CHAPTER 1

INTRODUCTION

Aluminium is one of the most abundant metals available in the earth’s crust as bauxite with wide range of applications in the modern world. There are many reasons for aluminum’s continued expansion into newer and wider fields of application. Light weight, excellent specific strength, high thermal and electrical conductivities, high reflectivity, good corrosion resistance, excellent workability, and attractive appearance are some of aluminum’s most appealing properties. However, its relatively low strength and poor castability limit its use largely to the production of rotor castings for electrical motors and other applications in which high electrical conductivity is required. Properties of Al are usually enhanced by the addition of major alloying elements such as Cu, Si, Mg, Mn, Zn, Li, Ni and then subjecting the alloys to various thermal, mechanical and thermomechanical treatments. Some of the minor alloying elements added to aluminium are Na, Sr, Sb, Ba and Ca to induce specific changes in the microstructure. Al alloys are available in both cast and wrought forms and about 20% of aluminium produced is used in the cast form mainly in the transport sector.

Figure 1.1 shows the major applications of aluminium. The metal makes a key contribution to fuel-efficient engines in cars and trucks as well as to high speed rail and sea travel. By reducing the vehicles weight, it cuts down on fuel consumption and emissions without compromising the size or the safety of the vehicles. Aluminium facilitates the construction of corrosion-resistant and low maintenance buildings. Around the world, most long distance overhead transmission and distribution lines are made of aluminium. Aluminium in packaging preserves food quality, reduces waste and provides convenience for the users. Aluminium can be rolled into ultra-thin foils, which are light, and strong, have unique barrier and insulation qualities and preserve food, cosmetics and pharmaceutical products by protecting them from ultra-violet light, odours and bacteria.
1.1 IMPORTANCE OF AI-Si ALLOYS

Among commercial aluminium casting alloys, those with silicon as the major alloying element are the most important ones mainly because of their excellent casting characteristics. Addition of Si to pure aluminium imparts high fluidity, good feeding characteristics, low shrinkage and good hot cracking resistance. The high strength to weight ratio is one of their most interesting characteristics. While the volume of most metals (including Al) shrinks substantially on solidification, two-phase Al–Si alloys contract relatively less. These are the only Al alloys that are not prone to hot-tearing during solidification. Aluminium has a density of only 2.7 g/cc, approximately one third of steel, copper or brass. As the density of silicon is 2.3 g/cc, it is one of the few elements which may be added to aluminium without loss of weight advantage. For a specific application, the selection of an alloy depends on its castability, the casting process, the required mechanical and physical properties and the end use of the casting. The properties of Al-Si alloys make them very popular in various applications including the automotive, aerospace and defense industries. Over the years, these Al-Si alloys have been specially developed to meet the increasing demands of today’s industry, which has resulted in the production of smaller, lightweight components to comply with property, environmental and other specifications. Further, the desirable mechanical properties in these alloys can be obtained by controlling chemical composition and process parameters during melting, casting and heat treatment. By weight, 90% of all shaped Al castings are made from Al–Si-based alloys.

1.2 AI-Si ALLOY SYSTEM

Al-Si binary alloy is a eutectic system with the eutectic composition at 12.6 wt.% Si and eutectic temperature at 850 K (Figure 1.2). The two phases in equilibrium will be α- solid solution (solid solution of Si in Al) and pure Si. The solid solubility of Si in Al at 850 K is 1.65%. Rapid quenching from the liquid raises the solubility up to 16% Si and shifts the eutectic point up to 17% Si. Silicon reduces the thermal expansion coefficient, increases corrosion and wear resistance and improves casting and machining characteristics of the alloy. When the Al-Si alloy solidifies, the primary aluminum forms and grows in dendrites or silicon phase forms and grows in angular primary particles. When the eutectic point is reached, the eutectic Al-Si
Figure 1.1: Aluminium’s Major Applications

Figure 1.2: Al–Si alloy phase diagram


phases nucleate and grow until the end of solidification. The alloys to the left of the eutectic composition are referred to as hypo eutectic alloys and those to the right as hypereutectic alloys. At room temperature, hypo eutectic alloys consist of a soft and ductile primary aluminum phase and a hard and brittle eutectic silicon phase. Hypereutectic alloy usually contains coarse, primary silicon cuboids as well as angular eutectic silicon phase.

In hypo eutectic alloys, the silicon varies between 5.5 and 10.5%, and primary aluminium is the first phase to solidify. The microstructure consists of primary aluminium dendrites within a eutectic matrix. Eutectic alloys contain 10.5 to 12.5% silicon and have microstructures consisting mainly of aluminium - silicon eutectic. In hypereutectic alloys containing more than 12.6% silicon, the first phase to solidify is silicon, the primary phase. These alloys having a distribution of coarse silicon cuboids provide excellent wear resistance. Although binary Al-Si alloys show excellent casting characteristics, the addition of Mg, Cu and Zn makes the alloys heat-treatable, providing the means to enhance their properties with the use of appropriate heat treatments. Magnesium contents are typically less than about 0.75%, because increased additions impair fluidity and feeding. The most common aluminium casting alloys in the Al-Si-Mg family is Al-7Si-0.3Mg (356) and Al-7Si-0.5Mg (357). The mechanical properties of an Al-Si cast alloy are mainly determined by its cast structure and the microstructural characteristics such as the grain size, dendrite arm spacing (DAS), the size, shape and distribution of the eutectic Si particles, as well as the morphologies and amounts of intermetallic phases present. Table 1.1 lists the composition and mechanical properties of some of the common Al-Si casting alloys. Al-7Si-0.3Mg [LM25 (UK standard)/356 (USA standard)] alloy is perhaps the most widely specified Al-Si-Mg casting alloy for sand and permanent mold castings.

1.3 RECYCLING OF ALUMINIUM AND ITS ALLOYS

Aluminium has been recycled since its first commercial production and today recycled aluminium accounts for one-third of global aluminium consumption.
Table 1.1: Common Al-Si alloys and their mechanical properties

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Composition</th>
<th>Mechanical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ultimate Tensile Strength (MPa)</td>
</tr>
<tr>
<td>356 (T6)</td>
<td>Al-7Si-0.3Mg</td>
<td>300</td>
</tr>
<tr>
<td>357 (T6)</td>
<td>Al-7Si-0.57Mg</td>
<td>365</td>
</tr>
<tr>
<td>319 (T6)</td>
<td>Al-6.5Si-4.5Cu</td>
<td>276</td>
</tr>
<tr>
<td>413</td>
<td>Al-12Si</td>
<td>200</td>
</tr>
<tr>
<td>A390 (T6)</td>
<td>Al-17Si-4.5Cu</td>
<td>310</td>
</tr>
</tbody>
</table>
Anything made of aluminium can be recycled repeatedly; not only cans, but also aluminium foil, plates, window frames, garden furniture and automotive components can be melted down and re-used. Aluminium is a sustainable material, whose recyclability and applications justify the high energy requirement of primary aluminium production. The transport sector is forecast to be the most rapidly expanding end-use sector due to the lightweight and energy saving qualities of the material. During an automobile's construction a kilogram of aluminium can replace two kilograms of conventional heavier materials, thus contributing to the reduction of the vehicle's weight and therefore its fuel consumption. This means that, over the vehicle's lifetime, every kilogram of aluminium used saves an equivalent of twenty kilograms of CO₂.¹³ Current estimates¹⁴ show that globally there will be, by the year 2020, a 35% increase of CO₂ emissions from all vehicles. An increased use of aluminium would reduce this increase down to 28% and thus help towards making the transportation sector more sustainable.

Recently, appeal for recycling of resources is becoming more and more intensive with increasing public awareness on environmental issues. Climate change is particularly important to the aluminium industry worldwide because of (i) the relatively high energy consumption and greenhouse gas emissions associated with the production of primary aluminium and (ii) the significant potential to reduce greenhouse gas emissions through increased use of aluminium in transportation applications and recycled aluminium.

Recycling of aluminium brings potential energy savings of up to 95% and produces 99% less emission than primary aluminium production from ores. The metal can also be recycled indefinitely, as reprocessing does not damage its structure.¹³ Therefore, secondary aluminium and alloys are getting wide acceptance world-wide. The efficiency of aluminium recycling translates into high recycling rates for the various applications. The lightness of aluminium products contributes to fuel savings and reductions in emissions. Recycling rates for building and transport applications range from 60-90 per cent in various countries.
The aluminium industry is working with the automobile manufacturers to enable easier dismantling of aluminium components from cars in order to improve the sorting and recovery of aluminium. During recycling, most of the parts are mixed together regardless of their chemical composition, as sorting of the parts may not be commercially viable. Efforts are then made to correct the composition of the resulting alloy on line. This practice also has economic limitations. Furthermore, certain elements are either difficult and/or expensive to remove (e.g. iron and magnesium). Iron is always present in commercial aluminium alloys and has consistently emerged as the main impurity element and perhaps the most detrimental to the mechanical properties of these alloys. Hence, the increasing use of recycled aluminum casting alloys raises the necessity for strict process control to remove the ill effects of impurity elements.