Corrosion Characterization of Al-4mg Based Metal-Metal Composite with High Strength Alloy Particulate As Reinforcement

Ch. Kishore Reddy, M. Gopi Krishna, V.S.N. Venkata Ramana

***Abstract:** A ternary alloy (Al20Cu20Mg) high strength metallic particulate was reinforced in a base matrix binary alloy of Al-4Mg to prepare a metal-metal composite. This was investigated for corrosion behaviour. High Strength Alloy particulate (HSAp) of non-uniform size from the ternary alloy was utilized with weight proportions of 5%, 10%, and 15% to prepare composites using stir casting process. The prepared composites were extruded into circular rods of 14 mm diameter. The potentiodynamic polarization test was conducted on the extruded specimen and it is found that the pitting corrosion was improved considerably by the addition of Al20Cu20Mg as reinforcement in Al-4Mg.*

***Keywords:** Al-4Mg alloy, High Strength Alloy particulate (HSAp), Pitting corrosion, Extrusion, stir casting.*

I. INTRODUCTION

Aluminium is special among all prominent metals with one-third density that of the density of steel or copper, but can be achieved higher strengths with special combinations in it. For specific applications where a high strength to density ratio is required, aluminium alloying or combining techniques may achieve this. This property of aluminium attracts many areas like transport, aerospace, etc., more specifically where the combination of electrical conductivity with higher strength, more thermal conductivity with higher strength, more wear resistance with higher strength, more corrosion resistance with higher strength and above all more recyclable.

Aluminium is the metal that has been used for various applications from the ages right from domestic unto anti-corrosion applications like marine by practicing a variety of processes like annealing combined with alloying followed by thermal aging [1]. In the present scenario of engineering and industrial applications, metal matrix composites (MMCs) with the combination of Aluminium as major ingredient and various metallic, non-metallic and hybrid reinforcements playing a vital role with their exhibition of rich properties [2]. Aluminium matrix composite (AMCs) have not only great scope for an extensive exhibition of properties suitable for industrial and aerospace applications but also finds solutions for multiple suitability with the combination of multiple property exhibition like high strength to weight ratio coupled with lower thermal coefficient and good wear and corrosion withstanding properties [3-5]. For domestic purposes like automotive, refrigeration, air-conditioning, doors and sliding frames the strength to weight ratio property is useful [6]. It is important to select a proper material combination for well-known corrosion conditions to prevent the loss due to corrosion by finding a suitable solution [7]. Pure or unalloyed aluminium has great anti-corrosion in nature but poor in strength. Some of the alloying elements improve strength but diminishes the corrosion properties. Hence, it is needed to choose the proper material selection for improving strength without altering corrosion properties or to improve anti-corrosion nature. Copper makes the strength improved almost nearer to that of steel. But the addition of copper leads to reduces the resistance to pitting corrosion [8]. Magnesium has both ends of effectiveness when alloyed both strength and anti-pitting corrosion effect against to copper effect. Very few researchers worked on the pitting corrosion characteristics of the extruded specimen of Aluminium alloy composites.

II. EXPERIMENTAL METHODOLOGY

In the present work, the ternary alloy (Al20Cu20Mg) fingers were prepared by the casting process. Later, Particulate from Al20Cu20Mg powders was prepared by filing operation. Metal matrix composites were made with Al-4Mg as matrix and Al20Cu20Mg powders as reinforcement with various proportions of Al20Cu20Mg powders viz. 5%, 10% and 15%. Finally, these composites' specimens were extruded into φ14 mm fingers. The chemical composition of base metal and reinforced particles was presented in Table 1. After extrusion, the specimens were tested for pitting corrosion behavior using potentiodynamic polarization test. Before the test, the samples were polished on emery papers and polishing cloth. Software-based Gill AC basic electrochemical system [Fig. 1] was used for conducting potentiodynamic polarization tests to study the pitting corrosion behaviour of extruded specimens.

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Table1. Chemical composition of Pure Al; Al4Mg alloy & Al20Cu20Mg alloy.

Element	Al	Al-4Mg	Al20Cu20Mg
Si	0.05	0.08	0.1
Fe	0.1	0.1	0.3
Ti	0.002	0.01	0.03
Zn	0.008	0.02	0.01
V	0.005	-	-
Mn	0.002	0.014	0.02
Na	0.004	-	-
Mg	0.002	3.6	19.2
Cu	0.005	0.005	19.6
Al	balance	balance	balance

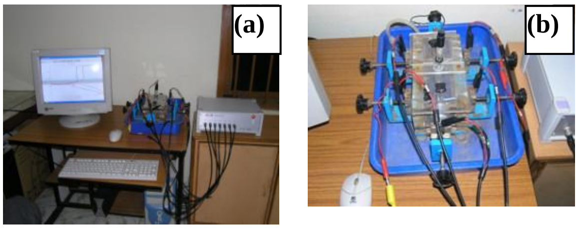


Fig. 1 Gill AC basic electrochemical system

(a) Basic electrochemical system (b) Electrochemical cell

III. RESULTS AND DISCUSSION

The extruded specimens were tested for pitting corrosion. The potentiodynamic curves of the specimen were shown in Fig. 2 and the SEM microstructures after corrosion were shown in Fig. 3 and the pit potential values were given in Table 2.

From the table, it is observed that the pitting corrosion resistance was improved with the addition of Al20Cu20Mg as reinforcement. It is also observed that the pitting corrosion resistance is high with 5% addition of Al20Cu20Mg. It is attributed to the fact that the addition of copper has increased the resistance to corrosion. But beyond 5% addition of the reinforcement, the corrosion resistance decreased. The wt % of elements present in the corroded portion of the extruded specimen are shown in Table 3. The reason for the increased corrosion resistance in 5% reinforcement composite is attributed to the lower amount of Mg and Cu present in this specimen.

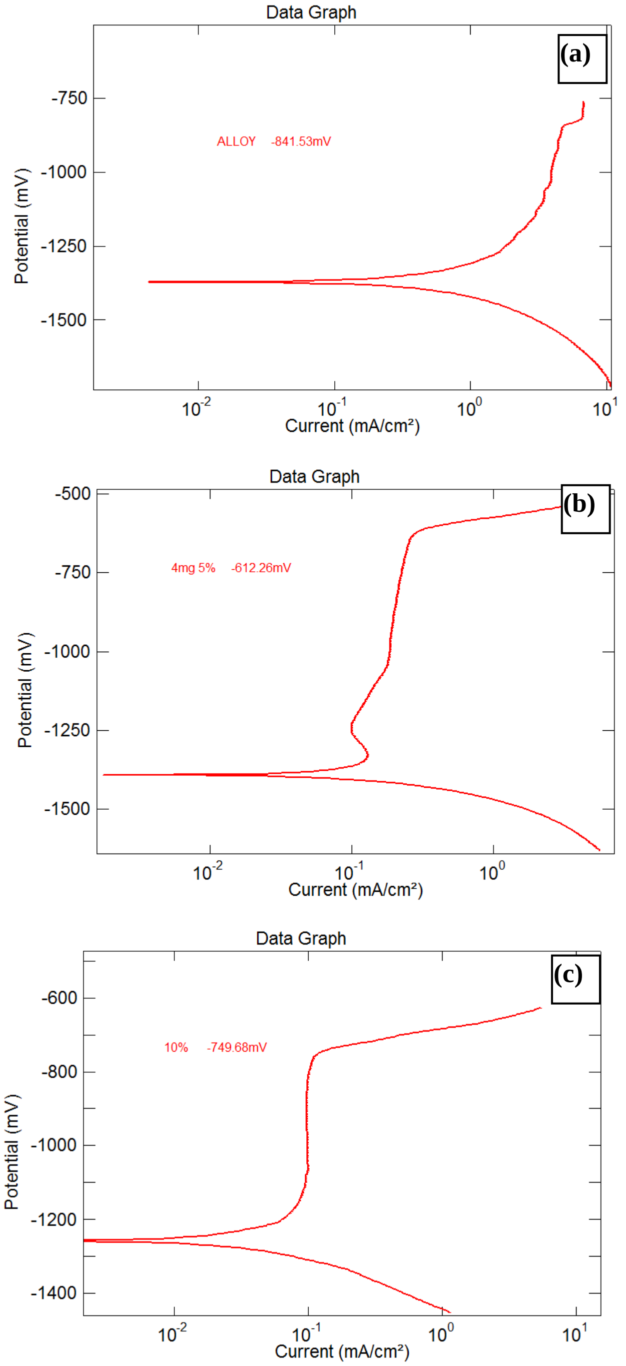
Table 2: Pitting potentials, E_{pit} (mV), SCE of the extruded composite specimen

Composite	E_{pit}
Al-4Mg	-841.53
Al-4Mg with 5% Al20Cu20Mg	-612.26
Al-4Mg with 10% Al20Cu20Mg	-749.68
Al-4Mg with 15% Al20Cu20Mg	-767.38

Table 3: Composition (in Wt.%) of the corroded portion (SEM-EDX) of extruded specimen

Element	Al-4Mg	Al-4Mg with 5% Al20Cu20Mg	Al-4Mg with 10% Al20Cu20Mg	Al-4Mg with 15% Al20Cu20Mg
Mg K	4.93	3.35	5.42	5.14
Al K	52.62	73.91	71.98	34.87
Si K	1.44	0.54	1.18	1.19
Cu K	-	-	1.35	3.76

The potentiodynamic polarization curves are shown in Fig. 2 also confirm the observations that the corrosion resistance is improved after the addition of Al20Cu20Mg to Al-4Mg.



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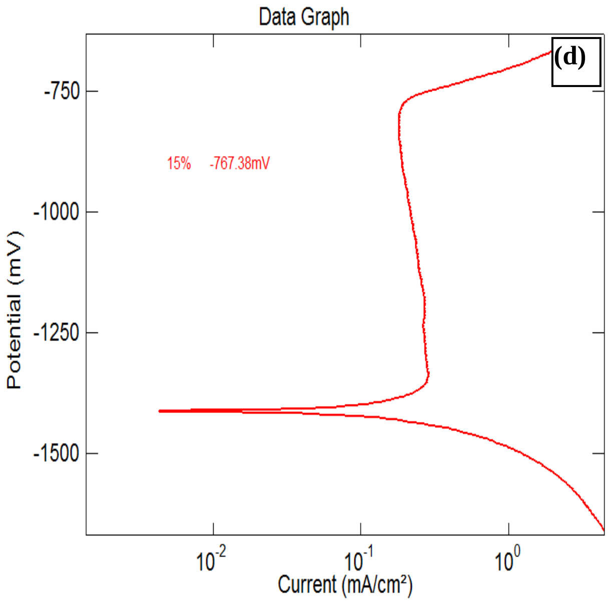


Fig. 2 Potentiodynamic polarization curves of extruded specimen

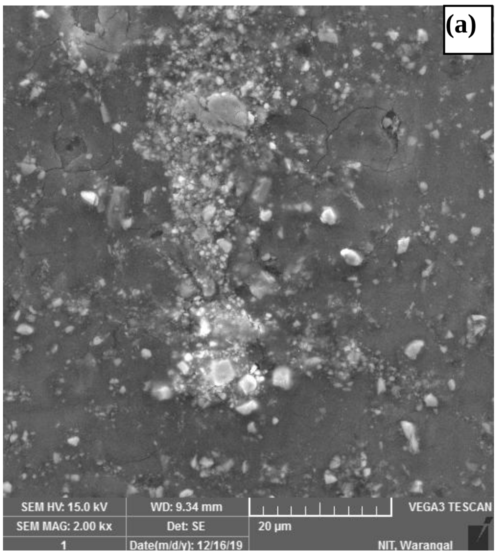
(a) Al-4Mg

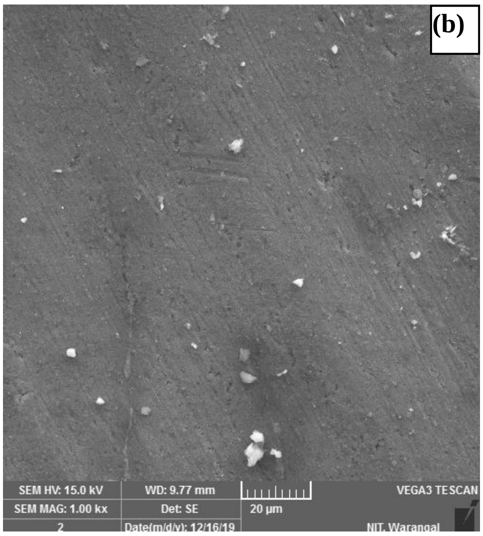
(b) Al-4Mg with 5% Al20Cu20Mg

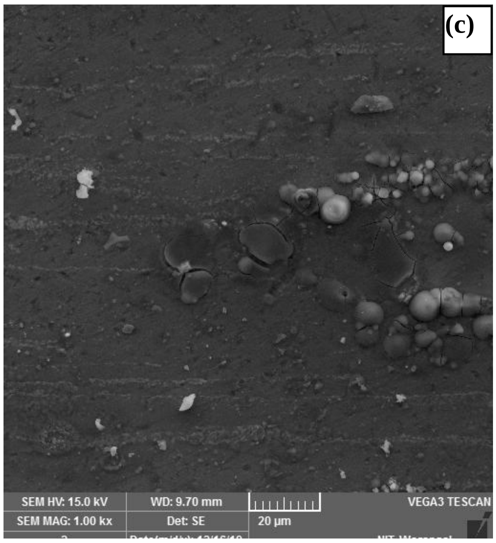
(c) Al-4Mg with 10% Al20Cu20Mg

(d) Al-4Mg with 15% Al20Cu20Mg

The SEM images of the corroded specimen were shown in Fig. 3. From these images, it is observed that the pit density is more in Al-4Mg composite without adding reinforcement. With the addition of Al20Cu20Mg as reinforcement, the pit density is considerably reduced. It is also observed that the pit density is minimum in the composite where Al20Cu20Mg reinforcement addition is 5% compared to 10% and 15%. This observation is in accordance with the pit potential values observed from the test.







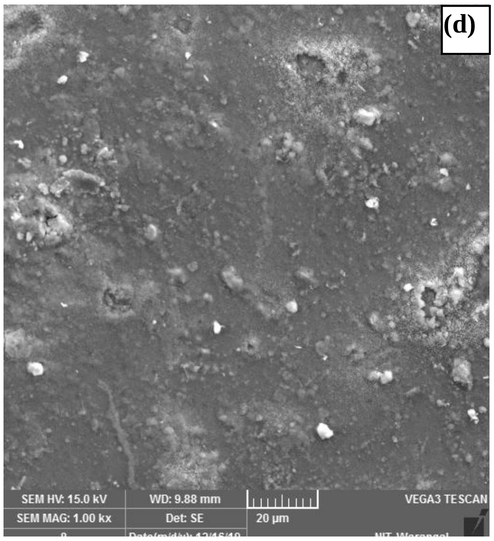


Fig. 3 SEM micrographs of corroded specimen after extrusion (a) Al-4Mg

(b) Al-4Mg with 5% Al20Cu20Mg

(c) Al-4Mg with 10% Al20Cu20Mg

(d) Al-4Mg with 15% Al20Cu20Mg

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IV. CONCLUSIONS

- The Al-4Mg composites were made successfully.
- Al20Cu20Mg composites were made successfully and chips were prepared from these composites to use them as reinforcement.
- Al20Cu20Mg chips were added in various proportions to Al-4Mg composite through stir casting and specimen were made.
- These specimens were extruded successfully.
- After extrusion, the microstructure of the specimens was observed. The volume of the reinforcement added and its distribution after extrusion is well observed from these microstructures.
- The potentiodynamic polarization test of the extruded specimens revealed that the pitting corrosion resistance is improved considerably by the addition of Al20Cu20Mg as reinforcement. It is also observed that the pitting corrosion resistance is better at 5% of the reinforcement addition.
- The potentiodynamic polarization curves and SEM micrographs after corrosion also confirm the above observation.

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