Effect of SiC Addition the on Adhesive Wear Resistance of 6061 T6 Aluminum Alloy

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ABSTRACT.

This paper is aimed to study the effect of SiC addition as reinforcement to 6061 T6 alloy. Al 6061 T6 alloy SiC composites were prepared by melting the alloy in a vortex and adding 4 % and 10% weight fractions of SiC. Then pouring the mixture into a mould to obtain a bar of 12 mm diameter and 150 mm length. Wear specimens were manufactured in dimensions of 20mm x 10mm according to ASTM to the base alloy and the cast matrix alloy. Microstructure have been carried out to understand the nature of structure and Hardness test also implemented to specimens.

Adhesive wear test have been conduct both on the alloy and composites at different parameters (time, load and velocity).

From the obtained results, it was found that wear resistance improved during the carbide addition comparing with the base alloy as a result of SiC addition which contributed in improving the hardness of the alloy that reflects to the wear resistance and these properties were improved as the increasing of the carbide silicon percentage.

Keywords: Metal matrix composite, adhesive wear resistance, Aluminum alloy 6061T6, SiC percentages

1. INTRODUCTION.

In recent years, aluminum alloys have attracted attention of many researchers, engineers and designers as promising structural materials for automotive industry or aerospace applications. Especially, 6xxx aluminum alloys have been studied extensively because of their benefits such as medium strength, formability, weld ability, corrosion resistance, and low cost, comparing to other aluminum alloys. The 6061 Al-alloy has been used in the automotive industry for the fabrication of several types of automobile parts, such as wheels, panels and even in the vehicle structure. It is expected that substitution of such aluminum alloys for steels will result in great improvements in energy economy, recyclability and life-cycle cost. However, it is necessary to improve the strength and the formability of aluminum alloys for further applications to the industries [1][2][3].

Metal matrix composites (MMC_S) are gaining wide spread popularity in several technology owing to its improved mechanical properties when compared with conventional metal alloys.

Among the several categorization, aluminum based composite are finding wide spread acceptance especially in application where weight and strength are of prime concern [4].

In the automobile sector, Al composites are used for making various components such as brake drum, cylinder liners, cylinder blocks, drive shaft etc. In aerospace industries, Al composites are used essentially. In structural applications such as helicopter parts (parts of the body, support for rotor plates, drive shafts), rotor vanes in compressors and in aero-engines.

The adhesive wear occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make a load plastic deformation and adhesion. This adhesion will be at a high grade of efficiency and capability in relative to the clean surfaces, and adhesion will take place between a number of these projections whose sizes will be bigger and the area will be increased during movement [5]. At the end there will be some relative wear in the superficial tissues in the weak points of the noticeable places This adhesion wear is proportional directly to the load applied and the sliding distance and indirectly with the hardness of the metal. The adhesion wear is one of the most prevailing wears, it forms 15% of the industrial wear [6]. Which was happens when the surfaces are sliding one over the other, so that the pressure between the adjacent projections is enough to produce some local formation adhesion and plastic [5].

Many studies were implemented in this area Prabhu Swamy N. R. *et al* [7] who studied the effect of heat treatment on strength and abrasive wear behavior of Al 6061/SiC composite showed that using composites exhibited better micro hardness and tensile strength then reduced wear loss when compared with Al matrix alloy.

Ehsani R. and Seyed Reihani S.M. [8] produced Al 6061 /SiC composites using a squeeze casting method. SiC preforms were manufactured by mixing SiC powder having a 16 and 22µm particles size, with colloidal silica as a binder. 6061 Al melt was squeeze cast into the pores of the SiC perform to manufacture a composite containing 30 vol. % reinforcement. The results show that the hardness, yield point and tensile strength increase with addition of SiC particles to 6061 Al alloy.

Bekheet, N.E. and R.M. Gadelrab [9] Studied the effects of aging on the hardness and fatigue behavior of 2024 Al alloy SiC composites, the results show that reinforcement and cold working before artificial aging have accelerated the reaction kinetics of the precipitation-hardening process of the composite. The peak hardness of these composite materials is found to be comparable to or slightly higher than that of the unreinforced alloy.

Lee, C. S., Y. H. Kim, K. S. Han and T. Lim[10] Characterized wear behavior of aluminum matrix composites by the dry spindle wear test under various conditions (volume fractions of reinforcements, sliding distances and speeds),they found that wear resistance of composites was improved due to the presence of reinforcements, but with no noticeable improvements observed in the wear resistance with more than 20% addition of reinforcements

The aim of the present work is to study the effect of adding (4% and 10 vol.%) SiC particles to Al 6061 (Al-Mg-Si) alloy matrix, and to study the adhesive wear, then comparing the results with other researchers who studied the same subject but with other percentages.

2. EXPERIMENTAL WORK.

2.1. Materials.

A liquid metallurgy route has been adapted to prepare the cast composites. Al6061 T6 has been chosen as matrix alloy. Preheated SiC of size (50) µm was introduced into the vortex of the effectively degassed Al6061 T6 molten alloy, then the mixture was poured into mold. The size of the produced samples was 15 mm in diameter and 150 mm in length. The weight fraction of SiC particles were 4% and 10%. **Table (1)** shows the chemical composition of the used alloy.

2.2. Preparation of Specimens.

Cylindrical specimens for the adhesion wear tests were prepared with dimensions (10x20mm) according to ASTM specifications for all specimens used. After completing the preparation of specimens, these specimens were classified and sorted into groups as shown in **Table (2)**.

2.3. Microstructure Examination.

The specimens were prepared from the microstructure as follows:

A- The specimens are grinned with emery papers of grades 120, 350, 500, 800, 1000 and 1200.

B- They were polished with cloth and Alumina Al_2O_3 solution.

C- Aqueous treatment with HF which consist of 52% of Hydrofluoric Acid and 48% of water.

D-The optical micrograph of the cast base alloy and the composites were taken.

2.4. Hardness Test.

Hardness test was conducted by using Vickers method on the specimens in **Table (2)**, the obtained results are shown in **Table (3).**

2.5. Adhesion Wear Tests.

Adhesion wear test is done by the weighing difference method on the specimens in **Table (2)** by the apparatus of wear test shown in **Fig. (2)**.The wear rate is calculated according to the following steps:

1- Weighing the specimen before test by digital sensitive balance, with accuracy 0.0001g of type XB 220 A precisa, as shown in **Fig.(3).**
2- Specify the variables which needed to know its effect on the wear rate like time and fixing other variables (load, sliding speed).
3- Specify the hardness of the steel disc and it was found, HRC=40 RC
4- Fixing the specimen by the bearer in vertical position on disc.
5- Fitting the operation time.
6- Checking the cleanness of the disc before the test start.
7- Operate the apparatus with the specified times (10, 20, 30) min., and fixing other Variables (load at 1 kg).
8- Stopping the operation and weighing the specimen.
9- Repeat the process with fixing time (10) and changing other variables (at load 1.0, 1.5 and 2.0) Kg and at sliding distance of (2.5, 5.0, 7.0) cm at time (10) and load (1.5) Kg

The wear rate is calculated from the following equation [5]:

$$Wr = \Delta W / 2\pi\, r\, n\, t \quad (1)$$

Where

Wr = wear rate.
$\Delta W = W1 - W2$ = The weight difference.
r = sliding distance (cm) =125mm
n = disc speed = 940 (rpm)
t = sliding time (sec)

3. RESULTS AND DISCUSSION.

3.1. Microstructure of Composites.

The optical micrographs of the cast base alloy Al 6061(Al- Mg- Si) and the compose are indicated in **Fig. (1)**. The microstructure consists of α-Al grains. The microstructures of Al60614wt % SiC and 10wt% SiC composites are shown respectively. The distribution of SiC particles in a matrix alloy is uniform. Further the micrographs reveal good bond between the matrix alloy and SiC particles .This is due to the presence of Mg in chemical composition of Al-alloy which improves the wet ability of ceramics particles with matrix alloy and also increases the retention percentage of SiC particles in matrix. X-ray diffraction analysis (XRD) results are confirmed the appearance of the SiC particles in the alloy matrix as small peaks in XRD pattern as shown in **Figs.(4 and 5)** for the base alloy of Al 6061 and composite material with 10wt%SiC respectively. These results are in agreement with those of other researchers [11, 12].

3.2. Hardness test.

From **Table(3)** we see that silicon carbide addition at 4% and10% have increased the hardness comparing with the as received alloy. Increasing the percentage to 10% have led to increasing the hardness more than in 4%. This is due to ceramic particle that has a high hardness.

3.3. Wear adhesive.

Fig. (6) show the relationship between wear rate and its parameters (Time, Load and velocity) we see in **Fig. (6.a)**, that when increasing time, the wear rate increases for all investigated composite specimen sat different percentage rate. Specimen C gave the lowest wear rate because of the silicon carbide effect which causes an increasing in hardness that contributed in improving in wear resistance. **Fig. (6.b)** shows the effect of second parameter (load). The same results obtained from **Fig. (6.a)** shown in this figure because of increasing in implemented load caused an increasing in the plastic deformation in surface tips peaks between two sliding surfaces. The adhesive process of the two tips surfaces depends on applied load, if the load is low the contact appears in upper bit and this was very thin during sliding process that causes a thin layer from Oxide works as a protective surface film which limits the touching between the two sliding surfaces and prevent the direct metallic connection between the surfaces tips thus the required force to cut and spate the occurred connection between the two surfaces tips less than the force between the metal atoms itself and that will cause a decrease in wear rate. On the other hand an increasing in applied load will break the oxide film because of its brittleness for its shoots out the friction sliding surfaces for both the discs and specimen during the sliding process which causes a strong metal contact between them make the required force to shear its contact tips more than the force between the metal atoms itself. The third parameter (sliding velocity) observed in **Fig. (6.c)** shows the same result in **Fig. (6 a.b)** for the same reasons which discussed above.

These results for all parameters are in agreement with researchers in [10].

4. CONCLUSIONS.

1-The addition of silicon carbide as a reinforcement to the alloy contributed increasing in hardness for all addition percentage of SiC and improves the wear resistance.

2-Increasing the SiC weight fraction have led to increasing the hardness and decreasing the wear rate.

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Table (1): Chemical composition of Al 6061T6 alloy.

Element wt%	Mg	Si	Fe	Mn	Cu	Cr	Zn	Al
Measured value	1.03	0.778	0.6	0.14	0.082	0.09	0.03	Rem
Standard value	0.8-1.2	0.4-0.8	Max 0.7	Max 0.15	0.15-.40	0.04-.35	Max 0.25	Rem

Table (2): Categorization of specimens.

Specimen symbol	State of specimens
A	As received alloy
B	4% SiC /Al -alloy
C	10% SiC /Al - alloy

Table (3): Hardness test result.

Specimen sample	A	B	C
Hardness Kg/mm^2	**58**	**80**	**104**

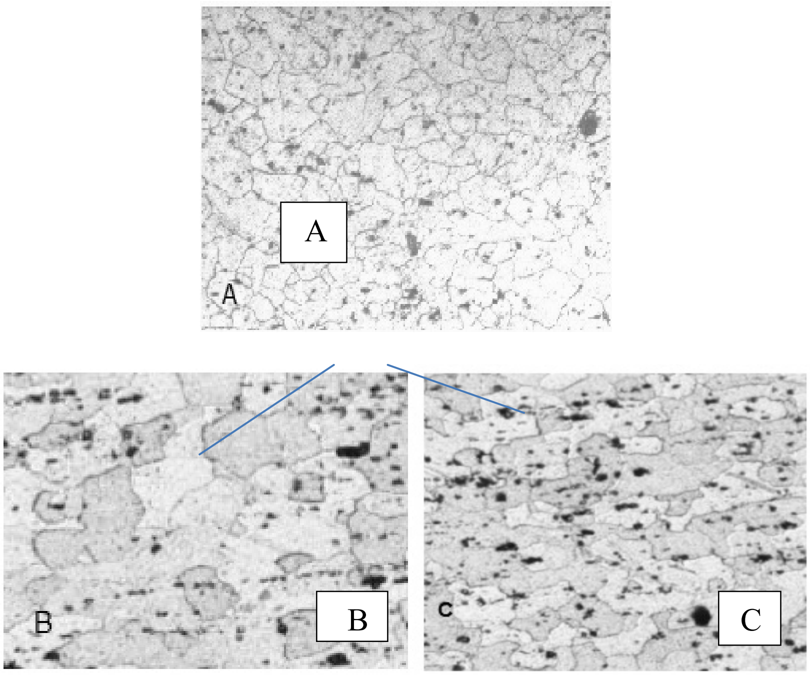


Figure (1): The microstructure of specimens in table (2) at magnification 100x .

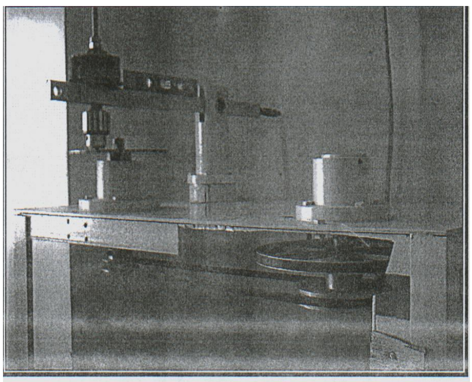


Figure (2): Apparatuses of adhesive wear test.

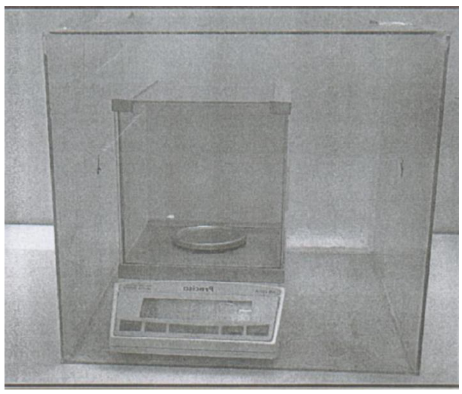


Figure (3): Apparatuses of the digital sensitive balance.

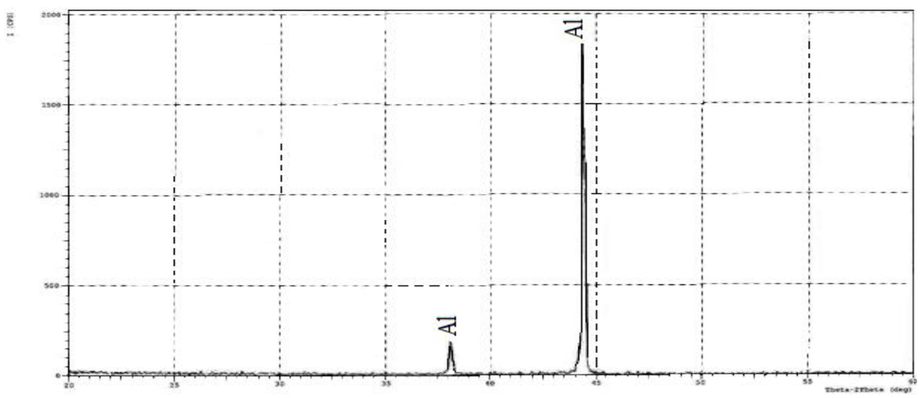


Figure (4): X-Ray diffraction analysis pattern of the base alloy Al 6061.

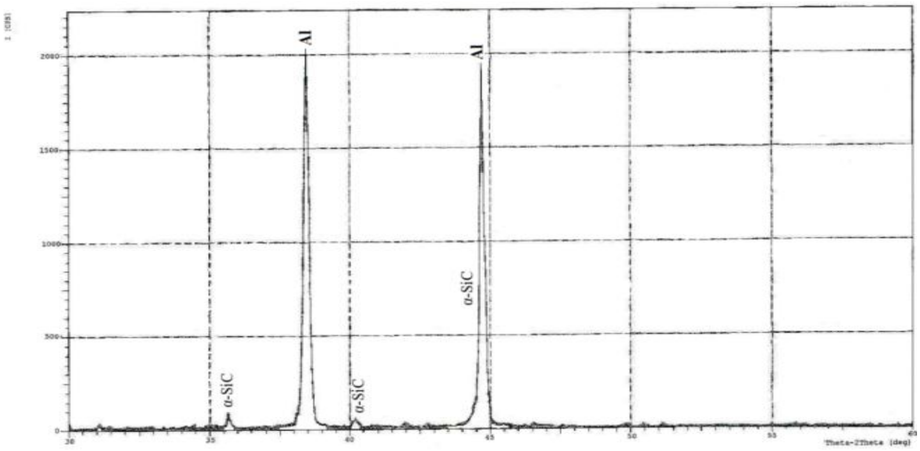
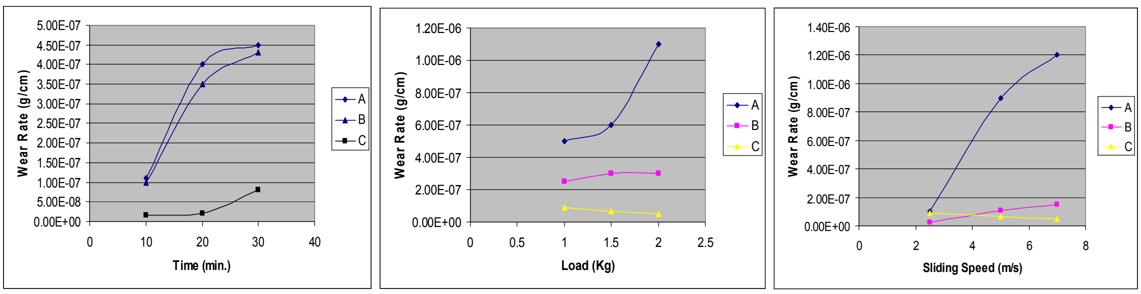


Figure (5): X-Ray diffraction analysis pattern of the composite material (Al 6061-10% SiC).



(a) (b) (c)

Figure (6): The relationship between Time, Load, Sliding speed and Wear rate for all specimens in Table (2).

تأثير إضافة كاربيد السيلكون على مقاومة البلى الالتصاقي لسبيكة الالمنيوم 6061T6

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الخلاصة.

يهدف البحث الى دراسة تأثير اضافة كاربيد السيليكون كمقويٍ لسبيكة الالمنيوم 6061-T6. تم تحضير المادة المتراكبة بواسطة صهر السبيكة في بودقة واضافة كاربيد السيليكون بنسبة وزنية مقدارها 4%و 10% مع التحريك المستمر للمنصهر، بعدها تم صب الخليط في قالب معدني للحصول على سبيكتين بقطر 12ملم وطول 150ملم. تم تصنيع عينات أختبار البلى الاسطوانية بطول 20ملم وقطر 10 ملم وفق المواصفة القياسية ASTM للسبيكة الاساس والمادة المتراكبة. تم اجراء فحص البنية المجهرية للسبائك وكذلك إجراء أختبار الصلادة وايضا تم اجراء اختبار البلى الالتصاقي على السبيكة والمتراكبة وعند متغيرات مختلفة (الوقت، الحمل، السرعة).

تبين من النتائج التي تم الحصول عليها ان مقاومة البلى قد تحسنت نتيجة إضافة SiC مقارنة مع السبيكة الاساس. ان اضافة كاربيد السيلكون بالنسب اعلاه قد ساهم في تحسن الصلادة مما انعكس على تحسن مقاومة البلى الالتصاقي، وان هذا التحسن في الخواص يزداد بزيادة نسبة إضافة كاربيد السيلكون للسبيكة.

الكلمات الرئيسية: خليط المواد المتراكبة، مقاومة البلى الالتصاقي، سبيكة الالمنيوم 6061T6، نسبة SiC