, to the surface of the main product. It is used to reduce corrosion as well as to improve the product's appearance.

Thermal Spray

Thermal spraying techniques are another popular finishing option, and often have better high temperature properties than electroplated coatings.

Case Hardening

Case hardening is the process in which an alloying element, most commonly carbon or nitrogen, is diffused into the outer layer of the base steel at high temperature. The resulting material is harder on its surface than the base material, improving wear resistance without sacrificing toughness.