Influence Of Ageing Heat Treatment And Magnesium On Wear And Corrosion Characteristics Of Aluminium Copper Alloy

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Abstract

The objective of this paper was to investigate the effect of ageing and magnesium on wear and corrosion characteristics of the Al6Cu alloys. The modifications of Al6Cu by adding Mg of 0.5 to 2 % in the interval of 0.5% mixing with stirrer and casted by gravity die casting. The effect of ageing and magnesium on wear out and corroded surface was studied by using scanning electron microscope. The wear and corrosion characteristics were studied using computerized wear testing machine and in NaCl solution respectively.

The addition of 1.5% Mg decreases the wear rate of 14.8% in as cast condition and 7.079% at 5hour ageing. Addition of 1.5% Mg also decreases Corrosion rate of 82.14% for 1Normality and 55.55% for 3Normality NaCl solution. The result shows, upto 5hr ageing, wear rate reduces the 14.7% and Corrosion rate reduces 45.15%.

Keywords: Al-Cu-Mg alloy, Wear, Corrosion characteristics.

1. Introduction

Owing to their low weight, high strength, good wear and corrosion resistance and easy casting the Al–Cu–Mg alloys have a wide range of usage in automotive and aerospace industries [1, 2]. The presence of magnesium improves strain, hardenability and enhances the material strength by due to the formation of solid solution [3, 4]. The mechanism of the strength increase cannot be easily explained by addition of various alloying elements and phase transformations alone. However, precipitation of θ" and θ' due to the presence of copper, and S' and β'' (Mg2Si) due to the presence of magnesium and silicon are expected. A good combination of mechanical properties can be achieved when all these hardener precipitates, namely θ', S' and β'' are present [5]. Heat treatment is generally carried out to obtain an optimum combination of strength and ductility in Al–Si–Cu–Mg alloys. Steps involved are solution treatment, quenching and artificial aging. Solution treatment at low temperatures will not dissolve the copper rich intermetallic components in aluminium matrix [6].

Hardening is provided by these artificial aging regimes. Accelerated artificial regimes at high temperatures for short periods are suggested to be almost equal to long artificial aging regimes at low temperatures and comparable mechanical properties can be obtained [7].

A lot of effort has been spent on the investigation on corrosion of Al-alloys [8-16] in many environments, including NaCl [8-10], acidic [11-14] or alkaline solutions [14-16]. Since aluminum is very anodic to the rest of alloys in most of normally used environments, it will tend to suffer from localized type of corrosion when it is alloyed since different kind of cathodic precipitates are formed.

2. Experimental Details

The investigated materials consists aluminum as a primary constituent and copper is the major addition with magnesium 0-2wt% varied in steps of 0.5Wt%.

2.1 Alloy preparation

All experimental alloys were prepared by liquid metallurgy route using pure aluminium (99.8%), electrolytic copper (99.9 %), and magnesium. The compositions were melted in an electrical resistance furnace, using graphite crucible. The molten metal was poured into permanent cylindrical die of diameter 25 mm having 200 mm long. Die was preheated to 200^0C. The composition of the alloy was determined using Optical Emission Spectrometer.

The experimental work was divided in two phases. The first phase consists of specimen preparation such as melting, casting of samples with different compositions in the aluminum-copper-magnesium system. The second phase includes characterization of wear and corrosion and fracture studies using scanning electron microscope of samples in different ageing conditions.

2.2 Wear and Corrosion Tests

The required size of the specimen for wear test is of Φ10mmX50mm length. These are prepared and tested in computerized wear testing machine. Tests are conducted for different loads and speeds with a fixed track diameter of 135mm and fixed sliding distances of 1Km. the contact surfaces between disc and pin were cleaned using acetone. Diameter of the pin was measured and then mounted on the specimen holder .weight of the specimen before mounting was recorded and noted as initial weight (W1). Specimens were loaded at 30N, 40N and 50N. Displacement sensor was adjusted to zero. The motor was then switched ON and the disc was made to revolve for the set time. Then the load is removed from the pan and pin from the holder. The specimen then weighed after thoroughly cleaning using an ultrasonic cleaner. The weight of the specimen is then taken as final weight (W2). The difference between the initial and final weight is the weight loss.

Specimens for corrosion test are made of following dimension, that is, Φ10mm X 25mm length and then kept in a solution of NaCl for three different normality's, after measuring the specimen's diameter. The specimens are weighed before placing it in the solution and this is taken as initial weight (W1). The specimens were kept in the NaCl medium for 90 days after which specimens are removed. The specimen was then cleaned thoroughly as per the ASTM G1 standard using a solution of 50mL phosphoric acid (H_3PO_4, specific gravity 1.69), 20grams of chromium trioxide (CrO_3) with reagent water. Then the weight of specimen was then measured and taken as final weight (W2). The difference between the initial and final weight is the weight loss due to corrosion.

3. Results and Discussion

3.1Effect of Mg on wear rate of heat treated Al-Cu-Mg alloy.

The aim of these studies was to reduce the wear rate by addition of Mg. Al containing Mg favours a reduction in the wear rate. The wear rates of Al-Cu alloy and its alloys having 0.5–2.0% Mg are given in figure 1 (a) as a function of ageing duration. It is seen that the wear rate decreases with increasing Mg amount. The wear rate of the sample with 1.5 wt. % Mg gives quite lower wear rate when compared with other samples containing Mg. This result is considered to be due to first formation of a lubricating film on the tribo-surface. This may be covered by a lubricating film, which is related to the volume fraction of soft Mg particles, is the controlling factor [17]. Secondly, it was seen that due to the usage of Mg, the concentration of porosity decreases. Therefore the decrease of porosity concentration may have an effect on the decrease in wear rate. Thirdly, depending on the aging processes, the increase in Mg concentration increases the micro-hardness of the alloy.

3.2 Worn-out surface studies

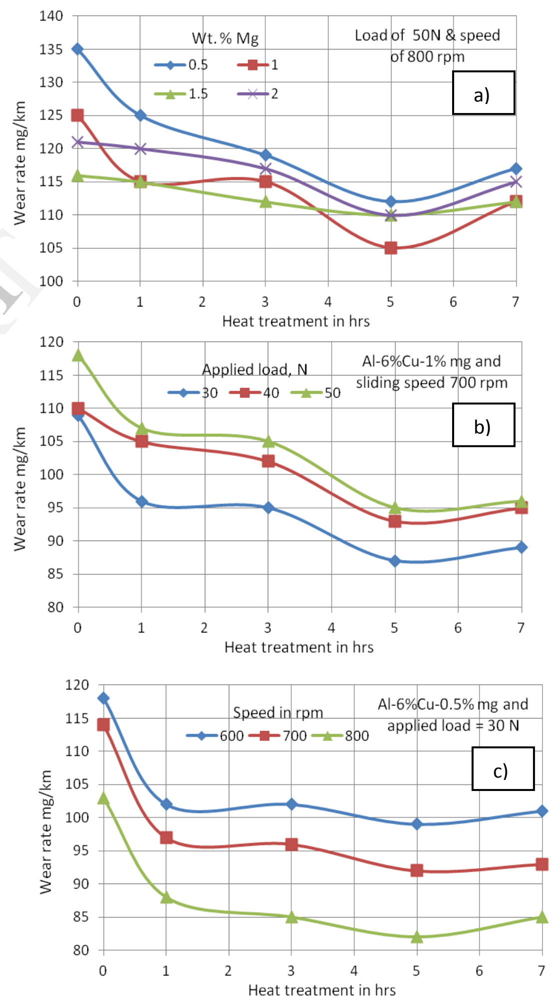

Figure 1: a) Effect of Mg content, b) Effect applied load and c) Effect of sliding speed and on wear rate of heat treated Al-Cu-Mg alloys.

The figure 2(a), (b) and (c) shows the SEM of worn surfaces of the Al-6%Cu-0.5% Mg alloy, Al-6%Cu-1% Mg alloy and Al-6%Cu-1.5% Mg alloy respectively. For brevity and convenience, only a few micrographs are shown. Large distinct parallel and continuous grooves are formed by the addition of 0.5% Mg and a small quantity of plastic deformation can also be observed from the Figure 2(a). As the Mg increases to higher values with the same conditions the large distinct grooves will reduce to fine scratches (Figure2 (b) and (c)). The damaged spots have been observed in the form of crater. When the Mg content is 0.5% the subsurface crack may be either exist earlier or get nucleated due to stress, these cracks tend to propagate. When such subsurface cracks join the wear surface, delamination is the dominant wear mechanism [18].

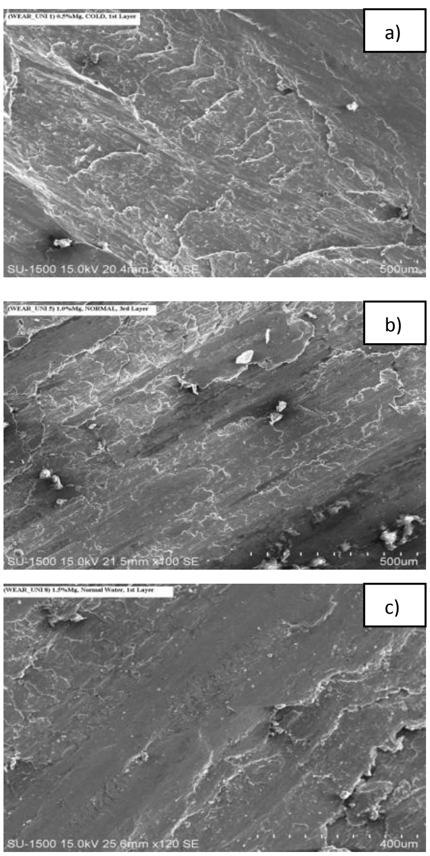

Figure 2: Effect of Mg on worn-out surface of Al-Cu-Mg alloys a) Al-6%Cu-0.5% Mg, b) Al-6%Cu-1% Mg and c) Al-6%Cu-1.5% Mg alloy

3.3 Effect of Mg on corrosion rate of heat treated Al-Cu-Mg alloy

Figure 3 shows the corrosion rate curves of as cast condition as function of Mg alloy in NaCl solution, with Al-6%Cu-xMg alloy as a control for different normalities. The corrosion tests reveal that there is no significant weight loss for normalities N1 and N2. However, normality's increased to N3. There is a significant effect of corrosion as indicated by weight loss. Additional, graphs indicates as percentage of Mg is varied from 0.5% to 1.0%, there is a significant change in the corrosion.

Heat treatment duration significantly affects corrosion behaviour between cathodic β-Mg17Al12 phase and anodic α-Mg matrix. In heat treatment, studies of microstructure, dissolution of the β-Mg17Al12 phase decreased the cathode to- anode area ratio, leading to accelerated corrosion of a-Mg matrix. Fine β-Mg17Al12 precipitates in heat treatment for 7 hours microstructure studies indicated facilitated intergranular corrosion and pitting. However the rate of corrosion was less than at as-cast for 1and 3 hour heat treatments.

As shown in Figure 3, the corrosion rate increased with increasing in acid concentration (normality of corrosion media). This mean that the energy barrier of corrosion reaction decrease as the concentration of hydrochloric acid increase and activated complex or transition state complex can be formed faster with acid concentration increasing.

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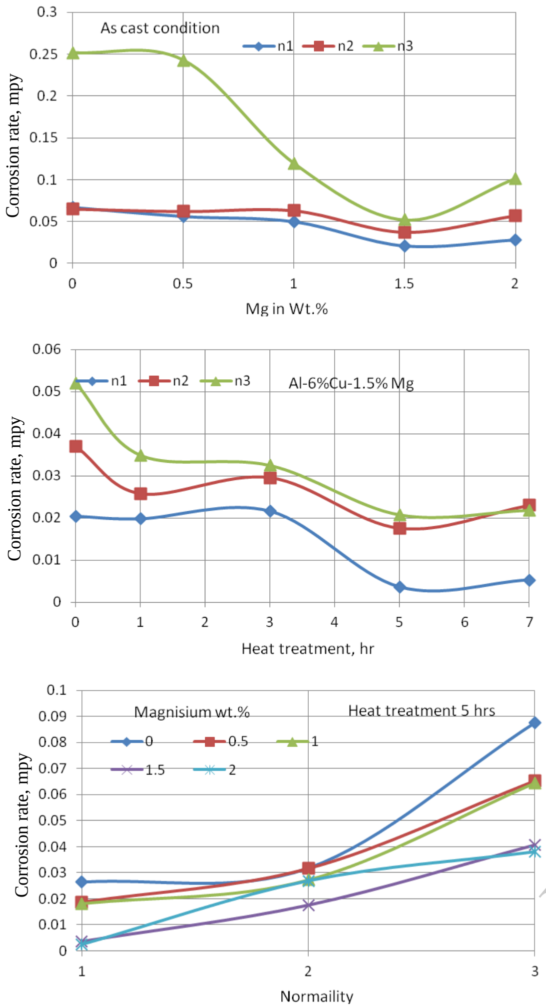

Figure 3: Effect of Mg content, heat treatment and normality on corrosion rate of Al-Cu-Mg alloys

3.4 Corroded surface studies

SEMs of the flakes that were formed from the corroded sample and the flakes still remaining on the sample were taken. The corroded surface morphology of Al-Cu-Mg alloys is shown in figure 4. Al-cu alloy with Mg shows pitting and this pitting depend on local Mg distribution and as well as the integrity of the surface Mg film. Large weight percentage of Mg could result in more opportunities for film distribution and more sites for pit initiation. It was found that the pits which were presence of Mg smaller and more numerous than in the alloy without the presence of Mg. However, no definite crack path can be clearly visualized. The connected cracks cause progressive removal of the material on the surface commonly called as flaking.

4. Conclusion

1) 1.5% Mg addition reduces wear rate at 1hour, 3hours and 7hours ageing condition. Also least wear rate occurs for 1.0% Mg addition at 5hour ageing.

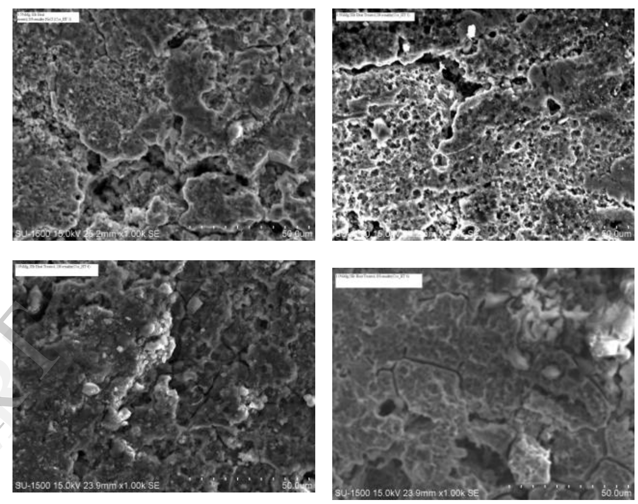

Figure 4: Effect of Mg and heat treatment on corroded surface of Al-Cu-Mg alloys

2) Wear rate increases with proportional increase of load. Optimum wear rate occurs at low loading condition. Also wear rate shows inverse effect on increase of speed.

3) Wear rate decreases with proportional increase of ageing duration in heat treatment process. Optimum wear rate occurs at 5 hour ageing duration.

4) Up to 1.5% Mg addition reduces the corrosion rate at as cast and heat treated condition.

5) Corrosion rate increases with proportional increase of concentration of NaCl solution, i.e., from 1Normality to 3 Normality. Optimum corrosion rate occurs in 1Normality NaCl solution.

6) Corrosion rate decreases with proportional increase of ageing duration in heat treatment process. Optimum Corrosion rate occurs at 5 hour ageing duration.

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