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The Effect of Adding Nickel Element on Mechanical and Wear Properties of SiC_p-Cu Composites

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Abstract

Reinforced composites are prepared from a Copper as a matrix with SiC powder in different percentage (i.e 5-25 vol.%) .For each prepared reinforced composite with respect to SiC addition , they divided into two parts , one undergo to addition of Ni in fixed percentage(2 wt%) and the other part leave without addition.

After drying , mixing and milling process, disc samples were prepared . these samples were heat treated at (900°C) using furnace at argon atmosphere. Density, porosity, Vicker microhardness , compressive strength were performed. Dry sliding wear tests of Cu–SiC_p composites were carried out using pin on disc apparatus with a typical experimental plan of simultaneous variation of loads (5,10)N . The results show that the density was decreased while porosity increased with SiC content , and this was less remarkable with nickel presence. Vicker microhardness, compress strength were improved by the nickel wettability on the reinforcement. Moreover decreasing in wear rate comparing with the absence one. The nickel presence modifies the interface structural model and is effective in passing load between the matrix and the reinforcement, by lessening the extent of interfacial debonding.

Keywords: Wettability, homogenous distribution, load transfer, interfacing.

تأثير أضافة النيكل على الخصائص الميكانيكية والبلى للمتراكب (SiC_p-Cu)

الخلاصة

تم تحضير المتراكب المكون من النحاس كمادة أساس ودقائق من كاربيد السليكون كمادة تدعيم بنسب مزج مختلفة (5-25% وزناً) , حيث حضرت مجموعتين من النسب أعلاه , الاولى تم أضافة عنصر النيكل اليها بنسبة ثابتة (2% وزناً) , والاخرى بقت كما هي. وبعد عملية التجفيف والخلط تم كبس النسب المحضرة على شكل أقراص تم تلبيدها عند درجة (900°C) وفي جو من الاركون . تم فحص الكثافة والمسامية والصلادة ومقاومة الانضغاط للعينات المحضرة, اضافة الى فحص البلى , حيث تم استخدام أحمال مختلفة (5,10N) . من النتائج المستحصلة , تبين ان الكثافة تقل بازدياد النسب الوزنية لكاربيد السليكون تقابلها زيادة في نسبة المسامية . لكن هذا العامل كان أقل تأثيراً في العينات التي تحتويعلى عنصر النيكل . اضافة الى ذلك ان تلك الاضافة فد حسنت من الخصائص الميكانيكية للمتراكب من صلادة ومقاومة انضغاط . علاوة على ذلك صغر معدل البلى مقارنة مع العينات التي يختفي فيها عنصر النبكل , حيث ان وجوده يؤدي الى توزيع الحمل الموضوع بين مادة الاساس ومادة التدعيم وبالتالي تفادي الانفصال الحادث في السطح البيني.

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1. Introduction

A metal matrix composites are strongly influenced by the reinforcement–matrix interface. Proper bonding at the interface can attain good load transfer between phases. In some composites, the intrinsic lack of wetting between the matrix and the reinforcement causes difficulties in production and even debonding of interface during the service life. In this case, adhesion promoters are needed to modify the interface structural model. Studies of the Cu–SiC system indicate poor wettability between them [1]. A value of (ϴ = 140°) was reported for the wetting of SiC by liquid Cu at (1100 °C) [2]. Cu–SiC system is considered to be weak for the practical application of composites. Interfacial reactions were reported in many cases when the temperature was lower than 900°C [3,4] .

The wettability of a solid by a liquid is characterized in terms of the angle of contact that the liquid makes on the solid [7,8].The contact angle, , which indicate to the degree of wetting when a solid and liquid interact, is obtained from a balance of interfacial tensions , and is defined from Young's equation, according to which [5]:

$$\gamma_{sv} = \gamma_{lv}.\cos q + \gamma_{ls} \quad .....(1)$$

The lower the contact angle the greater the wetting .Contact angle below 90° indicates that the liquid wets the solid spontaneously.

Contact angle θ can be decreased by increasing the surface energy of the solid γ_{Sl}, or by decreasing the surface tension of the liquid γ_{LV} [6].

One of effective ways of improving wetting is to alloy the lower melting point material with small additions of elements active at the AB interface[7].

The additions of elements tend to reduce γ_{AB}, generally tend to segregate at the interface so that the additions need not normally be large. The most effective additions will be elements which react with the substrate added in quantities sufficient to form an atomic monolayer of reaction product. A minimum harm is caused by the reaction product. Generally, the addition should it self has a similar or higher surface energy than the parent metal otherwise it will also segregate to the free surface and lower γ_{AB} [8].

Zhan et al [9], used Copper matrix composites reinforced with (10 vol.%) SiC particles with or without nickel coating were fabricated by powder metallurgy plus hot extrusion method. Their results are shown in Fig (3) illustrate TEM micrographs for a uniform nickel surface can be formed on the SiC particles with electroless plating process. Compact composites with coated or uncoated SiC particles dispersed uniformly in Cu matrix can be fabricated successfully by the powder metallurgy plus extrusion method. This layer may be found on Cu/SiC composite indicates that it contains such elements as Cu,C ,O.

. In this investigation, the effects of nickel presence on the mechanical and wear properties of silicon carbide particle-reinforced copper matrix composites were studied.

2. Experimental work

The starting material for the matrix was pure electrolytic copper powder having an average particle size of (<53 µm), SiC particles with a diameter of (25 µm) were irregular and angular in shape was added in(10 vt%) percentage , And with or without pure nickel with a diameter of (25 µm, 2 wt%), the composites were mixed in rotoring mill for one hour to get homogenous distribution . After that the blended powders were compressed in cylindrical steel die(11 mm diameter , 90mm height) using uniaxial hydraulic press to 350 MPa , making (4g) for each sample. The samples were sintered at (900 ºC) in electric furnace in argon atmosphere for two hours. The apparent density of copper composites was determined according to Archimedes̓ method. In this technique, density is determined by measuring the difference between the specimen̓s weight in air and when it was suspended in distilled water at room temperature. , using the equation [10]:

$$\rho_A = \frac{W_D}{W_S - W_I} \times \rho_w \qquad ..... \ (2)$$

W_D: the weight of samples after dried in oven. (gm)

W_S: the weight of samples immersion in water.(gm)

W_I: the weight of samples rise from water and wiped by clothes. (gm)

ρ_w : the density of tested water at this temperature. (gm)

Where the variation of density with SiC content is shown in fig.(4) .

The porosity can be determined by the equation [10] :

$$A.P\% = \frac{W_S - W_D}{W_S - W_I} \times 100 \qquad .... \ (3)$$

where (A.P%) is the pore volume percentage . Porosity results can be shown in Fig.(5)

the Vicker microhardness was measured by (HVS- 1000) instrument . It can be seen that the hardness obviously increased gradually with SiC content , and it is higher for nickel one, as shown in Fig.(6).

compressive strength test was measured using (ASTM standard-C773) as standard to test the for cylindrical specimens that calculated from the equation [11] :

compressive strength =F/A (MPa) ......(4)

where F:total load on the specimen at failure (N).

A: Cross section area of the specimen (mm^2)

The simple theory describing the stress distribution under a uniform compressive load on a disc-shaped specimen predicts a uniform tension field.

The stress field in the transverse direction is highly dependent on the width of load application and becomes highly compressive[11]. Hydraulic-piston type Leybold Harris No.36110 was used to measure the compressive strength of specimens at room temperature. The specimens are fixed between the surfaces of the piston, and the load is applied. Fig.(7) illustrates the compressive strength results, that it increased directly with sic content , and this result be higher with adding nickel metal.

Dry sliding wear tests were carried out using a pin-on-disc tester. The pins were slid against a hardened steel disc with a hardness of HRC60, within a load range of (5,10N) and at a constant sliding velocity of (2m/s). with diameter (70) mm . Both contact sample surfaces were polished, cleaned in acetone in an ultrasonic cleaner and dried. The sliding distance for each test was normally (1.5×10^3) m for all normal loads. The wear losses of the specimens were measured by weighting samples before and after wearing test..

Wear rate was measured using the equation [12] :

Wear rate(weigh loss) = (ΔW / S) $g.cm^{-1}$ …… (5)

ΔW: weight difference of sample before and after each test in mg ($\Delta W=W_1-W_2$).

S: total sliding distance in cm, which was calculated as follows:

$S= \nu \times t \times 100$ ……. (6)

ν **:**disk rotational speed (m/sec)

t: time of running in sec.

Wear rate measurements for two loads were shown in Fig (8) and (9).

The main wear mechanism, however, is the microcutting effect of the counterface asperity on the worn surface, and adhesion of the composite to steel induced by the

ductile deformation in the subsurface region. The interfacial modifying is effective to improve the wear resistance of copper matrix composites by preventing microcrack

3. Conclusions

1- The density of specimens that contain nickel is more dense than the absence one, and it will decrease gradually with SiC content because SiCp density is more less than copper one .

2-The porosity is directly proportional with SiC content , moreover this is less effectiveness in Cu-Ni-SiC composites. As the nickel presence reduces the

micropores near the interface .

3-The addition of SiCp is beneficial to the hardness of the material and the hardness of the composite increases monotonically as the SiC_p content increases, in spite of increasing porosity. Moreove Ni-SiC particles reinforced copper matrix composite exhibits higher hardness than the SiC reinforced one . It can be deduced that the bonding strength between copper matrix and SiC particle was increased by interfacial modifying.

4- An increase in wear rate with increasing normal load is observed for both types.. However, the Cu-Ni-SiC-reinforced composites exhibit lower wear rate than the Cu-SiC one at all load levels.

5- SiC particles act as load-bearing components and lessen the strain and strain gradient in the subsurface region, which mitigates the wear loss of the composite effectively.

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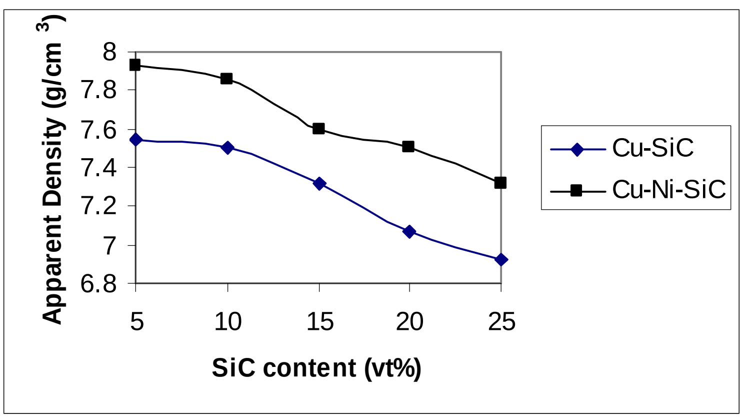

Figure (1) Variation of density with Sic content

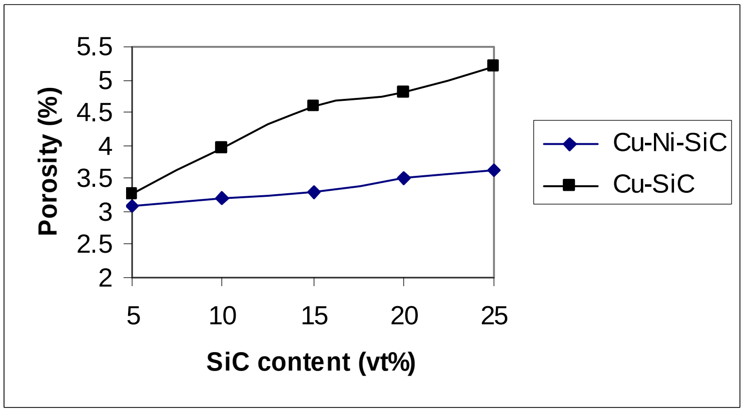

Figure (2) Variation of Porosity with Sic content

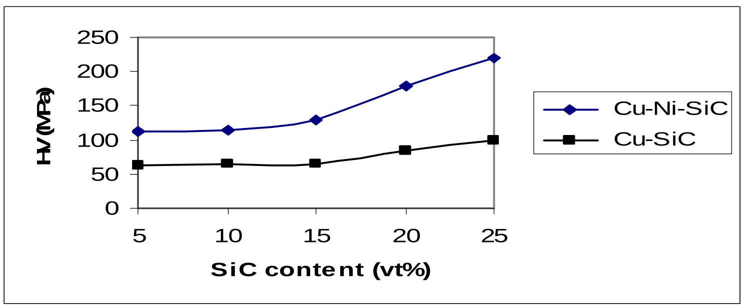

Figure (3) Variation of Vickers micro hardness with Sic content

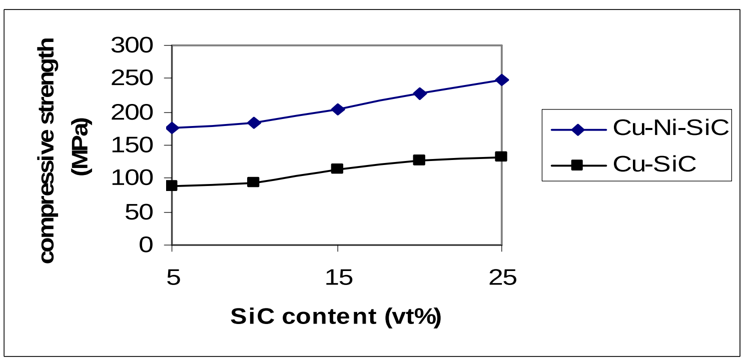

Figure (4) Variation of Compressive Strength with Sic content.

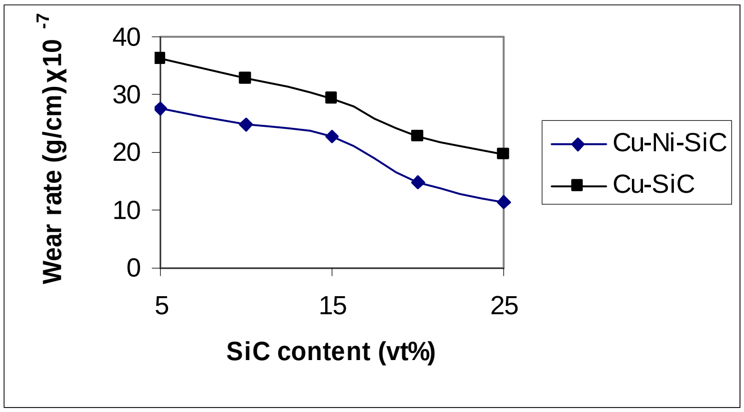

Figure (5) Variation of wear rate with Sic content for (5N) loaded

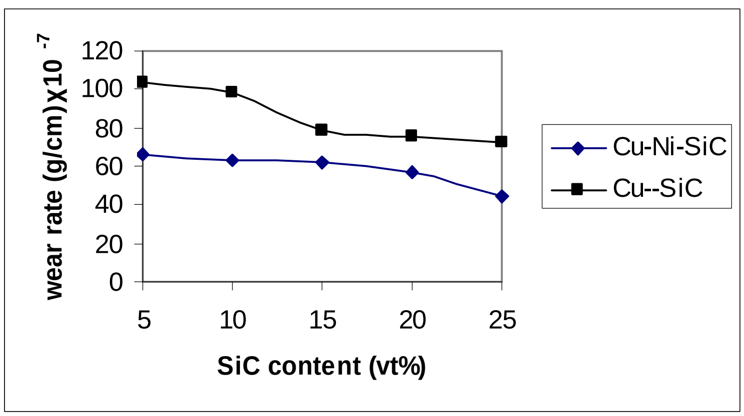

Figure (6) Variation of wear rate with Sic content for (10N)loaded