CORROSION BEHAVIOUR ON AA2014/15vol. %Al_2O_{3P} AND AA2009/20vol. %SiC_W COMPOSITE AFTER AGEING TREATMENT

BY

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ABSTRACT

The purpose of this study is to compare the corrosion behaviour between AA2014/15vol. %Al_2O_{3p} and AA2009/20vol. %SiC_w composites after ageing treatment. The former composite was cast composite supplied by Duralcan USA. The later composite was a powder metallurgy composites supplied by Advanced Composite Materials Corporation USA. The corrosion behaviour was investigated by means of immersion test and salt spray test. Before immersion test, the composites were examined for ageing response at 165^0C (0 - 12hours). Microstructure evaluation has been characterized using optical microscope, SEM and EDX. It was observed that the distribution of SiC whiskers in the matrix AA2009 is more homogeneous compared to the distribution of Al_2O_3 particles in the matrix AA2014. The secondary phases such as Al_2Cu and Al_2CuMg were identified in AA2014/15vol. %Al_2O_{3p} whereas Al_2Cu was identified in AA2009/20vol. %SiC_w composites after ageing. Localized corrosion is more intense in AA2014/15vol. %Al_2O_{3p} compared with AA2009/20vol. %SiC_w. The pit shape for composite of AA2014/15vol. %Al_2O_{3p} is shallow wide pit and differs to composite AA2009/20vol. %SiC_w which is shallow deep pit. Salt spray test has been used to assess the corrosion behaviour of the surface of as received composites. The corrosion product has been analysis using XRD after salt spray test. The qualitative diffraction pattern from both composites after 20 hours exposure in salt spray test shows the formation of the corrosion products. It was observed that three corrosion products were identified such as $Mg(OH)_2$, Al_2O_3, MnO_2 in composite AA2014/15vol. %Al_2O_{3p} and no corrosion product was identified for composite AA2009/20vol. %SiC_w.

ABSTRAK

Kajian ini bertujuan membandingkan kelakuan kakisan antara komposit AA2014/15vol.%Al_2O_{3p} dengan komposit AA2009/20vol.%SiC_w. Komposit pertama dibekalkan oleh Duralcan, USA yang difabrikasikan melalui kaedah tuangan adukan. Komposit kedua dibekalkan oleh Advanced Composite Materials Corporation, USA yang difabrikasikan melalui kaedah metalugi serbuk. Kelakuan kakisan dikaji menggunakan ujian rendaman dan ujian semburan garam. Kesan penuaan ke atas kedua-dua komposit pada suhu 165^{0}C (0 hingga 12jam) telah dikaji sebelum ujian rendaman dijalankan. Penilaian mikrostruktur dibuat menggunakan mikroskop optikal, mikroskop imbasan electron dan analisis EDX. Adalah diperhatikan bahawa taburan SiC_w dalam matrik AA2009 lebih homogen berbanding taburan Al_2O_{3p} dalam matrik AA2014. Keputusan SEM menunjukkan kebanyakan partikel dan wisker bertaburan secara hampir selari dengan arah penyempritan. Pembentukan mendakan Al_2Cu dan Al_2CuMg didapati dalam AA2014/15vol.%Al_2O_{3p} manakala Al_2Cu didapati dalam AA2009/20vol.%SiC_w selepas penuaan. Kakisan setempat lebih teruk dalam AA2014/15vol.%Al_2O_{3p} berbanding AA2009/20vol.%SiC_w. Bentuk bopeng pada komposit AA2014/15vol.%Al_2O_{3p} adalah bopeng meluas sebaliknya komposit AA2009/20vol.%SiC_w adalah bopeng mendalam. Ujian semburan garam telah digunakan untuk menilai kelakuan kakisan dan hasil karat pada permukaan komposit. Hasil kakisan di analisa menggunakan XRD. Keputusan analisa XRD ke atas kedua-dua komposit selepas 20 jam pendedahan dalam semburan garam menunjukkan adanya hasil kakisan seperti $Mg(OH)_2$, Al_2O_3, MnO_2 dalam komposit AA2014/15vol.%Al_2O_{3p} dan tiada hasil kakisan dalam komposit AA2009/20vol.%SiC_w.

CHAPTER 1

INTRODUCTION

The future of the fundamental and hi-tech industries depends on the development and improvement of engineering materials. For example, many aerospace applications required materials with high thermal conductivity to reduce component operating temperature and moderate density to reduce overall system weight. Since the 1960s, metals have been strengthened and stiffened by the incorporation of reinforcement. In the 1970s and 1980s, a considerable amount of research was expended in improving the mechanical properties of aluminium alloys (Budinski and Budinski, 2005).

Metal matrix composites (MMCs) are widely used in structures where a high strength to weight ratio is prime concern, such as in the transportation industry. MMCs, particularly with ceramic particles or whiskers reinforcing aluminium- based alloys, have been extensively investigated since 1980s (Borrego, 1998). Aluminium matrix composites (AMCs) are currently being developed for engineering components because of high stiffness, good elevated temperature properties and good fatigue resistance (Trowsdale, 1996). Research on the aluminium matrix composites is still at the development stage, but the outlook is very promising. In the next 20 years, these materials are expected to overtake conventional materials as base alloys. In recent years, the aerospace, military and automotive industries have been promising the technological development of composite materials to achieve good mechanical strength/density and stiffness/density ratios (Pardo et al, 2005).

To date, much of the researches are focused on the mechanical properties and correlations between fabricating route, microstructure and properties of AMCs. If AMCs are to become incorporated into current engineering systems, their corrosion behaviour must be determined and investigated before employing them to service environments. Therefore, corrosion behaviour studies on aluminium matrix composites in marine environments and the influence of the ageing, matrix composition, type of reinforcement and the chloride concentration should be conducted properly.

The limitation of AMC application is restricted due to the effect of the reinforcement on the corrosion resistance. The addition of the reinforcing materials to aluminium may influence the susceptibility to degradation. Reinforcement materials should possess significantly higher specific stiffness and strength, as well as high melting and decomposing temperatures compared to the base alloy. The ease of processing and part fabrication is key factors in determining the selection of the reinforcement form and type. The major reinforcements used in aluminium based MMCs are boron, graphite, silicon carbide and alumina. Majority of the current investigations appear to be focusing on SiC and Al_2O_3 reinforced Al MMCs.

Discontinuous reinforcement appears to influence the corrosion behaviour of MMCs not only by acting as nucleation site for primary and secondary phase precipitation during fabrication and heat treatment, but also hindering the formation of a coherent non-porous oxide layer (Lucas, 1992). Both factors are believed to be largely responsible for the corrosion site in the matrix and Al/reinforcement interface. The exact nature of the electrochemical events at corrosion site on MMCs is still under debates (Lucas, 1992). Therefore, the present study is carried out in order to understand the events leading to the corrosion site of aluminium matrix composite before and after ageing using immersion test as well as optical microscope, SEM and EDX. Whereas, salt spray and X-ray methods used in order to studied the corrosion product.

1.1 The aim of research.

Several previous studies on properties of aluminium matrix composite have been reported focusing on either comparative study between monolithic alloy and reinforced alloy in terms of influence of similar type of reinforcement or comparative study between different reinforced alloys in terms of similar type of reinforcement. Furthermore, several studies have focused on the properties of aluminium matrix composites from the same fabrication route such as casting and powder metallurgy. Some researchers studied the influence of heat treatment based on single aluminium matrix composite without comparison. Corrosion resistance of MMCs is also a subject of study to be discussed in order to compare their corrosion resistance towards corrosive environment and some studies have reported based on the effect of heat treatment to the corrosion behaviour.

Research works on the mechanical properties and corrosion behaviour of AA2009/20vol. %SiC_w have been reported by Chan and Tong (2000) and Yue (2000) respectively. Whereas, research works on mechanical properties and corrosion behaviour of AA2014/15vol. %Al_2O_{3p} have been reported by Molina et al (2004) and Lucas & Clarke (1992).

To date, there is no study carried out focusing on the corrosion behaviour between two different aluminum matrix composites in term of different type of reinforcement and fabrication route. Comparative study between different composites is required in order to develop information for all metal matrix composites. This information is very important for the user to select the best material for engineering applications with different properties required including its corrosion resistance. This thesis deals with the study of the corrosion behaviour of AA2014/15vol. %Al_2O_{3p} and AA2009/20vol. %SiC_w after artificial ageing under sodium chloride solution. AA2014/15vol. %Al_2O_{3p} was cast composite supplied by Duralcan USA. The particle size is 9 – 13 μm. AA2009/20vol. %SiC_w was a powder metallurgy composites supplied by Advanced Composite Materials Corporation (ACMC), USA. The dimension of beta-SiC whiskers reinforcement is 0.45 – 0.65 μm in diameter and 5 – 80 μm in initial length. Both of the composites were extruded by hot extrusion process into rectangular bar.

In the present research work, the corrosion behaviour of AA2014/15vol. %Al_2O_{3p} and AA2009/20vol. %SiC_w were investigated by immersion test and salt spray test in different chloride concentration. The objective was to study the corrosion rate and to clarify the influence of ageing, reinforcement, matrix composition and chloride concentration on the corrosion behaviour.

Studies on the acceleration of ageing kinetics in both aluminium matrix composites conducted by heat treatment process and monitored by scanning electron microscope (SEM), resistivity and hardness measurement. This thesis focuses on comparative study on pitting corrosion behaviour between AA2014/15vol. %Al_2O_{3p} and AA2009/20vol. %SiC_w in terms of:

1. Influence of different matrix element composition
2. Influence of different reinforcement
3. Influence of different fabrication method
4. Influence of artificial aging
5. Influence of chloride concentration and surface roughness

The corrosion studies include pitting, corrosion behaviour, corrosion product and pit shape.

1.2 Methodology of research

This research project used AA2014 (Al-Cu) matrix reinforced with 15vol. % of Al_2O_3 particles and AA2009 (Al-Cu) matrix reinforced with 20vol.% SiC whiskers. Methods of corrosion test used are immersion test and salt spray test. The immersion test was performed in 3.5%NaCl solution for both specimens at different time exposure at room temperature. Before corrosion test, the specimens were aging treatment under certain conditions. The salt spray test was performed in 3.5%NaCl and 5.0%NaCl solution for both specimens ant different time exposure at 50^0C temperature.

Microstructure characterisation was examined using optical microscope, scanning electron microscope (SEM) and energy dispersive x-ray (EDX). Hardness measurement was conducted using vickers microhardness. The specimens were prepared according to the ASTM E.3-01 (2001) Standard Guide for preparation of Metallographic Specimens for microstructure characterisation. Scanning Electron Microscopy was used to study the microstructure of MMCs. SEM micrograph offers considerable advantages over optical micrograph. In this technique, information about morphology and reinforcement/matrix interface obtained. The energy dispersive X-ray spectroscopy was used to analyse the chemical composition and phase formation on the surfaces. X-ray diffractor meter (XRD) was used to analyze the microstructure and micro-chemical comprehensively. The XRD offers solution encompassing wide-ranging analysis requirements, from routine qualitative to quantitative analysis.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction to aluminium and its alloys

Aluminium and its alloys are characterised by a relatively low density (2.7 g/cm^3 as compared to iron 7.9 g/cm^3), high electrical and thermal conductivities, and good resistance of corrosion in some common environments. These alloys are easily formed by virtue of high ductility. Since aluminium has an FCC crystal structure, its ductility is retained even at very low temperatures. The limitation of aluminium is its low melting temperature (660^{0}C), which restricts the maximum temperature at which it can be used (Callister, 2000)

Aluminium alloys can be divided into two major groups: wrought and casting alloys, depending on their method of fabrication. Wrought alloys, which are shaped by plastic deformation, have compositions and microstructures significantly different from casting alloys, reflecting the different requirements of the manufacturing process. Within each major group we can divide the alloys into two subgroups: heat-treatable and non heat-treatable alloys (Askeland & Phule, 2004).

The most commonly used alloy designation system in the United States is that of the Aluminium Association. The designations for groups of wrought alloys and groups of cast alloys are shown in Table 2.1.

Table 2.1: Aluminium alloy designation system in the U.S.A.
(Budinski & Budinski, 2005).

Wrought Alloy Designation	Major Alloying Elements
1xxx	Commercially pure aluminium (99% min)
2xxx	Copper (major alloying element)
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and silicon
7xxx	Zinc
8xxx	Other elements
9xxx	Unused series
Cast Alloy Designation	**Major Alloying Elements**
1-99(old system)	Aluminium + silicon
1xx.x	99.5 min. aluminium
2xx.x	Copper
3xx.x	Silicon + copper or magnesium
4xx.x	Silicon
5xx.x	Magnesium
6xx.x	Unused series
7xx.x	Zinc
8xx.x	Tin
9xx.x	Other element

For wrought alloys, it is based on four digits corresponding to the principal alloying element as shown in Table 2.1. The first digit indicates the major alloying element. The second digit in this system indicates chemistry modification or impurity. In 1xxx series third and fourth digit indicate % of Al concentration or purity of the alloy. In other series third and forth digit identified the particular alloy. Cast alloys have been identified by a four-digit identification number with last digit separated by decimal. A letter prefix is occasionally used to signify alloy or impurity limits. The first digit indicates the alloy group. The second and third digits identify an alloy within a group,