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Effect of Addition SiC Particles on the Hardness and Dry Sliding Wear of the Copper-Graphite Composite

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ABSTRACT

This research have been devoted to copper-graphite particulate composites which have high thermal/electrical conductivities and excellent dry lubrication for solid contacts and sliding that arise from a synergetic composite effect between copper and graphite. They have been widely used in their engineering application for sliding components, such as electrical brushes and bearing .This research is devoted to study the effect of addition of SiC particles at different weight percentage(1%, 1.5% , 2% and 2.5%), to the copper graphite composite as matrix, which consist of (90 wt% copper – 10 wt% graphite), on the resistance wear under dry sliding condition by using pin-on-disk technique and hardness, the structure produced by powder metallurgy methods (P/M).

The results showed that the composite material reinforced with SiC particles has wear rate lower than that of the base composite where, the wear rate of the base composite is (2.58×10^{-7}), which is become (0.6×10^{-7}) after addition of SiC at (2.5 wt% SiC), and the results of hardness for the base composite are (25, 7.61) in Vickers test and Brinell test which respectively become (60, 44) after addition of (2.5 wt% SiC).

Key words : Copper-graphite composite, SiC, hardness, wear rate

الخلاصة

يهتم هذ البحث بالمتراكب المكون من النحاس والكرافيت والذي يمتلك توصيلية كهربائية وحرارية عالية ويعتبر مزيت جاف للحركة الانزلاقية ، وهذا المركب ذو استخدام واسع في التطبيقات الهندسية مثل الفحمة الكهربائية والمحامل . يهدف البحث الى دراسة تأثير اضافة دقائق كاربيد السيلكون بنسب مختلفة هي (1%، 1.5% ، 2% ، 2.5%) الى مركب من النحاس والكرافيت مخلوط بنسبة (نحاس 90% - كرافيت 10%) ، على مقاومة البلي والصلادة تحت ظروف الانزلاق الجاف بأستعمال تقنية المسمار على القرص ، وقد تم تحضير هذا المركب بأستعمال طريقة ميتالورجيا المساحيق. النتائج اظهرت ان المركب المقوى بحبيبات كاربيد السيلكون يملك معدل بلي اقل من المركب الاساس حيث ان المركب الاساس يملك معدل البلي (2.85 * 10 -7) واصبحت بعد اضافة حبيبات كاربيد السليكون بنسبة وزنية (2.5% من وزن المركب) (0.6 * 10 -7) وكذلك نتائج الصلادة اظهرت للمركب الاساس (25 ، 7.61) بفحص فيكرز وبرينيل على التوالي في حين للمركب المقوى كانت (60 ، 44) .

1- INTRODUCTION

Copper-graphite particulates composite have excellent thermal / electrical conductivity and the lubrication for solid contact and sliding that stem from a synergetic composite effect of cooper and graphite . They have been widely used for sliding components, such as electrical brushes and bearing in their engineering applications. However the wear and contact processes and mechanisms of the composite under sliding condition have not been well understood because of their complicated microstructures and nonlinear mechanical behaviour . To develop high performance electrical brushes and mechanical bearing , it my be essentially important to study the microscopic processes and mechanisms of the contact surface deformation of copper- graphite particulate composites (Cousins, 2003). The mechanical properties of copper based conventional composites involving a single reinforcement have been studies (Rohatgi, 1996). Use of single reinforcement in copper may some times lead to the deterioration in the values of its physical properties . To overcome this , the concept of using different types of reinforcement is being tried out in copper matrix . Hard reinforcement such as SiC will enhance the hardness and abrasive where resistance of copper while it has a negative effect on the match inability and conductivity of copper. To set these effects, graphite being a solid lubricant and possessing good conductivity can be dispersed in copper along with SiC (Noor, 2004). However, major information is available as regards the processing and characterization of these novel hybrid copper composites (Klett, 2000 and Chan-Chao, 2009 and Anco, 2004). Silicon carbide is originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive, which has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractoriness, ceramics, and numerous high-performance applications. The material can also be made as electrical conductor and has applications in resistance heating, flame igniters and electronic components (John, 2000).

The polymorphism of SiC is characterized by a large family of similar crystalline structures called polytypic.

This variations of the same chemical compound, which are identical in two dimensions and differ in the third. Thus, they can be viewed as layers in a certain sequence (Chan-Chao, 2009 and Zhong, 2007).

Alpha silicon carbide (α – SiC) is the most commonly encountered polymoph; it is formed at temperatures greater than 1700 ˚C and has a hexagonal crystal structure (similar to Quartizite). The beta modification (β – SiC), with a zinc blended crystal structure (similar to diamond) as shown in table (1) which list the properties of major SiC polytypic), which formed at temperatures below (1700) ˚C. Until recently, the beta form has had relatively few commercial uses, although there is now an increasing interest in its use as a support for heterogeneous catalysts, owing to its higher surface area compared to the alpha form. Pure SiC is colorless. The brown to black color of industrial product results from iron impurities. The rainbow-like luster of the crystals is caused by a passivation layer of silicon dioxide that forms on the surface (Chan-Chao, 2009). In the light of the above, the present investigation is aimed at producing copper hybrid composite using pure copper as matrix and SiC and graphite powder as reinforcement.

2- EXPERIMENTAL PART

a) Base composite

The fine powders of copper and graphite and as SiC powder (Supplied from Merk Co. made in Germany) were used as starting materials to fabricate the particulate composites, the particles size of copper, graphite and SiC is measured by used the laser particle size in the ministry of since technology " SHIMADZU SALD-2101

(SALD-2101-WEAL:V1.20)" is a universally application unit for determination the particle size distribution of all kind of solids from (0.1-100)µm, see table (2).The mixture powder with polyvinyl alcohol (PVA) as binder at weight (2%) from graphite weight in the composites, are well-mixed, and then uniaxally cold pressed at (50) MPa, the dimension of samples was at diameter one cm and thickens one cm. The green compacts thus obtained are sintered in vacuum (10^{-3}mbar) at temperature of sintering (900) ˚C. The time of treatment at this temperature is (4) hours, and the rate of heating is (4.5) ˚C/min .

b) Copper-graphite-SiC composites

The same method of preparation of copper graphite composite adding, SiC at different percentage weight (1%, 1.5% ,2%, and 2.5%) additive to the base composite, the mixture a chive by use homogenous mixture instrument fined in ministry of since technology, dry mixing time is usually determined by experience. Homogenous mixtures is obtained in tow hours of mixing by mixing machine (type, made in England, fiend in collage of science in Al-Mustansiry university, of circumferential velocity of (60) r.p.m.

c) Mechanical properties and hardness

The wear test is carried out by "pin-on-disk technique" where the load used is (15) Newton and the sliding distance is (10) cm and the time is (10) min .

For each specimen. The disk used from cast iron and its velocity of rotation was (500) rpm, the hardness (Vickers micro and Brinel hardness) measured by used " Digital Micro hardness tester VHS 1000" , made in Japan, and Wilson Rockwell hardness tester model (B 554. T), is used . All test according to ASTM.

3- RESULTS & DISCUSSION

Table (2) shows the particle size of the materials used , its is clear that the particle size of copper powder is too small compared with graphite powder to make good distribution with it .

Tab (3) shows the physical properties of the used matrix material (90% Cu – 10% Gr)

Fig (1) shows the XRD spectium of the matrix doped with 2% of SiC, where all the peaks is belong to (Cu-Gr) Composite to the ASTM Cards ، and that means no oxidation occurred in the samples and the processing of sintering is fig.(2) the effect successful of SiC percentage on the Vicker´s hardness of the composite which is clear effect ;there is a good linearity in this relation (Zhou, 1997). Again a good increment in the Brinell hardness was shown due to the addition of silicon carbide that shown in fig.(3)

Fig.(4) shows the effect of SiC addition on the wear rate of the composite which shows a small increasing until 2% SiC and then remarkable increasing after this percentage (Williams, 2005).

The wear rate is expressed as the volume loss divided by sliding distance. Usually the wear rate increases with the applied load which that increases plastic deformation which leads to an increase in density of dislocations with the increase in this distortion, thus resulting increased hardness of the material gradually (Anco, 2004).

Also comes from the concentration of dislocations consist of small gaps, which combine to be small cracks in the surface of the material.

These cracks expander under the influence of stress imposed, on the surface of the sample and the direction of wears with weak converging with each other and made up so large cracks (Noor, 2004). The lack of wear due to the presence of find the graphite which work as lubricated which decrease the wear on the surface, it is known that the bend between copper and graphite in the composite is not strong and therefore increase wear rate up load or speed slide (Moustafa, 2002), and when you add Carbide silicon, it works to strengthen the links compound, thus increasing the hardness and less wear.

4- CONCLUSIONS

Copper-graphite-SiC composites have been successfully prepared by powder metallurgy (P/M). The composite reinforced with SiC particles posse`s values of hardness and wear rate excellent when compared with base composite where :

1- The wear rate is lower from (2.58 gm/cm) to the (0.6 gm/cm) at (2.5 wt% SiC).
2- The hardness is higher from (25 gm/mm^2) to the (60 gm/mm^2) at (2.5 wt% SiC) in Vickers test .

5- REFERENCES

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Table 1 properties of major SiC polytypic [5]

Polytypic	6H(α)
Crystal structure	Hexagonal
Space group	C^{4}_{6v} - $P6_3mc$
Lattice constants (A˚)	3.0730;15.11
Density (g/cm^3)	3.21
Band gap (e V)	3.05
Bulk modulus (GPa)	220
Thermal conductivity (W/cm.k)	4.9

Table 2 The particle size of the materials powder used in the present work

Materials powder	**particles' size** µm
Graphite	16.249
SiC	7.690
Copper	3.666

Table 3 The results of test sample (Cu90% - Gr10%).

sample	**V.H Vicker`s hardness**	**B.H**	**Wear rate Br**	**E.C $*10^{-3}$ gm/cm**	**T.C w/k.m**
Cu90%-Gr10%	24.8	7.61	2.78	81.20	128.37

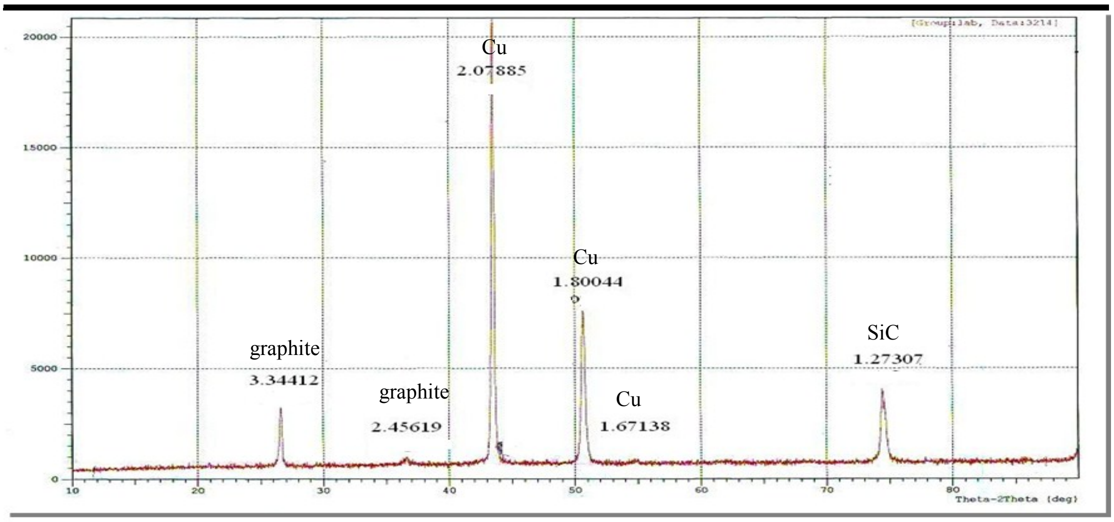

Fig. 1 The XRD patterns for copper- graphite –Silicon carbide Composite.

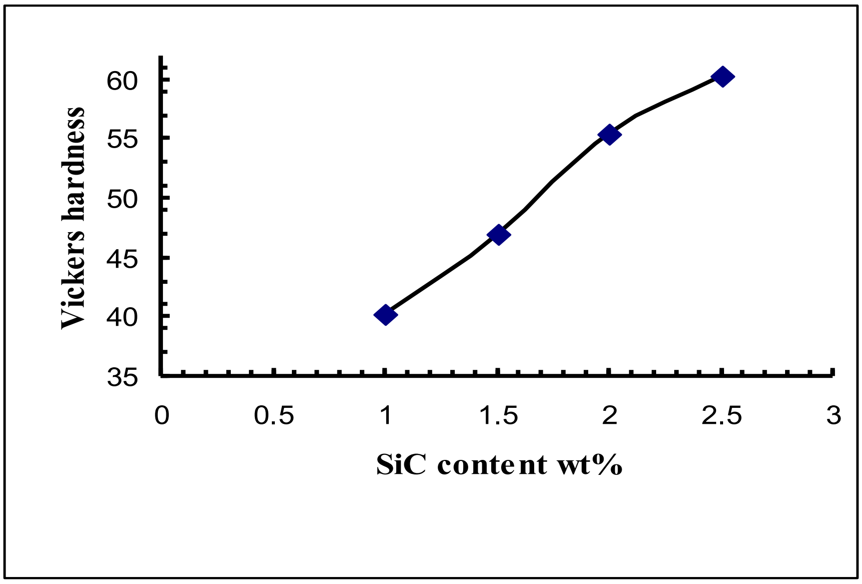

Fig. 2 The relationship between SiC content and Vickers Hardness

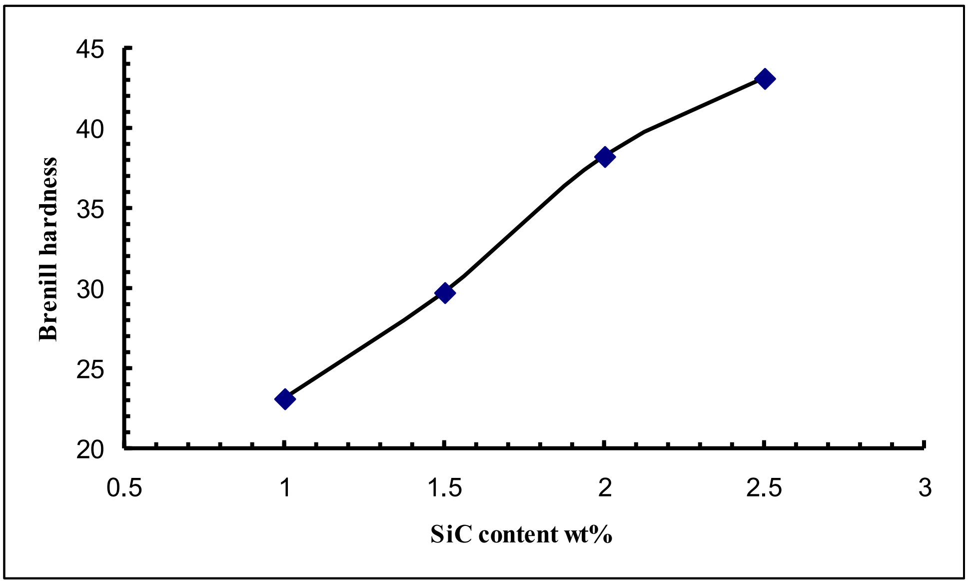

Fig. 3 Effect of SiC content on the hardness (B.H) of Cu-Gr composite.

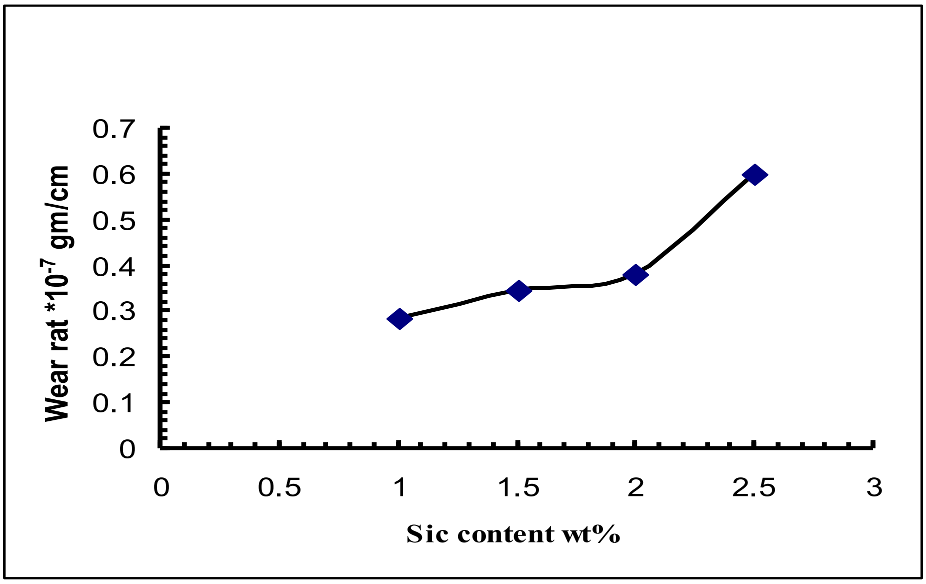

Fig. 4 Effect of SiC content on the wear rate of Cu-Gr composite.