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# The Effect of Artificial Aging on Mechanical Properties of Metal Matrix Composite

**Jenan S. Kashan***
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**Abstract**

Recently the use of the composite material based on aluminum alloys matrix is increased because of their good mechanical properties and light weight.
In this work the addition of % SiC particle to the aluminum (6063) matrix effect was considered and the solution heat treatment was applied on the produced composite material which has optimum properties followed by artificial aging.
The work shows that the hardness increased and the wear rate decreased with the addition of silicon carbide particles (SiC) , where as optimum produced composite material which has best properties is ( 15% SiC ) . On the other hand the increasing in temperature and time of artificial aging increases the properties.

**Keywords:** artificial aging, metal matrix composite, mechanical properties

## تأثير التعتيق الصناعي على الخواص الميكانيكية للمواد المركبة ذات الاساس المعدني

**الخلاصة**

يزداد استعمال المواد المركبة ذات الاساس من سبائك الالمنيوم كثيرا في الوقت الحاضر نظرا لما تملكه هذه المواد من خواص ميكانيكية جيدة مع خفة الوزن.
تم في هذا البحث دراسة تاثير اضافة نسب مختلفة من دقائق كاربيد السليكون و هي (5و10و15 )Wt% الى ارضية من سبيكة 6063 المنيوم ثم اجراء معاملة حرارية محلولية يتبعها تعتيق صناعي بدرجات حراريـــة و ازمان مختلفة للمادة المركبة الناتجة ذات الخواص الامثل.
اظهرت الدراسة ان الصلادة تزداد و معدل البلى يقل عند اضافة الدقائق السيراميكية المقوية و ان نسبة الاضافة البالغة 15% تعطي احسن الخواص. كما تبين من خلال النتائج ان زيادة درجة حرارة و زمن التعتيق الصناعي يزيد من الخواص.

## 1. Introduction

The use of aluminium – base bearing alloys has markedly increased over the past decade. These alloys have fairly adequate fatigue strength, good resistance to corrosion in the presence of lubricants, relatively high resistance to scoring, and and good antifriction properties. Such qualities can account for the trend towards the substitution of these alloys for led- and tin-base antifriction alloys and lead bronzes [1]
Aluminum-based metal matrix composites (MMC) reinforced with Ceramic particles is demanded because of their low density and high specific Stiffness. In addition, ceramic particles increase significantly wear resistance, high temperature strength and

* Production and Metallurgy Engineering Department, University of Technology/ Baghdad

refractoriness. Different processing techniques can be used to the production of MMC [2, 3].

The precipitation hardenable aluminium alloy 6063 is widely used in the structural applications, in which the wear behavior is a fundamental design requirement [4]. One of the known ways to improve the wear resistance of the heat treatable aluminium alloys is by using the artificial aging. It is a precipitation hardening alloy which is subjected to a solution heat treatment, quenching, and an artificial aging treatment in order to obtain the optimum combination of mechanical properties. The properties of various aluminium alloys can be altered by specific designated heat treatment. Some aluminium alloys can be solution treated to increase their strength and hardness [5,6].

Most of the work done so far on aluminum alloy composites has been based on the 2XXX series of Al-Cu alloys. The 6XXX series of Al-Mg-Si alloys are widely used as medium strength structural alloys made by extrusion, which have the advantages of good weldability, corrosion resistance, and immunity to stress corrosion cracking.6XXX type of aluminum alloy that could be used as a matrix for the composites is the 6063 alloy [7].

The purpose of this investigation is to prepare Sic/6063 alloy composite and then explore the effect of solution heat treatment on the hardness and wear resistance of the composite.

## 2. Experimental Work

### 2.1 Composite Preparation

Aluminum alloy 6063 is a medium strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish; high corrosion resistance is readily suited to welding and can be easily anodized. Table (1) shows the chemical composition of the alloy. In this study, the composite was produced by adding silicon carbide particles (5,10,15 wt%)to specify the better percentage of addition which gives better properties through wear rate examination and hardness test. To produce the composite materials of matrix from 6063 alloy, by melting the master alloy at 700 $C^o$ in an electrical furnace. And then the reinforcement particles were added and according to the required quantity. After that, the molten was stirred by 250 r.p.m speed and 3 min times by using vortex technologytoensure optimal distribution of particles (i.e. SiC particles). Identification of the composite material which possesses the best properties during the examination of the hardness and wear rate to be held the heat treatment.

### 2.2 heat treatment

In this part, the specimens, which have the best properties, are selected to apply the heat treatment. The steps for doing it as the following:

First, the specimen were heated at 520 $C^o$ and stay on this degree for 1 hr. secondly, they were quenched in water to room temperature. Thirdly, and finally, artificial aging is done the treatment specimen in the second step at 150 and 200 $C^o$ for 3, 6,9,12 and 15 hr.

### 2.3 Composite test

Brinell hardness and wear tests have been done. The hardness test a accomplished using a 0.5 Kg load applied on the test area for 10 second and the ball diameter is 10 mm, the load is removed and the trace was measured. Three readings have been taken for each sample. The hardness value was calculated using the following formula:-

$HB=F/A=2F/\prod D[D-(D^2-d^2)^{1/2}$

Were:-

HB:- Brinell hardness $Kg/mm^2$

F:- the load Kg

D:- the ball diameter

d:- trace diameter

The wear test was applied on cylindrical samples. These samples were made for each material (the base alloy and the silicon carbide particles reinforced composite material) and they were prepared to get a good contact between the sample and the rotary disk in wear test machine.

The preparation process has been done as follows; at the beginning the samples were cutted in cylindrical form 10 mm in diameter and 20 mm in high.

The grinding process was applied using grinding papers with different particle size (500, 800, 1000 and 1200) micron, after that the surface is grinded by using polishing clothes and $Al_2O_3$ suspension, they were lifted to dry.

The samples fixed by sample holder. Verifying applied load values used (5,10and 15 N). the steel disk (35) HRC will rotate by electrical motor in (510) r.p.m. this disk cleaned after each test to remove the wastes from the previous test. And the time of sliding that are used to measure the wear rate are 30 minutes. The wear rate (wr) for specimens is calculated from measuring the weight of each specimen before starting the test (wo), and then measuring the weight after the test (w1). The sensitive scale used is with accuracy (0.0001 gm). The wear rates which have units (cm3/cm) are calculated from the following equation:

Wear rate (wr) $=\Delta w / \pi\rho DNt$

Where:-

wr=wear rate ($cm^3/cm$) ,$\Delta w$=lost weight after the test

$\rho$ = density of the material ,D= distance from the centre of specimen to the centre of disc,N= average disc speed (r.p.m),t= time of test in minute.

## 3. Results and discussion

### 3.1 composite materials

The Figures (1) and (2) show increasing in hardness and decreasing in the wear rate for the composite material if it is compared with base material. This belongs to increase the mechanical properties as a result of addition ceramic particles (SiC). The hardness with SiC ratio, and from the hardness concept, it could be criterion of plastic deformation which can effect the material under external stress. Therefore, addition particles lead to increase the hardness of material as a result of its strength to the elastic deformation. The specimen that has 15% SiC, the highest of hardness reaches brinal hardness.

Figure (2) shows the wear rate is affected by the percentage of ceramic particles, where it's reduced with increasing of the particles percentage because of the increase in the mechanical properties of the composite material according to the increase of the ceramic material. As shown in the figure the minimum wear rate is found in the 15% SiC sample.

The addition of the ceramic material is classified according to the particles hardness into hard (SiC and Al2O3) and soft (graphite). In this study the SiC used which has a hardness ( 24.5-29 GPa). And based on the elastic theory, these are the hard particles will increase the strain hardening during tribological interaction between two surface. Also, the particles will bear the load with the matrix and reduce the rate of wear.

### 3.2 Artificial aging

The composite which have the best properties has been heat treated to improve the mechanical properties. The applied heat treatment on the composite material (based on aluminum alloy 6063 matrix) consist of quenching or hardening and aging depending on the solution of the redundant phases in aluminum and the decomposition of supper saturation solid solution, this means that the heat treatment related to the solution of different elements in the aluminum and temperature change, where as the solution of most elements decreases with temperature decreasing. The Figures (3) to (6) shows increase in mechanical properties of the composite material with increase in temperature and artificial aging time. Because of the precipitate particles, it is clearly from figure (3) that the hardness increased with the increase in temperature and artificial aging time. These particles increase the strain along the precipitate matrix particles and this will work as an obstacle to dislocation movement leads to increase in the hardness of the composite material after heat treatment. During the aging the supper saturation solid solution decomposed increasing the alloy strength, therefore, when the temperature increased the amount of this solution will increased leading to increase the composite material properties. As shown in figures (4) to (6) the properties are increased with the increase in aging time up to 12h, after that they appear constant. The reason of that increase is the generation of strengthening phases in the alloy and the increase of the time after 12h a crystals growth occurs leading to decreasing in the properties.

### 4. Conclusions

1. The addition of SiC particles is increasing the mechanical properties and the optimum properties are obtained by adding 15%SiC.
2. The heat treatment increases the mechanical properties of the composite material.
3. The temperature increasing of the industrial aging increases the properties.
4. The increasing of aging time up to 12h will increase the properties.

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**Table 1 chemical composition of the alloy.**

| Si | Fe | Cu | Mn | Mg | Cr | Ti | Al |
|---|---|---|---|---|---|---|---|
| 0.2-0.60 | 0.35 | 0.10 | 0.10 | 0.45-0.90 | 0.10 | 0.10 | Rem. |

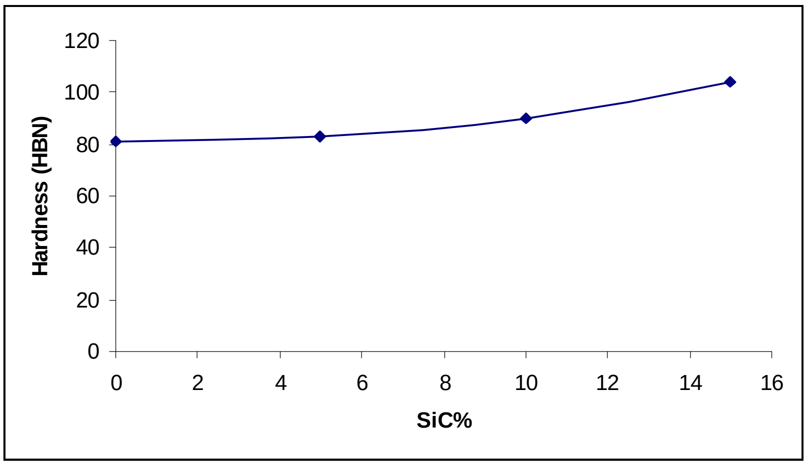


**Figure (1) relationship between the hardness and SiC%**

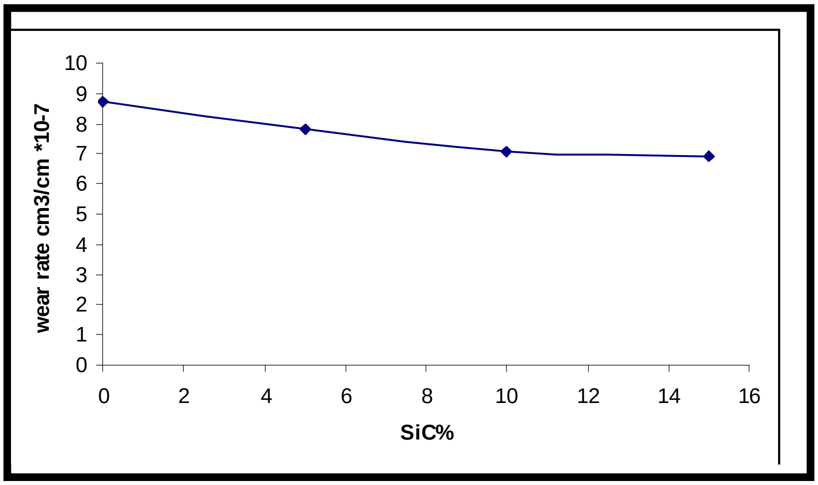


**Figure (2) relationship between the wear rate and SiC%**

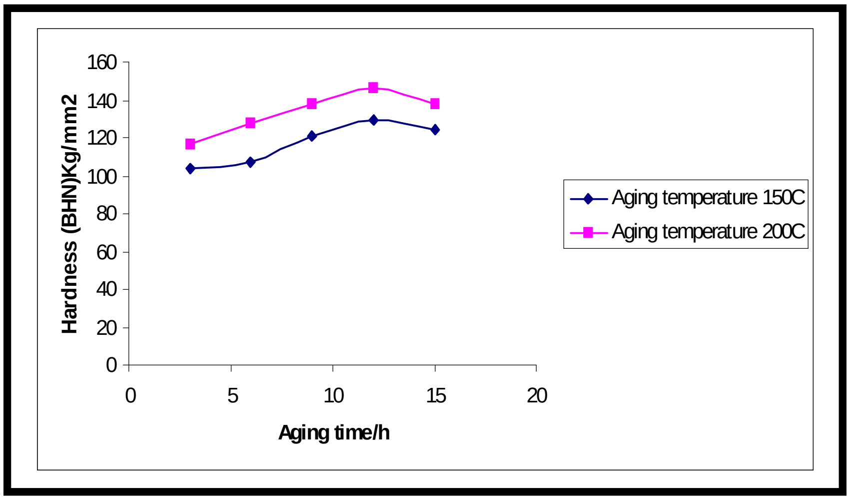


**Figure (3) relationship between the hardness and aging time for the composite has 15%SiC**

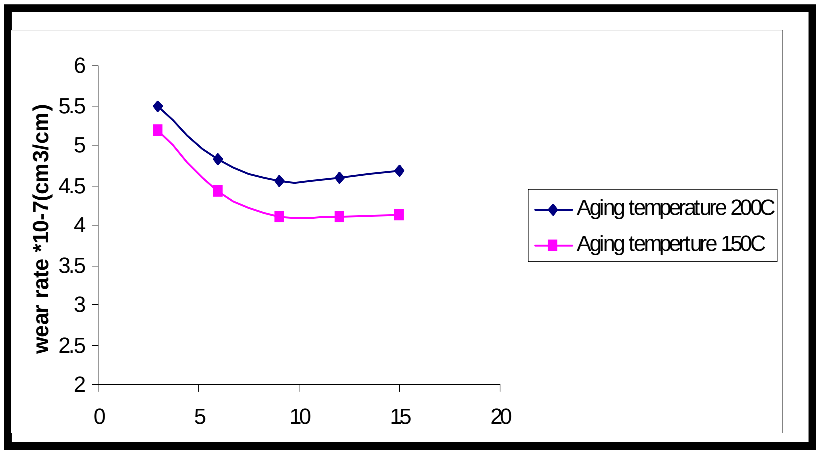


**Figure (4) relationship between the hardness and aging time for the composite has 15%SiC**

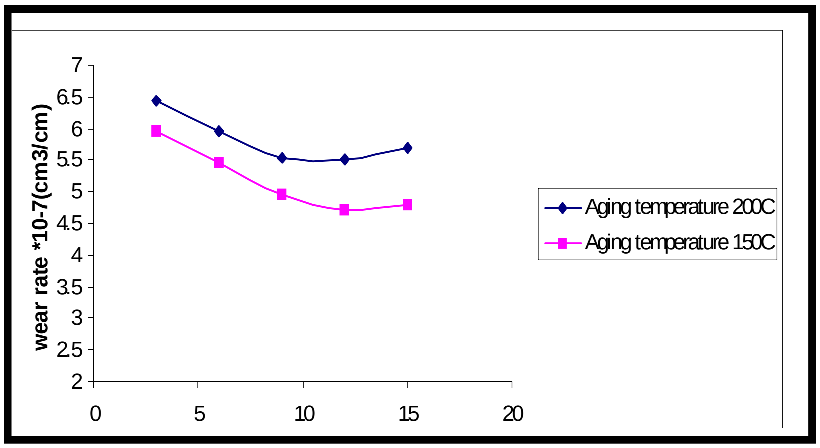


**Figure (5) relationship between the hardness and aging time for the composite has 15%SiC**

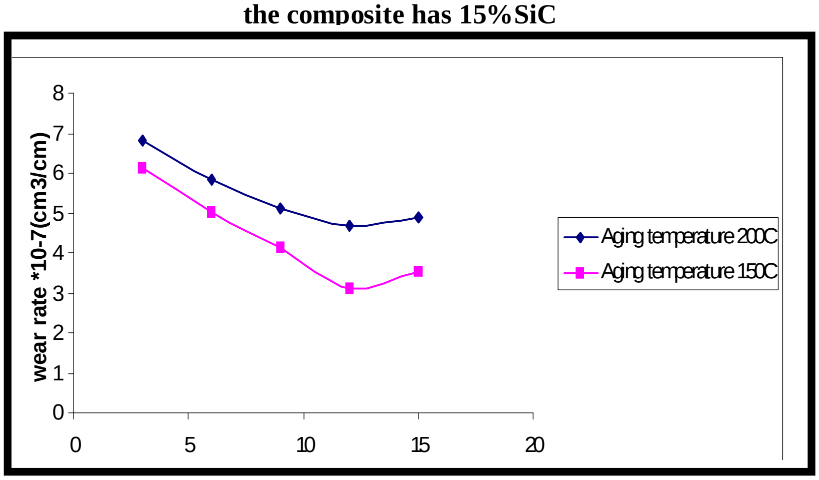


**Figure (6) relationship between the hardness and aging time for the composite has 15%SiC**