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Investigation of the Influence of Cu on Mg Added Al-Si-Cu (A319) Alloy

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Abstract

Aluminium is the third most abundant element on the earth's crust. Most important characteristics of aluminium are its versatility and high strength to weight ratio. The range of mechanical properties that can be developed through alloying is remarkable. The properties of the aluminium that makes it attractive for wide usage today are its light weight, fabricability, corrosion resistance and mechanical properties. A variety of cast Al alloys are available depending on major alloying element like Al-Cu, Al-Mg, Al-Si, Al-Zn etc. Among these, detailed study has been done in Al-Si alloy owing to their excellent properties like good castability, high strength to weight ratio, better wear and corrosion resistance. Although the Al-Si alloys possess good properties much greater strengthning is achieved through addition of other alloying elements like Copper, Magnesium etc. Al-Si-Cu (A319) is characterized with aforesaid properties along with good response to heat treatment which is why this alloy is taken for study. Mg addition to Al alloys is known to improve strength by forming precipitates. By adding Mg to Al-Si-Cu alloy the ageing response is expected to improve. Increasing the copper in Al-Si-Cu alloy would improve strength and in Al-Si-Cu-Mg alloy the strength gets even better. The purpose of this study is to investigate the influence of Cu on Mg added Al-Si-Cu alloy.

Keywords: *Aluminium, A319 alloy, Effect of Mg and Cu on A319 alloy.*

1. Introduction

Aluminium is the third most abundant element on earth's crust. Most important characteristics of aluminium are its versatility and high strength to weight ratio. The range of mechanical properties that can be developed through alloying is remarkable. The properties of aluminium that makes it attractive for wide usage today are its light weight, fabricability, corrosion resistance and mechanical properties. On the contrary, it has a few disadvantages which include low elastic modulus and low elevated temperature properties etc. Although aluminium alloys can be used for short times at temperatures as high as 200-260 ^{0}C, their long term usage is limited to 120-150 ^{0}C.

Aluminium is almost always alloyed, which markedly improves its mechanical properties. It is used as pure metal only when corrosion resistance and/or workability are more important than strength or hardness. The main alloying agents are copper, zinc, magnesium, manganese and silicon with the levels of other metals in a few percent by wight. With a density one third to that of steel, the fuel efficiency is considerably improved which makes it as useful in automotive application. A variety of cast Al alloys are available depending on major alloying element like Al-Cu, Al-Mg, Al-Si, Al-Zn etc. Among these, detailed study has been done in Al-Si alloy owing to their excellent properties like good castability, high strength to weight ratio, better wear and corrosion resistance. Although Al-Si alloys possess good properties much greater strengthening is achieved through addition of other alloying elements like Copper, Magnesium etc. Al-Si-Cu (A319) is characterized with aforesaid properties along with good response to heat treatment which is why this alloy is taken for study. This alloy is mainly used in the fabrication of cylinder heads, engine blocks, crank cases, exhaust manifold etc.

In the developing automotive sector, need of light weight, high strength materials seek the potential replacement or property enhancement of conventional steel materials. Mg addition to Al alloys is known to improve strength by forming precipitates. By adding Mg to Al-Si-Cu alloy the ageing response is expected to improve. Increasing copper in Al-Si-Cu alloy would improve strength and in Al-Si-Cu-Mg alloy the strength gets even better. Heat treatment is an important method that helps to activate inferior properties in the as- cast state due to segregation of alloying elements. The enhancement in mechanical properties after thermal treatment has largely been attributed to the formation of non-equilibrium precipitates within primary dendrites during ageing. The properties of alloy under study were evaluated by conducting hardness test, tensile test and wear test.

1.1 Aluminium

Aluminium denoted as Al is a silvery-white, soft, non-magnetic, ductile metal with atomic number 13 and standard atomic weight 26.98gm. It is a light weight metal with density 2.7gm/cc. It's melting point is 660.32^{0}C. The Young's modulus, Shear modulus, Bulk modulus of Al is 70 N/mm^2, 26 N/mm^2 and 76 N/mm^2 respectively.Aluminium alloys are classified as wrought alloys and cast alloys.

Wrought aluminium alloy designation system

Wrought aluminium alloy designation consists of four digits sometimes including alphabet prefixes or suffixes. First digit indicates major alloying element of the series. Second digit indicates the variation in that alloy from the original composition. The third and fourth digits identify the particular alloy. There is no other specific importance these numbers.

Cast alloy designation system

Cast alloy designation system also has four digits. First digit specifies the major alloying constituent. . The next two digits identify the particular alloy (eg. 319, 356 etc) and the digit after the dot indicates whether it is cast or ingot form. 319.0 is cast whereas 319.1 is an ingot.

Alloying Elements In Aluminium

Alloying of aluminium plays a major role in enhancing the properties such as increased strength, hardness and resistance to wear, creep, fatigue etc. The intensity and range to which the alloying affects the properties of aluminium is specific to different alloying elements and combinations of them. Although most elements readily alloy with aluminium, comparatively very few have sufficient solid solubility to serve as major alloying additions. Among the commonly used elements, only copper, magnesium, silicon, zinc and iron have significant solubility. However, other elements like manganese and chromium with solubility below 1% confer important improvements to alloy properties.

Al-Si System

Aluminum with silicon as the major alloying element is the most common of aluminum casting alloys (about 80% of the Aluminium casting alloys) due to their high fluidity, high resistance to corrosion, good weldability, reduction in shrinkage and low coefficient of thermal expansion etc. As a result they are widely used in the automotive and aerospace industry. Commercial Aluminium- Silicon alloys are as polyphase materials belonging to 3xx.x series or 4xx.x series. 4xx.x series are not heat treatable as it does not contain precipitating elements. 3xx.x series consist of Al-Si system with Cu or Mg addition and 4xx.x series consist of Al-Si alloys. This study focuses on 3xx.x series ie, Al-Si system with Cu/Mg.

Aluminum-silicon alloys are divided into three groups based on silicon content

1. Hypoeutectic containing 5-10% silicon
2. Eutectic containing 10-13% silicon
3. Hypereutectic containing 13-25% silicon

Aluminium - silicon eutectic system

Aluminum-Silicon system is a simple binary eutectic with limited solubility of aluminum in silicon and limited solubility of silicon in aluminum. The solubility of silicon in aluminum reaches a maximum 1.65 at% at the eutectic temperature while solubility of Al in Si is almost zero. Eutectic point of Al-Si system is at 12.6 wt% Si at 577^0 C. Alloys with silicon composition to the left of this point are termed as hypo eutectic and alloys to the right are termed as hyper eutectic.

Al-Si-Cu (A319) ALLOY

A319 is a hypoeutectic Al-Si alloy with 3-4% Cu for strengthening. It has a density of 2.79 g/cm^3 and an elastic modulus of 74GPa. It's liquidus and solidus temperature are 605 °C and 515°C. Melting temperature of A319 is in the range 675 to 815 °C and thermal conductivity is 109 W/mK at 25 °C.

Heat Treatment Of 319 Alloys

The Al-Si-Cu alloy has greater practical importance because of its response towards heat treatment. The reason is the presence of excess alloying elements that form particles in the solid solution as during heat treatment which in turn improve mechanical properties especially strength. Commonly employed heat treatment method is either age hardening the as-cast alloy (T5-type) or solution treatment followed by age hardening (T6-type). For most applications, the T6 treatment is usually adopted because it produces maximum tensile strength and hardness. As T6 type heat treatment can be done in two ways with natural ageing between solutionising and artificial ageing or without natural ageing.

2. Objective

The purpose of this study is to investigate the influence of Cu on Mg added Al-Si-Cu alloy. In recent years 319 alloys is widely used in automotive sector. Increasing demand for automotives with high power and light weight led to the study of improving the strength of 319 alloys. Several studies suggested that up to 0.5% Mg addition is having a positive influence in enhancing mechanical properties by forming additional precipitates. The main objective of this study is to understand the combined effect of both Mg and Cu on strength and their response towards heat treatment. Also, phases precipitated, their distribution and its effect on mechanical properties

are of greater importance. The mechanical properties depend on precipitates in microstructure which in turn is influenced by heat treatment. In order to optimize heat treatment parameters, study of effect of precipitation hardening heat treatment is relevant.

From the above study it's clear that the Al-Si-Cu alloys of the 319 type are age hardenable alloys and has good mechanical properties with excellent corrosion resistance, castability and low cost, which is why it is mainly used in the automotive industry. The mechanical properties of Al-Si-Cu alloys can be improved by minor alloying additions. Increasing the copper content in Al-Si-Cu alloy would improve strength and in Al-Si-Cu-Mg alloy the strength gets even better. Magnesium is not present in the 319 alloys composition. As per ASM standards the Mg content in A319 alloy is limited to 0.1%. But several studies suggests that addition of Mg up to 0.45% would enhance the response of the alloy to this precipitation hardening heat treatment particularly in the T6 condition and has been found to be effective in enhancing mechanical properties.

3. Conclusions

The study about the Al-Si-Cu alloys of 319 types is conducted. From the above studies it is understood that Al-Si-Cu alloys of 319 type posses good mechanical properties with excellent corrosion resistance, castability and low cost and is used widely in Automotive industries. Studies suggest that increase in the Mg content may increase the strength considerably.

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