

Materials

Iron and Steel

Introduction

Iron and Steel, referred to as ferrous metals, are the most widely used metal group, mainly due to its strength, low cost, availability, and its wide ranging versatility. Iron and steel, except for stainless steel, are susceptible to corrosion and require protective coatings to provide a barrier against the environment to reduce the rate of degradation.

Iron

Two forms of iron are available, these are Cast Iron and Wrought Iron.

Cast Iron

There are a number of different cast irons available, including Grey Flake, Spheroidal Graphite, White Heart Malleable, Blackheart and White Cast Irons. The properties of these base cast irons can be modified by adding alloying elements.

Cast iron is normally supplied in billet form, which is melted down and used for producing complex shaped components. Cast iron are generally strong in compression, but weak in tension and are susceptible to fracture if significant impact loads are experienced.

Grey Flake Cast Iron contains 'flake' graphite and is the most commonly used. Applications include machine tool bearing surfaces due to its self lubricating and vibration damping properties. It is one of the lowest cost engineering casting materials available. On cooling very little shrinkage is experienced and the resulting component is easily machined. The suggested design stress limit is suggested to be a quarter of the UTS. Alloys of grey cast irons are available to improve strength, resistance to wear and corrosion resistance, but inclusion of certain elements can reduce the machineability properties of the component.

Spheroidal Graphite or Nodular Iron contains spheres of graphite, this material is similar in properties to Grey Flake Cast Iron, but generally has a higher ductility and higher tensile strength.

White Heart Malleable Cast Iron has improved casting, welding, machining and shock resisting properties. The wear resistance of this material is less than that of grey cast iron. Components should be annealed after welding to remove localised stresses.

Blackheart Malleable Cast Iron provides excellent machineability and strength properties, but does not exhibit the wear resistance of grey cast irons, although the pearlitic version of blackheart increases the wear resistance. This pearlitic version can be heat treated to provide a wide variety of properties.

White Cast Iron is not easily machined due to its hardness and it can only support compressive loads. The speed at which the casting is produced must be carefully controlled, otherwise the resulting component will shrink and be distorted. Other forms of white cast iron are available, including martensitic and high chromium, these improve upon the toughness and hardness properties.

Wrought Iron

Wrought Iron is a low cost material that can be easily formed into shape by working, cold or hot. Two types of wrought iron are available, puddled and charcoal wrought iron. Puddled iron is more resistant to corrosion and charcoal iron is better for working when cold. Wrought iron is supplied in strip, bar or sheet form and is used for manufacturing low specification and architectural products, such as gates, fences and garden frameworks.

Steel

Steel is a highly versatile alloy of iron with carbon. Other elements are added to steel to improve its properties, primarily Silicon and Manganese, other elements include Sulphur, Molybdenum, Phosphorus, Nickel and Chromium. There are three main types of steels, these are Plain Carbon or Non-Alloy Steel, Alloy Steel and Stainless Steel. Many different forms of steel products are available, depending on type of steel, these include, strip, bars, sections, plate and wire.

Plain Carbon Steel

In the Plain Carbon Steel group there are four main types, these are graded depending on their percentage of carbon content.

| | |
|---------------------|-------------------------------|
| Low Carbon Steel | Up to 0.05% carbon |
| Mild Steel | Between 0.05% and 0.3% carbon |
| Medium Carbon Steel | Between 0.25% and 0.6% carbon |
| High Carbon Steel | Between 0.55% and 1.1% carbon |

Heat treatment and tempering processes carried out on these steels can improve their hardness and/or toughness properties, depending on the methods used.

Alloy steel

The inclusion of alloying elements provides a multitude of different physical properties depending on the number of elements added, the quantity of each element and the material structure changes during heating, cooling and heat treatments. The three classifications are low, medium and high alloy steels.

Alloying elements have different effects on the resulting alloy, the table below provides an indication of the effect of some of the common alloying elements.

| Element | Effect |
|----------------|---|
| Chromium | Increases Resistance to Wear, Oxidisation & Scaling Increases Strength Increases Ability to be Hardened |
| Manganese | Depending on percentage content Reduces Sulphur Brittleness Increases Hardness Improves Strength and Toughness |

| Element | Effect |
|------------|---|
| Molybdenum | Improves the Grain Refinement Increases Strength for High Temperature Applications Increases Creep Resistance Increases Ability to be Hardened |
| Nickel | Improves Strength Properties Increases Toughness Increases Ability to be Hardened |
| Silicon | Increases Strength Increases Ability to be Hardened Reduces Ductility |
| Sulphur | Improves Machineability Reduces Ductility Reduces Weldability |
| Tungsten | Produces Grain Structure With Improved Hardness Increases Toughness Retains Properties at High Temperatures |
| Vanadium | Used With Nickel and/or Chromium Refines Grain Structure Improves Wear Resistance Improves Casting Performance |

The resulting alloy steel groups include, Free Cutting Steel, Weldable Steel, High Speed Steel, Structural Steel and Heat Resisting Steel.

Stainless steel

Stainless steels contain a minimum of 10.5% of chromium.

The superior qualities of stainless steel promote its use in a wide variety of applications including cutlery, food manufacturing and storage equipment, medical equipment and power generation. In the food industry, components are manufactured from 304 and 316 stainless steels, utilising their properties of being able to resist attack from acid food substances and wash down chemicals, whilst not contaminating the food itself.

Stainless steel components provide good life-cycle cost benefits, as a result of their ability to perform well for long periods of time with minimal degradation and low maintenance requirements. Furthermore, statistics show that approximately 90% of the stainless steel that is produced is made from recycled stainless steel.

Stainless Steels are classified into five main groups, as shown in the table overleaf.

| Stainless Type | Grades | General Properties |
|--------------------------------------|--|--|
| Ferritic | 403 405 409 430 434 444 | Low cost Lower strength Lower corrosion resistance grade Magnetic Low Carbon content Between 13% and 17% Chromium No large quantities of other alloying elements Not hardenable by heat treatment |
| Austenitic | 303 304 305 316 317 | Most widely used grade Higher strength Higher corrosion resistance Non-magnetic Between 17% and 20% Chromium Between 6% and 24% Nickel Between 0% and 6% Molybdenum |
| Martensitic | 410 416 | Higher carbon content provides ability to be hardened Around 12% Chromium |
| Duplex (Ferritic + Austenitic) | 318 | Magnetic Better formability than ferritic Improved stress corrosion cracking resistance Between 22% and 25% Chromium Between 0.4% and 3% Molybdenum |
| Precipitation Hardenable | 630 631 | High strength capabilities up to 1700MPa Between 14% and 17% Chromium Between 4% and 7% Nickel |

Internet Resources

The [UK Steel Association](#) represents the steel industry and promotes the industry and the importance of steel to the public and provides information and services to its members. Over 95% of UK steel producing companies are members of the UK Steel Association.

The [British Stainless Steel Association](#) (BSSA) provides support to its members by promoting the use of stainless steel in the UK. The website provides a useful source of technical information on many different types of stainless steels and their application.

The [International Iron and Steel Institute](#) acts to support the interests of its members by conducting and publishing research activities, and acting as an iron and steel information source.