Materials — Aluminium

Introduction

Aluminium performs well in both mechanical and electrical applications. For mechanical applications, aluminium can provide a high strength to weight ratio, ease of manufacture of complex shapes and excellent resistance to corrosion. In electrical applications, aluminium is a good conductor of heat and electricity (approximately 65% of the conductivity of electrical standard copper), is non-magnetic and non-sparking. Aluminium is also non-combustible and non-toxic, can be highly reflective and is impermeable to liquids and air.

Aluminium's resistance to corrosion is a result of a microscopic oxide coating which is formed on contact with air. This layer can be easily removed as its structure does not provide much mechanical strength. If the material is anodised, a harder more dense oxide layer is created which is more resistant to abrasion.

Aluminium can be easily extruded, rolled, cast and machined. Extruded products include bars, tubes and special sections. Rolled products include foil, sheet and plate. The two main types of casting processes are sand and die casting.

Aluminium is a very low density metal that can be alloyed with a number of different elements to provide a wide range of different physical properties. Alloys of aluminium can possess significantly increased strength, ductility and castability, especially after heat-treatment processes. Also, aluminium is often used as an electrical conductor.

The international classification of Aluminium Alloys follows as show in the tables below.

Wrought Alloys

1XXX	Aluminium of 99% minimum purity
2XXX	Aluminium and Copper alloys
3XXX	Aluminium and Manganese alloys
4XXX	Aluminium and Silicon alloys
5XXX	Aluminium and Magnesium alloys
6XXX	Aluminium, Magnesium and Silicon alloys
7XXX	Aluminium, Zinc and Magnesium alloys
8XXX	Miscellaneous alloys, e.g. Aluminium-Lithium alloys

Cast Alloys

1XX.X	Aluminium of 99% minimum purity
2XX.X	Aluminium and copper alloys
3XX.X	Aluminium, Silicon and Copper & / or Magnesium alloys
4XX.X	Aluminium and Silicon alloys
5XX.X	Aluminium and Magnesium alloys
6XX.X	Unused Classification
7XX.X	Aluminium and Zinc alloys
8XX.X	Aluminium and Tin alloys
9XX.X	Miscellaneous alloys

Cast alloys generally contain a higher proportion of alloying elements than wrought alloys. The presence of manufacturing defects reduces the strength and strain properties of cast alloys.

The performance of the alloys can be varied through the use of a variety of techniques, either individually or in combination. These techniques include strain hardening, heat treating, annealing, work hardening and precipitation hardening.

The different temper letter designations are classified as shown in the following table.

F	As fabricated
O	Annealed
H	Strain or Work Hardened (wrought aluminium only)
W	Solution Heat Treated
T	Thermal Treated

A numbering system for temper these designations is used to represent the sequence of treatments that is applied to provide the desired temper.

Wrought Alloys

1XXX – Aluminium of 99% Minimum Purity

This aluminium is used for applications where the support of significant loads is not required, but for applications where extremely good corrosion resistance is required, where an impermeable barrier is required, or where electrical conductivity is a prime consideration. Depending on the requirements different purity levels of this grade of aluminium are available, where ‘1100’ has a minimum 99% aluminium and is used for food and pharmaceutical packaging, and ‘1350’ is used for electrical conducting applications, where a tight restriction is placed on the elements that are not aluminium, to optimise the electrical conducting properties. This aluminium grade is non-heat treatable, but can be strain hardened. The low strength properties of this grade allows for the material to be shaped easily.

2XXX – Aluminium & Copper Alloys

This aluminium grade is heat treatable and provides high strength alloys that perform well over a wide temperature range. The strength to weight ratio of the alloy ‘2024’ promotes its use in aerospace applications that are bolted or riveted together. For welded structures, the alloys ‘2219’ and ‘2048’ are used, although these need to be painted to provide additional resistance to corrosion. The content of impurities is controlled in alloys similar to ‘2124’ to provide a material structure that is significantly more resistant to shock loads.

3XXX – Aluminium & Manganese Alloys

This alloy group is widely used in applications that require resistance to corrosion and chemical attack, properties that allow it to be formed into complex shapes and the ability to be joined by welding, brazing or soldering. These alloys provide medium strength characteristics that can not be improved by heat treating, but they can be strain hardened. Applications include sheet metal cladding for the construction industry and beverage cans.

4XXX – Aluminium & Silicon Alloys

The addition of silicon to aluminium in this range of alloys improves the ability of the material to be formed into complex shapes for forging and to provide an excellent gap filling capability when used as a filler in the welding of aluminium alloy parts, especially welding of 6XXX series components. These alloys are heat treatable and provide medium to high strength alloys.

5XXX – Aluminium & Magnesium Alloys

These alloys exhibit medium to high strength properties and are strain hardenable. Their ability to provide load support at temperatures as low as absolute zero, and their excellent corrosion resistance finds their use in a wide range of applications in the cryogenic freezer, construction, and marine industries. The good weldability and toughness properties of this alloy group are utilised in the previous industries and promote its use in the automotive industry. For components that are exposed to temperatures above 100°C, the content of magnesium must be limited to a maximum of 3% to reduce the potential for stress corrosion cracking problems.

6XXX – Aluminium, Magnesium & Silicon Alloys

As with the 4XXX series, the addition of silicon to the composition provides an ability to be formed into complex shapes. This functionality is used in the manufacture of complex-shaped extruded sections to allow the designer to provide strength and/or stiffness in the areas where it is needed to provide a high strength/stiffness to weight ratio component. These alloys are heat treatable, providing medium to high strength properties. They provide very high resistance to corrosion, can be easily welded and conduct electricity well. Applications of these alloys include automotive body panels and structures, machine and civil engineering structural members and high strength electrical conductors.

7XXX – Aluminium, Zinc & Magnesium Alloys

These are heat treatable and can provide very high strength and very high toughness aluminium alloys. The toughness levels are achieved by controlling the levels of impurities to provide a refined grain structure. These alloys can be welded, but this requires advanced technology and which is avoided if mechanical fastening can be used. The corrosion resistance of 7XXX alloys is average, so for exposed applications a coating is required. These alloys can be costly and sometimes require advanced tempering methods, so their application is normally limited to high performance applications in aerospace structures.

8XXX – Miscellaneous Aluminium Alloys

This alloys group encompasses aluminium alloys that include elements that are not used in significant quantities in the other grades, such as Iron, Nickel and Lithium. Iron and Nickel alloys generally increase the strength of aluminium without reducing the electrical conducting properties. Lithium is used to increase the stiffness and strength properties for low component mass requirements.

Casting Alloys

1XX.X – Aluminium of 99% Minimum Purity

1XX.X grade aluminium does not produce cast components that are suitable for supporting loads.

2XX.X – Aluminium & Copper Alloys

Used for high strength and high toughness components. Addition of the other elements provides special alloys for high performance in high temperature applications. These alloys are heat treatable.

3XX.X – Aluminium, Silicon and Copper and/or Magnesium alloys

As with the wrought aluminium alloys, the addition of silicon improves the ability of the material to be formed into complex shapes. These alloys can be cast using a variety of techniques to provide components that exhibit moderate strengths, and some alloys provide good toughness properties. Selection of the alloy depends on the casting technique being used. Some of the alloys in this range can be formulated using recycled aluminium.

4XX.X – Aluminium & Silicon Alloys

These alloys cannot be heat treated and provide medium strength materials. Again the silicon component provides excellent fluidity. The resulting components can be welded and they provide good corrosion resistance.

5XX.X – Aluminium & Magnesium Alloys

These alloys are selected for components that require high levels of corrosion resistance and moderate strength properties. These alloys are not widely used as a result of difficulties experienced in casting. Resulting components can be easily machined and specific alloys can be anodised.

7XX.X – Aluminium & Zinc Alloys

These alloys can be heat treated to provide medium to high strength properties. The resulting components exhibit a superior surface finish and can be machined easily. Applications of this alloy group are limited to low specification components, because of complications experienced during casting.

8XX.X – Aluminium & Tin Alloys

Aluminium and tin alloys exhibit similar properties to that of the 7XX.X alloys, except for their lower strength. Again they are difficult to cast, but the higher quality of the finished machined parts makes them suitable for bearing applications.

Aluminium Matrix Composites

Reinforcing aluminium with short fibres, whiskers or powders provides components with high strengths, improved wear resistance and low densities. The relatively new technology of metal matrix composites and the expense of manufacturing MMCs limits their use to high performance aerospace and automotive applications. Some reinforcing materials used in aluminium alloys are Silicon Carbide and Alumina.

Internet Resources

The Aluminium Federation acts as an information resource for manufacturers of aluminium products. ALFED provides this information in the form of books, publications, reports and standards. Furthermore ALFED has launched the Aluminium Information Service (AIS) to enable member and non-members to access the ALFED information resources.

The International Aluminium Institute is a body that represents the aluminium industry and its associations to promote understanding and use of aluminium and its alloys.

The Interdisciplinary Research Centre in Materials Processing is based at Birmingham and Swansea Universities and conducts research into Materials for High Performance Applications. The research themes are advanced melting, atomisation, powder and spray forming, casting, powder and ceramics processing, designer materials and their processing, machining and forming technology, and process modelling.