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Effect of Al_2O_3 and Fly Ash Addition on Mechanical, Wear and Corrosion Properties of Al-Mg-Si Base Alloy

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Abstract

The aim of this study is to studding the effect of addition of alumina and fly ash with the particles size 106µm and different weight rations (2:2, 2:4, 4:2) to aluminium-magnesium-silicon alloy on microstructure, mechanical properties, corrosion resistance, and wear. The vortex technique was used to prepare the composite material. The microscopic structure was also examined using optical microscopy and mechanical tests (hardness, tensile strength, yield strength and elongation) and wear test. The results showed that the composite material the containing (2% fly ash and 4% alumina) had the highest tensile strength (119 Mpa), yield strength (76 Mpa) and hardness (89 kg \ mm^2), while it has the lowest ductility (5.3%). It was also found to have the lowest wear rate (1.8* 10-6gm \ cm) and the highest corrosion resistance.

***Keywords**: Al_2O_3 and fly ash, Al-6061 Alloy, mechanical properties, composite material*

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1. Introduction:

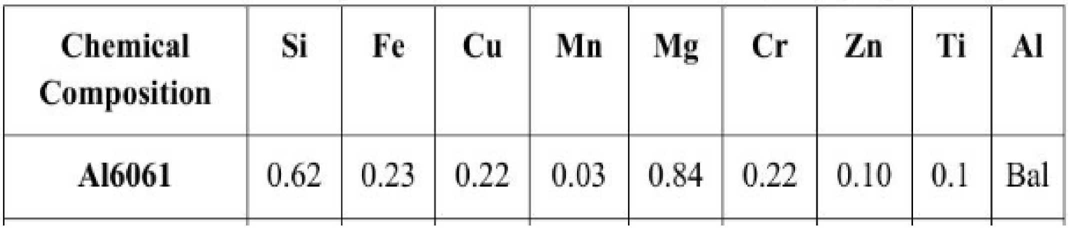
Modern engineering applications require the development of advanced materials that provide a broad spectrum of property combinations, such as: (i) high specific strength (lightweight and high strength) and ductility for aerospace and automobile applications where fuel economy and enhanced engine performance become critical, (ii) low coefficients of thermal expansion (CTE) and high thermal stability for engine components that are exposed to high temperatures, (iii) superior wear resistance, high specific stiffness and satisfactory corrosion resistance in defence applications, and so forth[1,2]. Tailoring these property combinations is a great challenge if only monolithic material systems are considered. Hybrid materials such as metal matrix composites (MMCs) have been widely developed and investigated over the past fifty years, in an effort to achieve the aforementioned property combinations [3]. MMCs are generally referred to the materials consisting of a metallic matrix and ceramic reinforcement, such as oxides, borides and carbides [4]. Aluminium MMC (alloy) has several great characteristics which make it suitable to be used in automobiles and building industries. Such characteristics include; easy to be extricated in nature, acceptable strength and considerable corrosion resistance .Particulates such as SiC, TiC, Al_2O_3, TiB2 and fly lung burning ash have been widely used to reinforce Al alloys to improve their mechanical properties and wear resistance [5]. Production of aluminium alloy/fly ash/Al_2O_3 composite materials is difficult due to the poor wettability of fly ash and Al_2O_3 as well as low weight. there are several requirements that should be achieved to enhance the poor wettability between solid particulates (reinforcement) and liquid Al (matrix) and hence promote the interfacial bond strength. Firstly, the surface energy of the solid should be raised; second, solid-liquid interfacial energy should be minimized, and thirdly, the surface tension of the liquid Al metal should be reduced. As good practice, one of the wide used metals as wetting agent between solid-liquid interface is the Magnesium; it helps in scavenging oxygen from solid surface and hence making the gas layer around reinforcement thinner [6]. The present experimental work aims to firstly fabricate an MMC of Al 6061/Al_2O_3/fly ash and then to investigate the mechanical properties of the composite by testing various percentages of the solid particles

2-Exprimental Work

1-2 Preparation of composite materials:

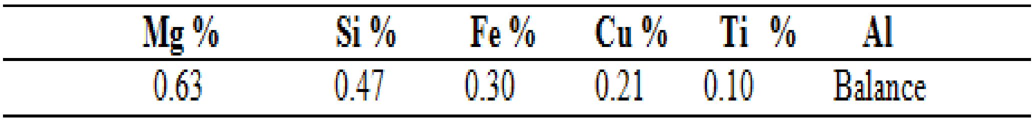
The Aluminum MMC in the present work has been fabricated (A1, A2, A3 and A4) alloys by the method of stir casting following the next steps. At first, the weighed quantity of Al-Mg-Si alloy the chemical composition as shone in table2, was assembled in a suitable container before putting it in the furnace to be heated up to (750C°). In the second step, the melting matrix is blended sufficiently. Next, fly ash composition represent in table 3, and Al_2O_3 particles were preheated at (350°C) for a period of 20 min. before adding them to the melted matrix metal. The fly ash and Al_2O_3 constitutes materials which have been used to fabricate the composite are with average grain size dimension of (106um) after wrapping with aluminum foil. After that, a vortex is created in the melted metal using stainless mechanical stirrer with 400 rpm speed and for 10 minutes in order to obtain good distribution of fly ash and alumina within aluminum alloy. Finally, composite slurry is poured into preheated iron bucket of before the casting process and hence cylinders of 15mm * 100 mm cast composite of Al6061/fly ash/Al_2O_3 is formed.

Table1. Standard of Chemical composition of Al-6061 alloy



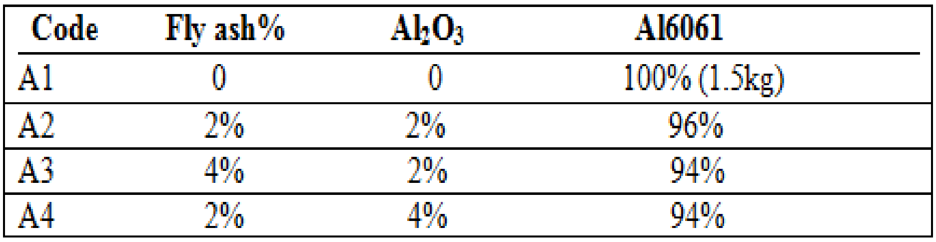
Chemical Composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al6061	0.62	0.23	0.22	0.03	0.84	0.22	0.10	0.1	Bal

Table2. Chemical composition of Al-Mg-Si alloy by weight percentage .



Mg %	Si %	Fe %	Cu %	Ti %	Al
0.63	0.47	0.30	0.21	0.10	Balance

Table 3: Composition of Constitutes (wt %)



Code	Fly ash%	Al_2O_3	Al6061
A1	0	0	100% (1.5kg)
A2	2%	2%	96%
A3	4%	2%	94%
A4	2%	4%	94%

2-2 Hardness and microstructure test:

To examine the macrostructure of the bottom alloy and the spreading composites, the sample's centre was chosen to take the specimen from it. The silicon carbide (SiC) papers of three grit sizes (320, 500, and 1000) were used to perform the milling and the grit by the grinding machine. Thereafter, the samples are exposed to polishing with 0.5m alumina polishing cloths before etching with (2. 5% HNO_3, 1. 5% HCl, 1% HF and 95% H_2o) solution. Finally, the normal water and alcohol are used to wash the resulted specimens before being dried up by heating. The macrostructure of base alloy and composite was analysed by optical microscopic lenses with digital camera. The macro hardness of the base alloy is quantified by using Vickers hardness apparatus, and calculated by the following formulas [7].

$$HV = 1.8544 * P / dav^{2} \quad (1)$$

Where:-

P : The applied load (1 Kg).

Dav :The average diameter of the rhombus indentation in(mm) .

HV : Vickers hardness .(Kg / mm^2).

Tensile test:

Tensile test was performed on all specimens produced in this work accordance to specifications of ASTM E-8 standards [8]. The test sample is of circular shape of 7mm in diameter and 36 mm in length. The Instron universal testing machine was employed to perform the test under room temperature and with an extension rate of 1mm/min. For assuring the reliability of results, the tests performed for both the base alloy and composite structure have been repeated twice. Typically, in this test both ultimate tensile strength, yield strength and elongation can be computed based on the generated stress-strain curves. A typical tensile specimen as per ASTM standard is shown in figure 1.

2-2-WEAR RATE TEST:

Testing the wear for base alloy and composite materials was conducted by using pin-on-disk a homemade device that shown in figure (3), that existing at the University of Technology Department of production engineering and metallurgy, with 10N normal load value and at 2.7 m/sec sliding movement rate. A cylindrical pin is with diameter of 10mm and height of 20mm has been prepared from base alloy and ceramic material. The carbon steel has been utilized to fabricate the rotating disc of (50mm) diameter and 32 HRC hardness. The wear test lasted for 20 minutes and performed under room temperature. The required weight was calculated before and after the test by an electric scale of (0. 0001) gm precision. The Wear rate and of the base alloy is quantified by using Vickers hardness apparatus, and Sliding distance calculated by the following formulas [9].

$\Delta W = W1 - W2$
(2)

Wear rate= $(\Delta W) / SD$
(3)

Where: -

W1: Specimen weight before wear test (gm).

W2: Specimen weight after the wear test. (gm)

SD: Sliding distance (cm)

$S = V \times t$
(4)

Where: -

t: Running time (20) min each and every test,

V: Linear sliding speed (m/sec).

2-3-CORROSION TEST

The weight loss method has been utilized to quantify the corrosion behaviour of the matrix alloy and the MMC. The weight loss method was used for assessing the test data. The procedure involves putting the specimens in the NaCl solution of 3. 5wt% concentration. The specimens for test were cut to size of 15*10 mm before grinding with 220 to 1000 grades emery paper in order for reaching a smooth surface. The samples, thereafter, have been degreased using acetone. After rinsing in distilled drinking water, the specimens have been dried up in air and then submerged in solutions of 3.5wt% NaCl at 25°C. The weight loss readings were for a period of 30 days.

3-RESULTS AND DISCUSSION

Figure 2shows the hardness test of Al-Mg-Si alloy and ceramic material. It can be observed that the hardness of the composite has been improved after adding ceramic particles (Al_2O_3 and fly ash) into the Al-Mg-Si alloy. This is most likely since these particles are in essentially harder than Al-Mg-Si alloy matrix and as a result adding them would promote the hardness of composite; this behavior is agreed with previous studies such as [10]. Figure (3a) tensile specimen after test and Figure (3b) shows the tensile strength, yield strength and elongation of Al-Mg-Si alloy and ceramic material. It can be noticed that the addition of Al_2O_3 and fly ash particles has improved the MMC's tensile and yield strengths alike. The expected reason is that the dispersion of Al_2O_3 and fly ash particles in Al-Mg-Si matrix would tend to increase structural efficiency; this behavior is agreed with the results reached by [11]. As well as embrace strength is most likely due to the discrepancy in temperature between the Aluminum matrix and the ceramic particles, which can be considered as a principal approach for raising the dislocation thickness of the matrix. In consequence, this will directly lead to enhance the MMC's strength and hence enhancing the constraint to plastic deformation; this behavior was also reported in [12]. In contrast, a decrease in elongation of composite materials was noticed; this can be attributed to the rising of hardness due to the existence of ceramic materials (fly ash and Al_2O_3); similar results were reached by research [20]. Figure 4 shows the variation of wear rate for Al-6061 alloy and composite materials, at load (10N), time (20min.) and sliding acceleration (2.7 m/sec). It can be seen that the wear rate significantly decreases after adding the fly ash and Al_2O_3 in comparison with Al-Mg-Si alloy. This can be attributed to the presence of fly ash and alumina (Al_2O_3). These ceramic particles will act as a contact between the hard disk and the base and hence reducing the rubbing between them. The allergens also act as carriers, thus reducing the plastic deformation. Also it can notice that (2%Flay ash &4% Al_2O_3) alloy with high percent of Al_2O_3 are with less wear rate; this is probably because Al_2O_3 has higher hardness potential than fly ash. Figure 5 shows the relationship between weight loss and exposure time for Al-Mg-Si matrix and composite material. It is obvious that the weight loss for Al-Mg-Si alloy is high in contrast to that for the composite materials. This is logically because the increase in the added materials will reduce the area of Aluminum matrix exposed to the corrosive solution [13]. Figure 6, the optical microstructure of Al-Mg-Si alloy and composite materials is shown. It is noteworthy that the random distribution of Al_2O_3 and fly ash particles were both in the grains and along grains as well as the grain size of the Al-Mg-Si alloy is slightly bigger than that of the composites, this is probably due to the act of the ceramic particles (Al_2O_3 and fly ash) as nucleation sit (inoculation) and therefore improved mechanical properties.

4-CONCLUTION

1. 1-Adding of fly ash and Al_2O_3 to Al-Mg-Si alloy leads to a decrease in the wear rate, elongation and corrosion rate.
2. 2-Adding of fly ash and Al_2O_3 to Al-Mg-Si alloy aided in increase the tensile strength, yield strength and hardness. The composite material which contain (2% fly ash and 4% Al_2O_3) represent the highest tensile strength, yield strength, and hardness but the lower elongation.
3. 3-The grain size of Al-Mg-Si alloy has been refined after adding Alumina and fly ash particles.

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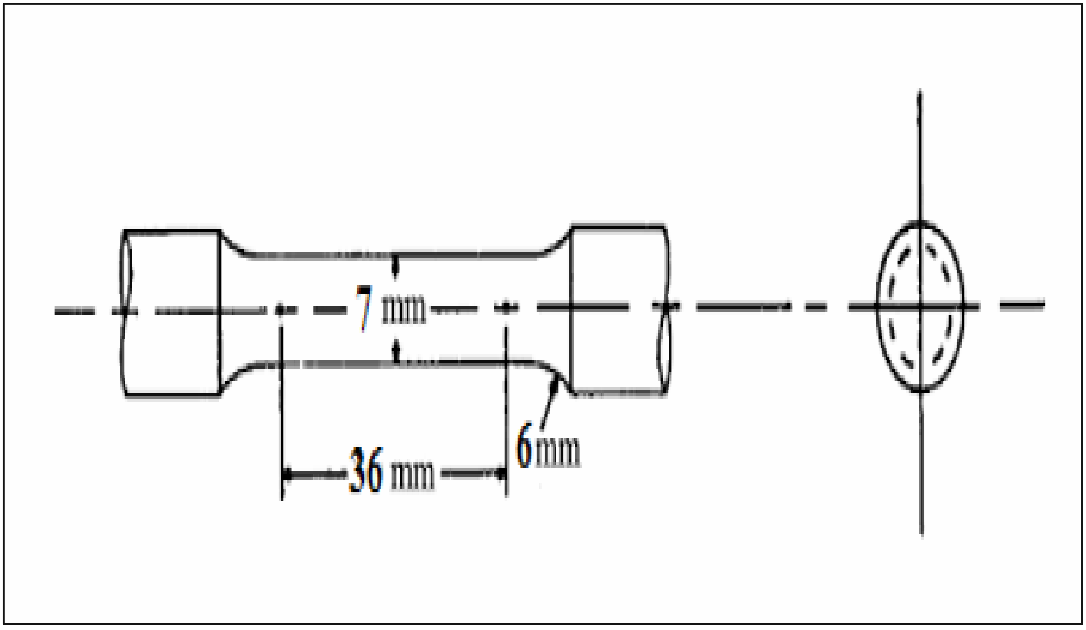

Fig. 1 ASTM standard tensile specimen

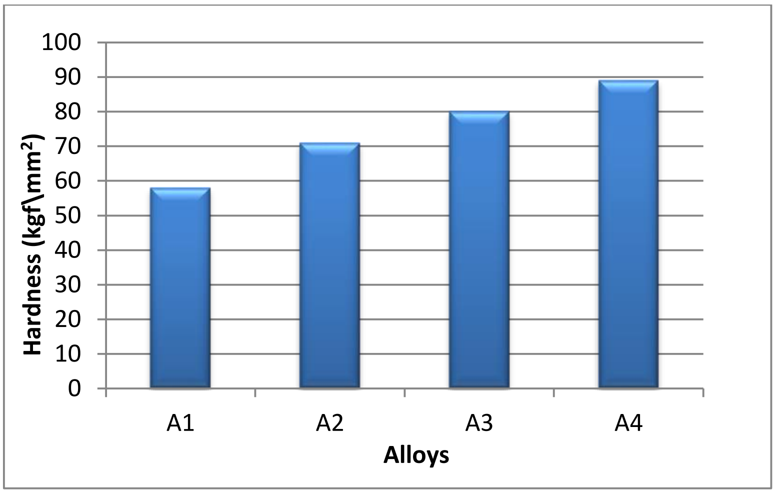

Fig.2 Hardness test of Al-Mg-Si alloy and composite

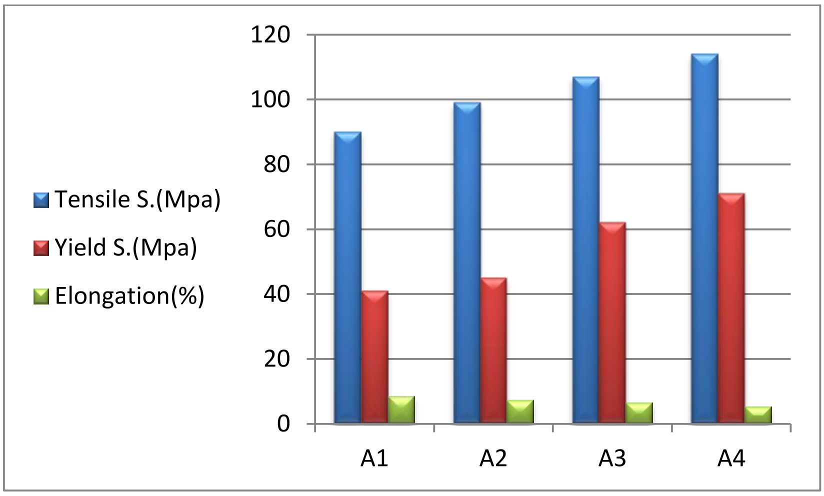

Figure (3a) tensile specimen after test

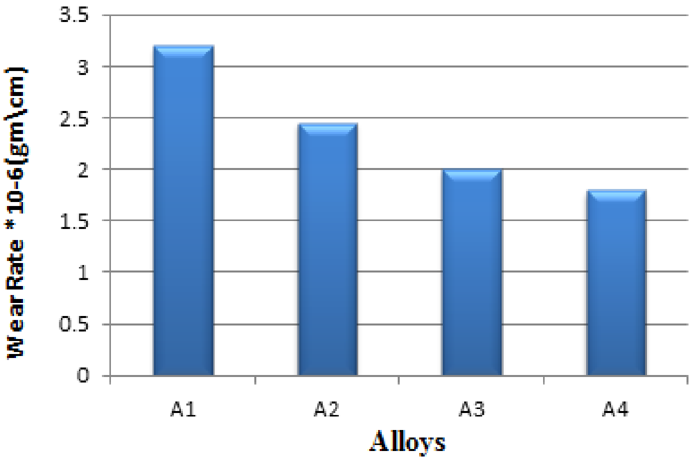

Fig.3b Mechanical properties of Al-Mg-Si alloy and composite materials

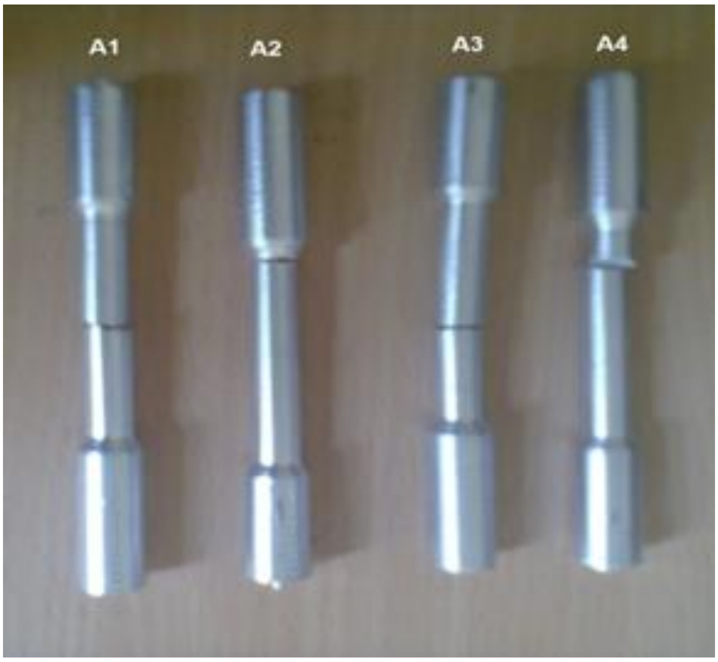

Figure.4 Wear rate of Al-Mg-Si alloy and composite materials

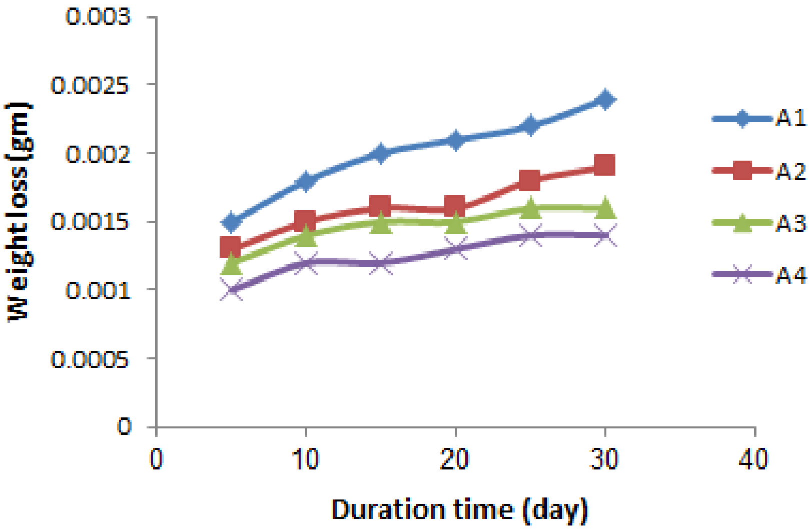

Fig.5 Weight loss with exposure time of Al-Mg-Si alloy and composite materials

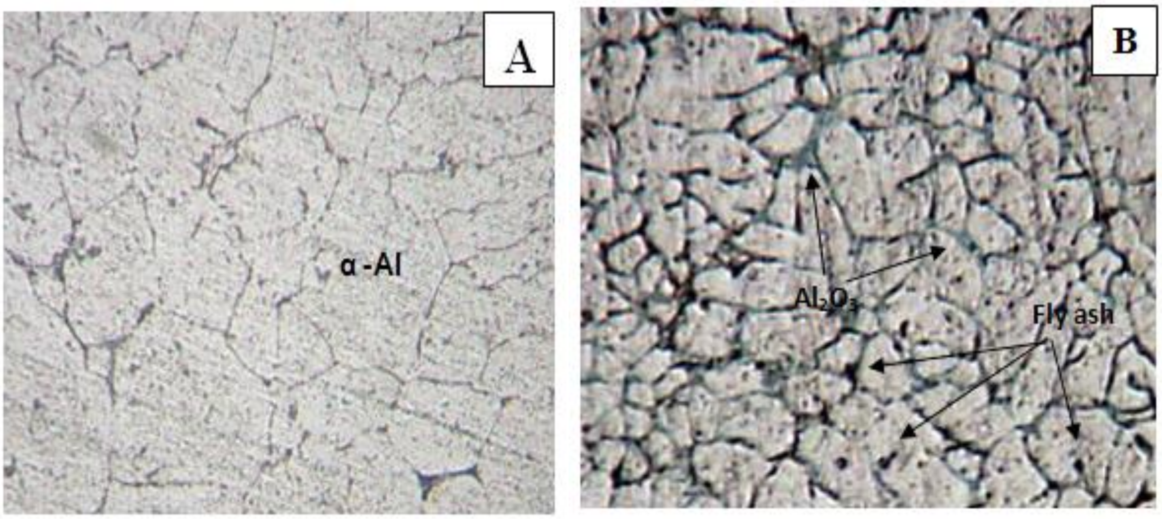

Fig.6 (A) Al- Mg-Si alloy and (B) composite materials at magnification 125X