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STUDYING THE EFFECT OF REINFORCING BY SICP ON THE DRY SLIDING WEAR BEHAVIOR AND MECHANICAL PROPERTIES OF AL- 4% CU MATRIX ALLOY

Israa .A.K
Department of Production Eng. & Metallurgy, University of Technology
Israa _1963 @ yahoo.com
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ABSTRACT:- This research is devoted to study the effect of addition of different weight percent from SiCp (2, 4, 6, 8) to Al– 4 Cu alloy which have been fabricated by liquid metallurgy method on the dry sliding wear behavior and mechanical properties. Wear characteristics of Al–SiC composites have been investigated under dry sliding conditions and compared with base alloy. Dry sliding wear tests have been carried out using pin-on-disk wear test under normal applied loads 5, 10, 15 and 20 N and at different sliding velocity of (2.7, 3.7, 4.7) m/sec. It was also observed that the wear rate varies linearly with increases normal applied load but lower in composites as compared to the base material. The wear mechanism appears to be oxidative for both Al – Cu alloy and composites under the given conditions of load and sliding velocity as indicated by optical microscopic of the worn surfaces. Further, it was found from the experimentation that the wear rate decreases linearly with increasing weight percent of silicon carbide. The best results have been obtained at 8 % wt SiC . We also observed that the yield strength, tensile strength increases with increasing wt% of SiC , but the ductility decreases.

Key words :- Composites, Wear Al- alloy , Silicon carbide, Mechanical properties.

INTRODUCTION

Metal matrix composite materials (MMCs) are exponentially growing and gaining importance because of their potential to produce components, which possess high strength to weight ratio at elevated temperatures, improved shock resistance properties, relatively higher wear resistance, toughness, etc, which make them candidates in automotive, aerospace and many engineering fields. Metal matrix composite containing ceramic particulates tends to improve mechanical properties as well as wear properties by way of creating restriction to deformation of material during mechanical working. Metal matrix composites (especially aluminum and titanium based) are used in aerospace and automobile industries due to their enhanced properties such as modulus of elasticity , hardness, tensile strength, and wear resistance combined with significant weight saving (1,2) Aluminum with ceramic reinforcements such as Al_2O_3, SiC, TiC, and TiB_2 are used for structural applications, for their good toughness and wear resistance (3) . Modulus of composite increases with TiC- and TiB_2-particle addition it is greater than that for composite with Al_2O_3 and SiC. Also, interfacial bonding is enhanced in the TiC- and TiB_2 - added composites (4) . There are different techniques of forming TiB_2 in the matrix such as powder metallurgy method, spray, deposition and several casting methods such as rheocasting, squeeze casting, stir-casting and compo casting (5, 6) . Different systems are used for synthesis of this composite such as TiO_2-Al-B, TiO_2-Al-B-CuO , TiO_2-Al-B_2O_3, $NaBH_4$, and $TiCl_4$.

Like all composites, aluminum matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of the reinforcement, location of the reinforcement and fabrication method has all varied to achieve the required properties. The aim involved in designing metal matrix ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produce a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. These properties have further improved by carefully controlling the relative amount and distribution of then gradients of a composite as well as the processing conditions among discontinuous metal matrix composites, stir casting has generally accepted as particularly promising route because of its simplicity, flexibility and applicability to large quantity production. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production and allows fabrication of very large sized components. (7)

In order to achieve the optimum properties of the metal matrix composite, the distribution of the reinforcement material in the matrix alloy must be uniform, and the wettability or bonding between these substances should be optimized. The major problem was to get homogenous dispersion of the ceramic particles by using low cost conventional equipment for commercial applications. The rate of solidification has a significant effect on the microstructure of cast composites, which in turn affects their mechanical properties.

Aigbodion V.S and et.al [8]study the effect of SiCp on the as cast microstructure and properties of Al-Si-Fe alloy composities produced by double stir casting method. A total of 5-25 wt% SiCp were added . The results revealed that addition of SiC reinforcement increased the hardness values and apparent porosity by 75 and 39 % respectively and decreased the density and impact energy by 1.08 and 15% respectively , as the weight percent of SiC increases in the alloy . The yield and ultimate tensile strength increased by 26.25 and 25% up to a max . of 20% SiC addition . Bindumadhavan P.N. and et.al [9] study the Al-Si-Mg alloy composites reinforced with up to 15 vol % of SiC particles were prepared by the melt stirring process . The wear behavior under low loads of the un reinforced Al-Si-Mg alloy and the metal matrix composites was investigated using a ball –on-disc test at room temperature under dry conditions . It was found that the maximum. effective increase in wear resistance (ratio of percentage reduction in weight loss and volume percent of SiC added to a achieve reduction) occurred for the composite with a bout 7 vol% SiC. The wear resistance and mechanical properties of low volume fraction composites is to incorporate small and large SiC particle sizes. P. Shanmughasundaram and et.al. [10] studying the Aluminium reinforced with conventional ceramic materials such as SiC / Al_2O_3 are gradually being implemented into the production of pistons, cylinders, engine blocks, brakes and power transmission system elements in automobile industry. Fly ash (SiO_2, Al_2O_3, Fe_2O_3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituents) is one of the most inexpensive and low density material which is abundantly available as solid waste byproduct during combustion of coal in thermal power plants. The present investigation has been focused on the utilization of fly ash in useful manner by dispersing it into aluminium to produce composites by a two step stir casting method to overcome the cost barrier for wide spread applications in automotive systems. An attempt has also been made to investigate its microstructure, mechanical, wear and corrosion behavior of composites. The results show that :-

1. The density of the composites decreased with increasing fly ash reinforcement content. Hence Al- fly ash composites can be used in applications where weight reductions are desirable.
2. Hardness, tensile strength and compressive strength were determined for the test materials. Increasing fly ash content resulted in increase in the tensile strength of the Al. However, the tensile strength begins to drop when the fly ash content exceeds 15wt% due to the decrease in solid solution strengthening and particle clustering.

Hardness and compressive strength of composites were found to increase with increased fly as content. Above 20 wt% of fly ash, both hardness and compressive strength of composites begins to decrease.

3. Wear resistance of the commercial Al was considerably enhanced by the addition of fly ash particles and the wear resistance of the composites was much superior to the unreinforced aluminium over the entire load range tested under dry sliding conditions. This may be due to the favorable effect of the fly ash particles which is a dominating factor affecting the wear resistance. However the addition of only 20wt% fly ash particle to the Al was very effective to reduce its wear loss.
4. It was observed that the high proportion of fly ash reinforcement shows the poor resistance to corrosion. Moderate corrosion resistance is seen when the fly ash content is about 15 wt% .From the results it can be concluded that the Al-fly ash composites could be considered as an excellent material in sectors where light weight, enhanced mechanical properties and wear resistance are prime consideration especially in automobile applications

EXPERIMENTAL WORK

The liquid metallurgy technique was used to fabricate the composite specimens. This method is the most economical route to obtain composites with particulates. In this process, the matrix alloy Al- 4% Cu alloy. The chemical composition of the alloy used in the present investigation is given in table (1).

The alloy was first superheated above its melting temperature to create a vortex in the melt using a stainless steel mechanical stirrer. The alloy was melted in electrical melting furnace whose maximum temperature 1200 ^{o}C. This furnace was also used to heat the die before casting, also the reinforcement particles was heating before adding into the melt. The SiC of average particle size (+53- 75) µm was used to having 2,4,6,8 wt% of second phase particle , the composite was synthesized by vortex method . During melting 1 wt% Mg was added to improve the wetability of the matrix and improving the interfacial bonding between the particles and matrix.

When the amount of reinforcement was 2, 4 , 6 and 8 wt% the particles were wrappin avery thin foils and heated to 400 ^{o}C for 1 hrs in heating furnace then adding the heated SiC particles with the Al foil to the molten Al-4Cu alloy for 10 minutes using an electrical stirrer at speed of 600 rpm after then the molten composite is put again in the melting furnace as shown in fig (1) for increasing the temperature to 700 ^{o}C , nitrogen gas was injected for degassing purpose followed by stirring the molten composite again for 10 min and then pouring it into the die cavity 10 mm in diameter and 50 mm high which preheated at 300 ^{o}C for 30 min. To examine the microstructure of the base alloy and the casting composites, the specimens were cut from the center of the samples, grinding was conducted with silicon carbide papers 1000 grit using grinding machine (Struers DAP-5, Denmark).

The specimens were then polished on polishing cloth using 5 µm and 0.3 µm alumina suspension consequentially. These samples were then washed in water and alcohol, and then dried in hot air. The worn surface was examined by an optical microscope with digital camera. The micro hardness of the base alloy and composites was measured by using Vickers hardness apparatus, and calculated by the following [11] :-

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

Where:-

P : The applied load 1 Kg.

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

HV : Vickers hardness . Kg / mm^2

A pin-on-disc test apparatus belongs to tribology laboratory, and metallurgy, university of technology as shown in fig. (2). It was used to investigate the dry sliding wear characteristics of the aluminum alloy and Al-SiCp composites. Wear specimens 10 mm in diameter and 20 mm high were cut from as-cast samples, machined, and then polished. Wear tests were conducted with loads ranging from 5 to 20 N and sliding speeds of 2.7 m/s, 3.7 m/s and 4.7 m/s. All tests were conducted at room temperature.

The wear test carried by using pin –on- disc machine, the following procedure was conducted as follows:-

1- Carbon steel disc was mounted in its position with hardness 60 HRC.
2- The pin was weighted accurately before test and then mounted on the specimen holder.
3- The lever arm was balanced by adjusting the weights in the rear position, and kept at a horizontal position so that the specimen was close to the disc but no force acted on it.
4- The pin was loaded normally by adding (5, 10, 15, 20) N load.

5- At the instance of running system, the stop watch was started for the purpose of measuring the testing time. Each test took 20 min, and the weight loss from the specimen was recorded, for the purpose of calculating the wear rate.

The wear rate was calculated from weight loss measurement, by using sensitive balance with an accuracy of ± 0.0001 gm (Mettles type AE 200, Swaziland) and the wear rate calculated as the following formulae [12] :

Wear rate (Wr) = (W_1-W_2) / S------ (2)

Where:-

W_1: Specimen weight before wear test (gm).

W_2: Specimen weight after the wear test. (gm)

S : Sliding distance (cm)

S= V x t - ----(3)

Where:-

t : Running time (20) min at each test.

V: Linear sliding speed (m/sec).

The disc rotational speed was 520 rpm . The tensile strength measurement by using the Instron machine type 1195, the specimen dimensions with standard (ASTM, E8).

RESULTS AND DISCUSSION

The wear rate of the metal matrix reinforced with SiC particles reduces with increasing reinforcement content for dry sliding wear tests under different applied load as shown in Fig. (3). When the applied load increases the morphology of worn surfaces gradually changes from fine scratches to distinct grooves, and damaged spots in the form of craters. The asperities of both the pin and counter face are in contact with each other and are subject to relative motion under the influence of applied load. Initially, both the surfaces are associated with a large number of sharp asperities, and contact between the two surfaces takes place primarily at these points [13,14]. In the present case, the asperities of the pin also have a large number of reinforcements in the form of asperities. Under the influence of applied load and speed, when the asperities on each surface come in contact, they are either plastically deformed or remain in elastic contact [15]. As the asperities have very sharp edges the effective stress on these sharp points may be more than the elastic stress, and then all these sharp asperities are plastically deformed at their contact points except for the partially projected points of the SiCp reinforcement. The other plastically deformed surface may fill the valley of the material both on pin and counter face during the course of action. Thus, there is a possibility of fracturing a few asperities on both surfaces, leading to very fine debris particles. At lower loads, the projected SiC particles in the composites will be in contact with the counter face during the course of wear. The asperities of the sliding pin surface come into contact with the steel disc surface, and are work hardened under the applied load and speed due to cold working on the surface of the pin (15). Therefore, instead of the surfaces of particles cracking, they will be pushed back into the soft Al alloy. The initial run in period in all cases, the wear rate is more due to the fact that a few highly projected broken SiC particles on the pin will act as debris and plough the surface, particularly in the Al -SiCp composite specimen, leaving projecting SiC in the composite. The stress on the surface of the Al alloy is almost uniform and contact between the pin and counter face results in a larger contact area and hence larger stress and wear.The examination of the worn surfaces as represented in fig (4) shows areas from where material has been removed. Fig. (5). shows the relationship between the wear rate and different sliding speed (2.7,3.7,4.7) m/sec under constant load (15 N) it is clear that the wear rate decreases with increasing the sliding speed but the composite pin reinforced by 8 wt% SiCp which has lower wear rate when compared with the base alloy and other composites. The wear rate at the beginning is larger, because the asperities of SiC particles are not projected and the entire surface is under the same amount of stress, so that the asperities deform easily and the fractured particles and un fractured SiC particles plough the surface of the counter face and pin. When the speed increases, the ploughed surface of the counter face (i.e. steel) reacts and forms Fe_3O_4, which causes SiC particles to crush and form very minute particles (16, 17). Fe_3O_4, Fe, and minute particles of SiC form a layer between the works hardened pin and the counter face and reduce the wear rate. With increasing sliding speed, this flash temperature may reach the melting point at surface asperities (18) . The flow of heat through the specimen metal at higher sliding speed is lower than that at lower sliding speed. At low sliding speed there is enough time for metal contact for cold welding, because of the atomic diffusion between contact surfaces. Also plastic deformation of these asperities is higher than that at high sliding speed , this cause a strong contact between surfaces and finally the wear rate will increase (19) . Fig (6) represent that the hardness increases with increasing Wt % SiCp explored the significance of hard ceramic particles in increasing the bulk hardness of Al-MMCs. Howell et.al.(20) and Vencl et.al. (21), of reasoned the improvement of the hardness of the composites to the increased the

Wt % of SiCp, the increase in hardness of the composites to the increased strain energy at the periphery of particles dispersed in the matrix, that the increase in the hardness of the composites containing hard ceramic particles not only depends on the size of reinforcement but also on the structure of the composite and the load from the matrix to the reinforcement .

CONCLUSIONS

1- The wear resistance increases with increasing Wt % of SiCp . the composite materials which consist of 8 Wt % SiCp represent higher wear resistance when compared with the other composites and the base alloy.
2- Generally the wear rate increases with increasing the normal applied load but decreasing with increasing the sliding speed.
3- The ultimate tensile strength, yield strength and hardness increases with increasing Wt % of SiCp .
4- The ductility decreases with increasing Wt % of SiCp.

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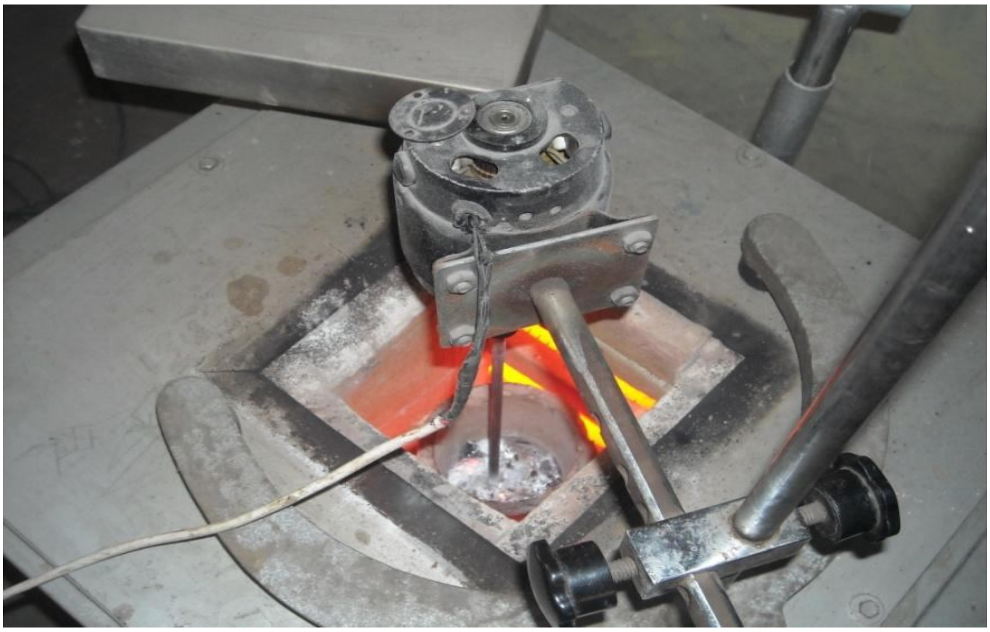


Fig . (1): Laboratory stir casting.

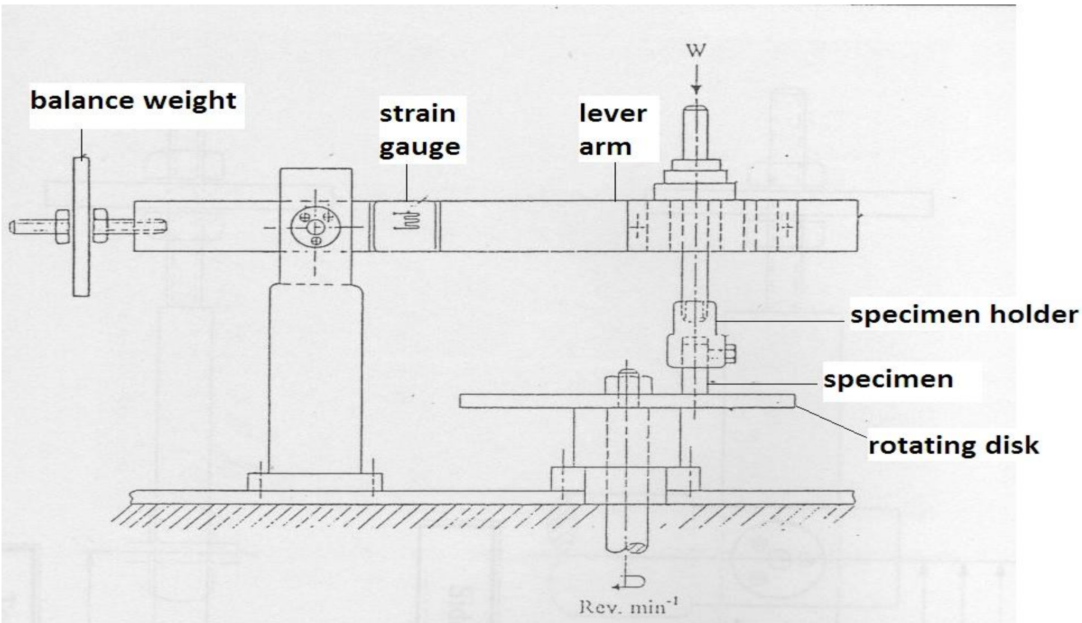


Fig . (2): Pin on Disc Machine.

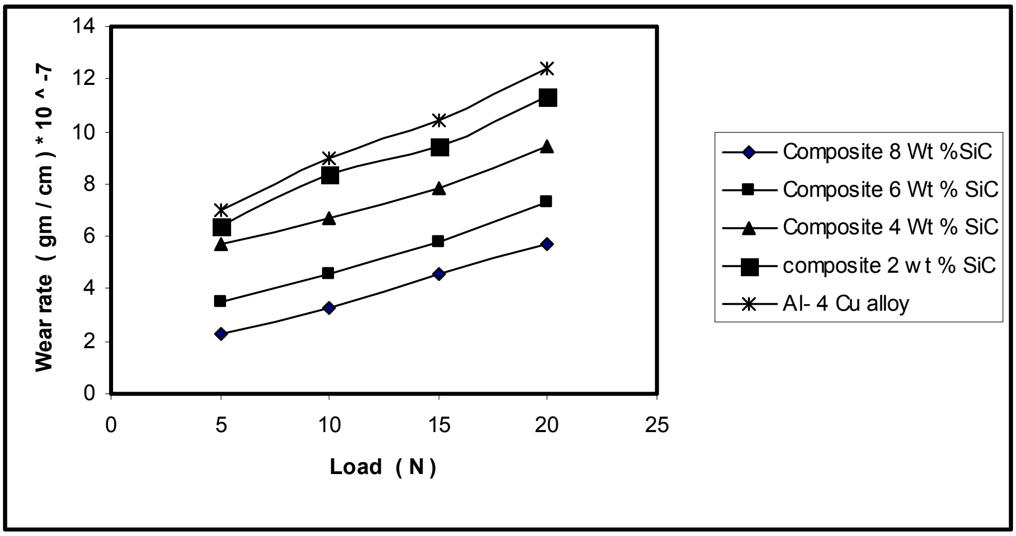
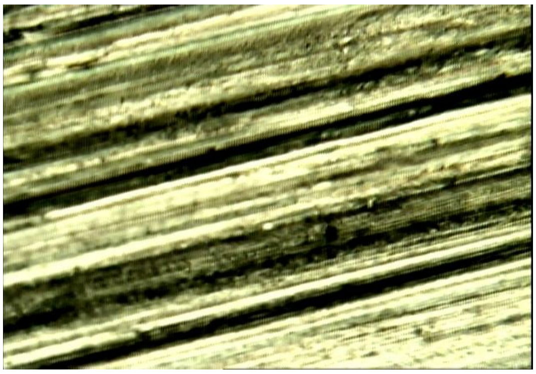
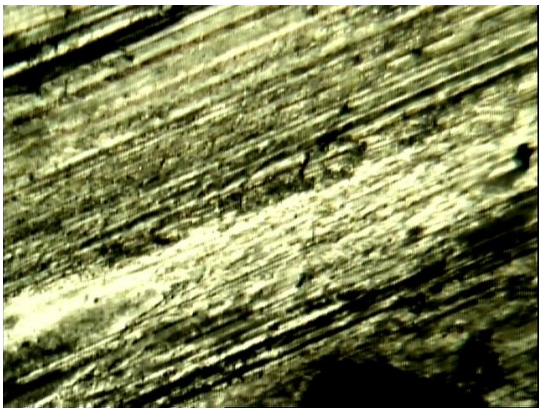


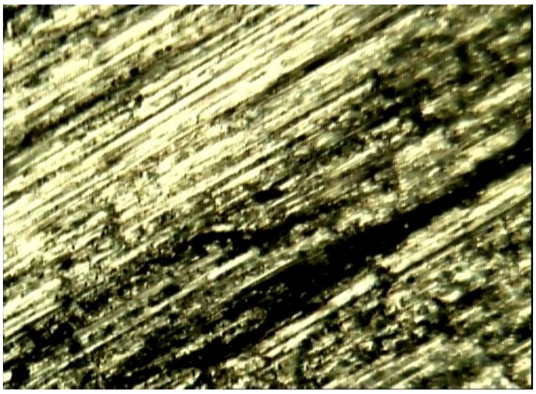
Fig . (3): The effect of normal applied load on the wear rate at constant sliding speed 3.7 m/sec.



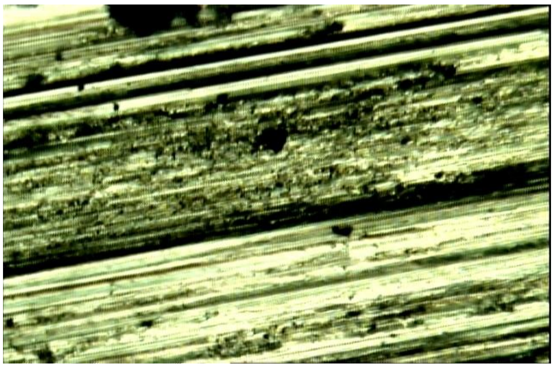
(A)



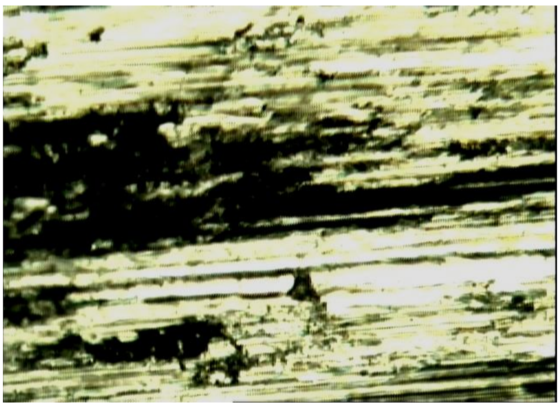
(B)



(C)



(D)



(E)

Fig. (4): Optical micrograph of worn surface at 20 N applied load , sliding speed 3.8 m/sec . 125 x.

A- Composites 8 Wt % SiC.
B- Composites 6 Wt % SiC.
C- Composites 4 Wt % SiC.
D- Composites 2 Wt % SiC.
E- Al- 4Cu Alloy .

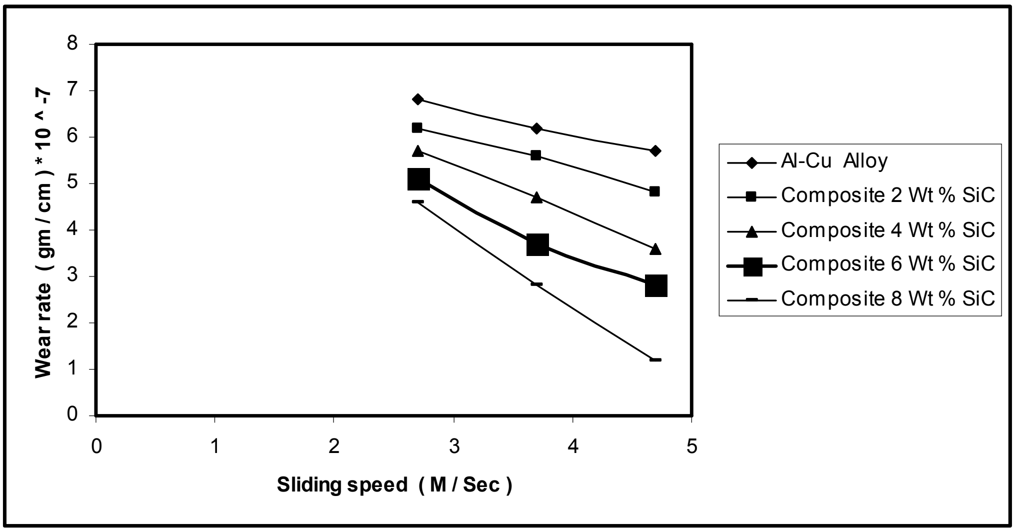


Fig . (5): The effect of sliding speed on the wear rate at normal applied load 15 N .

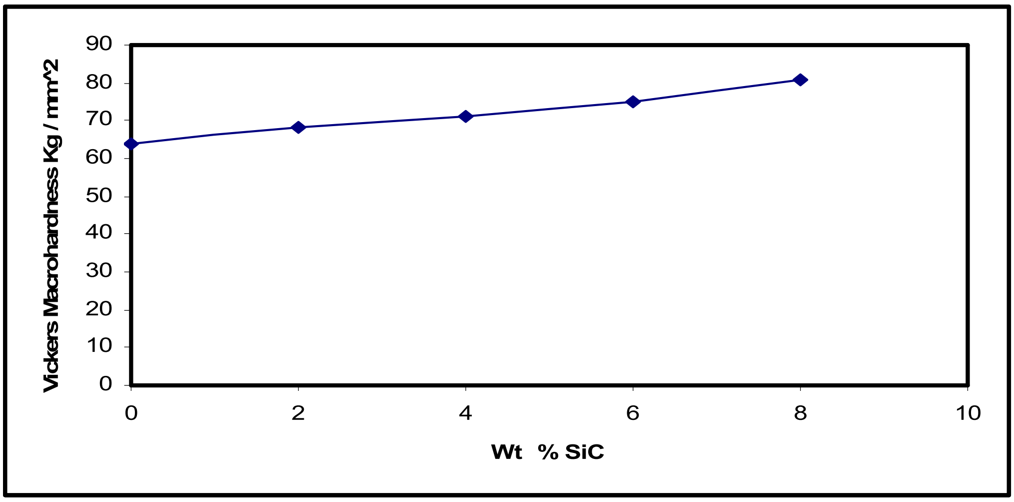


Fig. (6): The effect of Wt % SiC on the Vickers macrohardness.

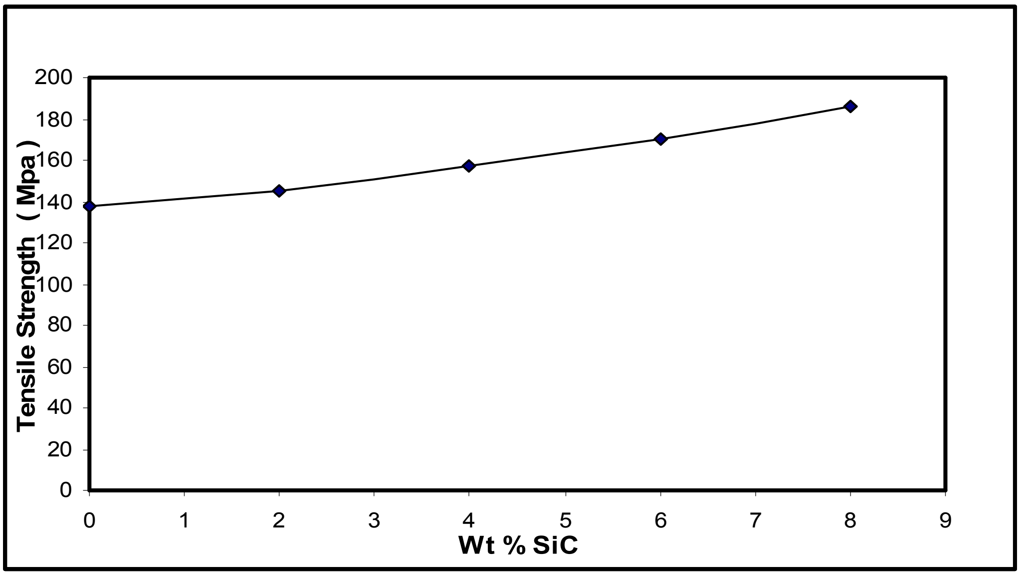


Fig . (7): The effect of Wt % SiC on the tensile strength .

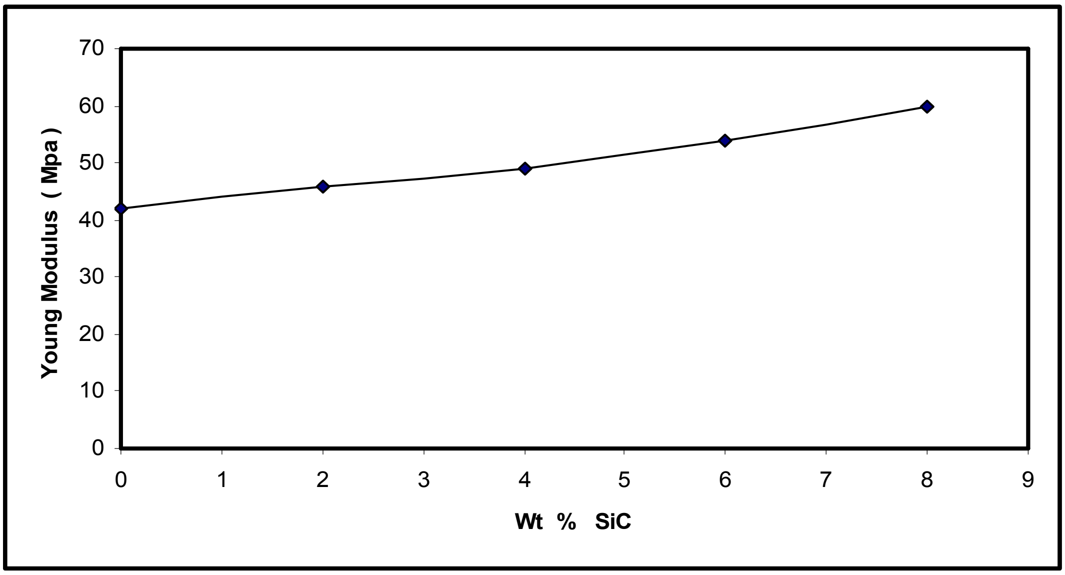


Fig . (8): The effect of Wt % SiC on the young modulus.

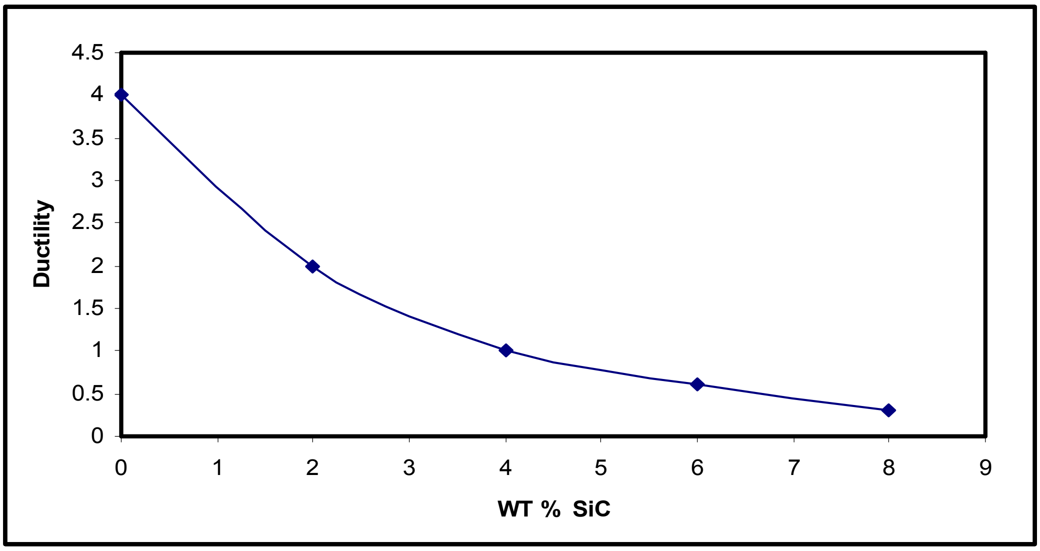


Fig . (9): The effect of Wt % SiC on the ductility.

دراسة تأثير التقوية بواسطة دقائق كربيد السليكون على البلى الانزلاقي الجاف والخواص الميكانيكية لسبيكة ذات اساس من المنيوم –٤% نحاس

اسراء عبد القادر

استاذ مساعد

قسم هندسة الانتاج والمعادن _ الجامعة التكنولوجية

الخلاصة:-

يهدف البحث الى دراسة تأثير اضافة دقائق من كربيد السليكون بنسب مئوية وزنية مختلفة (٢,٤,٦,٨) على سلوك البلى الانزلاقي الجاف والخواص الميكانيكية لسبيكة ذات اساس المنيوم. وهذه المواد المتراكبة تم تصنيعها بطريقة (liquid metallurgy) . ان اختبار البلى الانزلاقي الجاف تم اجراؤه باستخدام تقنية المسمار على القرص حيث تم تسليط احمال ٥,١٠,١٥,٢٠ نيوتن وسرع انزلاقية مختلفةm/sec (2.7,3.7,4.7) . وقد تبين من النتائج ان معدل البلى يتغير خطيا " بشكل عام ،حيث ابدت المادة المتراكبة المقواة بدقائق كربيد السليكون وبنسبة 8 wt% أعلى مقاومة للبلى مقارنة" مع المواد المتراكبة الاخرى والسبيكة الاساس .ان الية البلى تبدو اوكسيدية لكل من السبيكة الاساس والمواد المتراكبة عند تسليط احمال وسرع انزلاقية مختلفة . كما تبين من الفحص بالمجهر الضوئي للسطح المتضرر ان معدل البلى يتناقص بشكل خطي مع ازدياد النسب المئوية الوزنية لكربيد السليكون وقد اعطت المادة المتراكبة المقواة بنسبة 8wt% أعلى مقاومة للبلى . وقد تبين ان الصلادة ، مقاومة الشد القصوى ومقاومة الخضوع تزداد مع ازدياد النسب المئوية الوزنية لكربيد السليكون ، وبينما المطيلية تنخفض .