

Studying Some of Mechanical and Thermal Properties of Al-SiC composites

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Abstract

In this research two groups of composites have been made : the first group has been sintered. For (1 hour) the second group has been sintered for (2 hours) and they were heat treated at 550°C. Mechanical properties such as wear rate ,impact strength from and thermal conductivity for different compositions of SiC% and they were tested .from the results one can see that increasing the SiC% composition increased the thermal conductivity to 150 W/mK for samples sintered (2hours) and 150 W/mK for (1hour)sintering while impact strength have the value of 9.8 J and 9.5 J for samples sintered for 1 and 2 hours respectively, decreasing in wear rate value with the increase of SiC composition to $1 \times \exp(-8)$ rather than $0.5 \times \exp(-8)$ gm/cm for 1 and 2 hours of sintering respectively .

Introduction

The recent evolution in different engineering applications scopes and advanced technological demands, require using engineering materials of special characteristics which suit different applications and solve many problems which face traditional materials like metals, ceramic and polymer materials. These materials are characterized by the ability to combine many different characteristics through composing between two materials or more which have different characteristics, those are called composite materials [1,2]. These materials are characterized by high resistance to temperatures under different ambient conditions, in addition to good mechanical properties like having high strength, toughness and stiffness, besides light weight with low density and resistance to corrosion which suit usage fields in advanced applications like spaceships, satellites, electronics, aircrafts, cars and many military applications [3,4]. The composite materials result from binding between two phases, the first is the Matrix Phase, and the second is the Reinforcement Phase. The distinguishing characteristics for composite materials result from the final result of binding the two phases and organizing the distribution of reinforcement phase inside the matrix phase. Usually, it is possible to divide the composite materials according to the type of matrix used to Metal Matrix Composites [5,6]. Al-Rubaie [7] in 1999, studied the abrasive wear of Al-SiC composites. The metal matrix composites were fabricated by a

powder metallurgy method. Air atomized aluminum powder Al was used as matrix and SiC as reinforcement with mean size of 10, 27 and 43 μ m; in the proportions of 5, 10 and 20 vol%, using a pin-on-disc apparatus and a wet monolayer tester. Relationships between size and volume fraction of the SiC reinforcement and wear resistance are discussed. It was shown that SiC particles reinforcement increases the abrasion resistance.

Taminger [8] in 1999, studied the creep behavior of unreinforced Al and Al reinforced with 15wt % SiC whiskers at temperatures from 120°C to 260°C. Tensile test were conducted to determine the basic mechanical properties. The results demonstrate the applicability of traditional creep analysis to non-traditional materials. Al-Sultani [9] in 2001, studied the production of composite materials based on Al-Mg reinforced with different volume fractions of SiC (5,10, 15, 20, 25 wt %). The composite materials were produced with high recovery of SiC and good wetability. Fine scale microstructures are obtained due to high cooling rates associated with high hardness depending on the process variables. In 2004 S. S. Tawfeeq studied A series of an abrasive composite of aluminum and silicon carbide were developed where The lower Al-compositions were heat treated differently at 750°C for 3hrs, while the higher Al-concentrations were processed at 550°C for 2 hrs, The wear and grinding behavior of the series were also investigated, where higher Al-content reduces the grind efficiency and enhances the wear rate.

Table (1)
Materials Employed in the Research.

<i>Material</i>	<i>Purity</i>	<i>Particle Size</i>	<i>Source</i>	<i>Density gm/cm³</i>	<i>Melting point</i>
Al	99.98%	10µm	Vienna, Austria	2.70	660°C
SiC	99%	37µm	Gt. Britain	3.17	2700°C

Mixing

To get a homogeneous and fine mixture of Al & SiC, a composition of percentage weight is made in mixing process which has been done by using a ball mill. The amount of powder required for all specimens has been poured in ball mill for (3 hrs). The percentages weights are: 5%SiC:95%Al, 10%SiC:90%Al, 15%SiC:85%Al,20%SiC:80%Al, 25%SiC:75%Al.

Sintering Process

An electrical furnace (type: Carbolite) was employed in this process using Argon gas to prevent pollution and oxidation of samples. The temperature was 550°C for different sintering durations (1 and 2) hours, this difference in sintering durations was to make the specimen more firm.

Specimens Photomicrography

After finishing specimens preparation, A photomicrography was carried out by using optical microscope which had a camera connected to computer. The examination was carried in the Department of material engineering at the University of Technology.

Measurements

Impact test:

Impact test is done using apparatus of type (Avery –Denison)made in England for (10) specimens of dimensions (1×1×8) mm (length* width*height) , The magnitude of the impact bearing is measured According to Charpy method [6].

Wear test:

Wear test is done using sliding wear apparatus .The velocity of the disk is about (500 r.p.m) which is the sample rotation velocity In this test the samples is cleaned and

smoothened to get a surface free from scratches before testing.

Thermal conductivity:

The thermal conductivity measurements are carried out by using Lee’s Disk method [10]. Assuming, that the heat flow in the specimen is the mean of the quantities of heat flowing into it and out of it, therefore:

$$K \frac{T_U - T_M}{d_s} = h \left[T_M + \frac{2}{r} (d_M + \frac{1}{4} d_s) T_M + \frac{1}{2r} d_s T_U \right] \dots\dots\dots(1)$$

where, T_U : temperature of disk (U), T_M : temperature of disk (M), r : radius of the disk, d_M : thickness of the disk M, d_s : thickness of the disk (S) (specimen)

K: Thermal Conductivity measured in W/mK. Lee’s disk system is isolated from external effects by using glass desiccator’s. When the system is linked to an electric power supply; then the power in watt is:

$$H_t = I V \dots\dots\dots(2)$$

where V : is The Voltage (6 V) and (I) is the current equal to 0.25 A. The dimensions of device is $r = 20.7$ mm and $d_M = d_U = d_c = 13$ mm.

Impact strength:

Impact strength has been tested using apparatus of type (Avery-Denison), the magnitude of impact bearing has been tested using charpy method directly from the apparatus for specimens of dimensions (1×1×8) mm.

Optical Microscopy

The optical microscope was provided with digital camera and computer system. This system is used to study the surface of some specimens as shown in Fig.(4). The specimen

must be grinded and polished. Then putting the specimen in the photographing area after choosing the appropriate magnifying of the lens which is about (x 250).

Results and Discussion

Wear rate test:

The Wear rate can be defined as the volume of lost material per length according to the external load exposed during friction. The manner of the curve is found to be linear for all the specimens and proportional where the wear rate increase with decreasing the SiC concentrations and this is an advantage from the industrial application, in Fig.(1) It was found that at lower sintering time less wear rate was measured related to the lower value of porosity and this is also due to the shrinkage of linking material as a result to the increase in sintering time, the wear represents the quantity of lost material which has a direct relationship with the properties of the linking materials which represents the toughness of the samples.

Impact test:

After checking curves of impact strength we notice that porosity is inversely proportional with the impact strength. Fig.(2) shows that the sintering time clearly raise the toughness of the ceramic body which increases the impact strength ,this is because the shrinkage and accumulation of linking liquid

towards the center of the sample. The SiC concentration affects on the impact strength as shown in Fig.(2), the increment in SiC is accomplished by an increment in impact strength. The best value of impact strength was found to be at 25% SiC concentration which is related to the high value of porosity.

Thermal conductivity:

Porosity has an important effect on the value of thermal conductivity. The difference between the open and closed pores should be noticed where the open pores lead to hot gas transportation from the hot side to the cold side through the bearing current which increases the thermal conductivity, while the closed pores prevent the hot gas transportation, it means no moving currents; consequently porosity effect is neglected on the thermal conductivity of ceramic (porous) material. Fig.(3) show the relationship between the thermal conductivity as a function of SiC composition, an increase in thermal conductivity is noticed with the increase in sic composition and this is due to the low porosity of highly composition of SiC. The increment in sintering times means increasing the melting material and consequently decreasing the porosity which leads to closing the existing open pores.

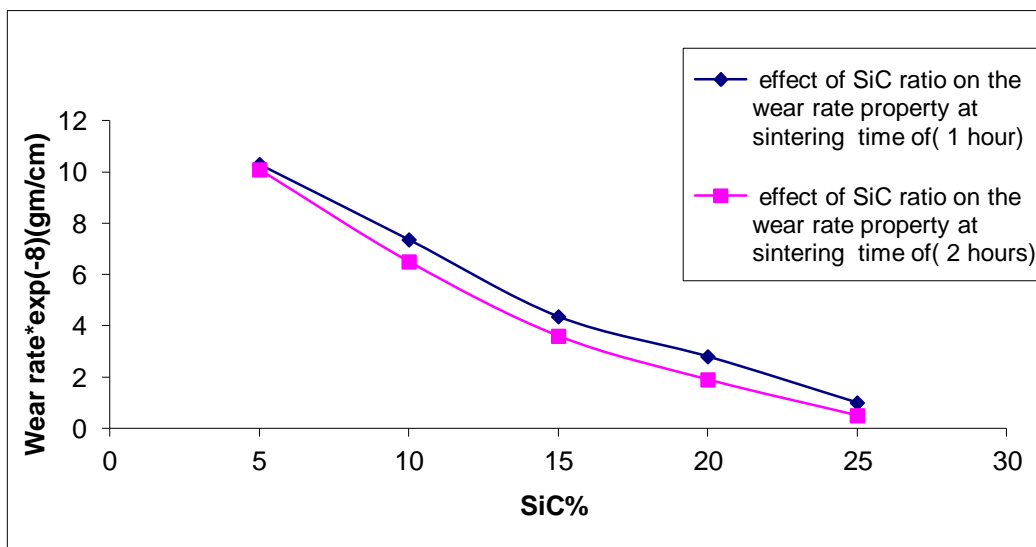


Fig.(1) Shows the effect of SiC composition on wear rate.

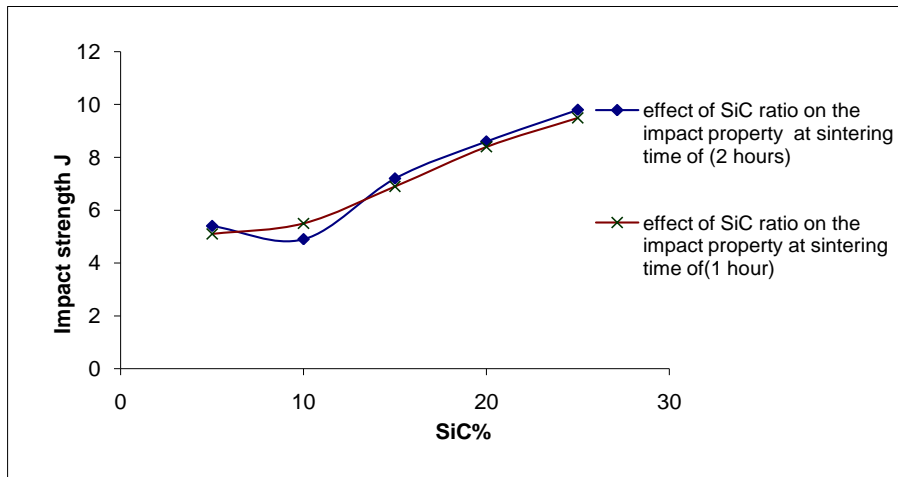


Fig.(2) Shows the effect of SiC composition on impact strength.

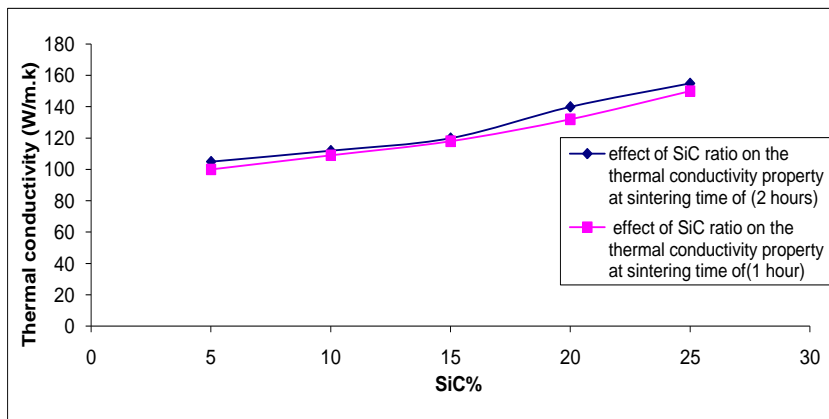


Fig.(3) Shows the effect of SiC composition on the thermal conductivity.

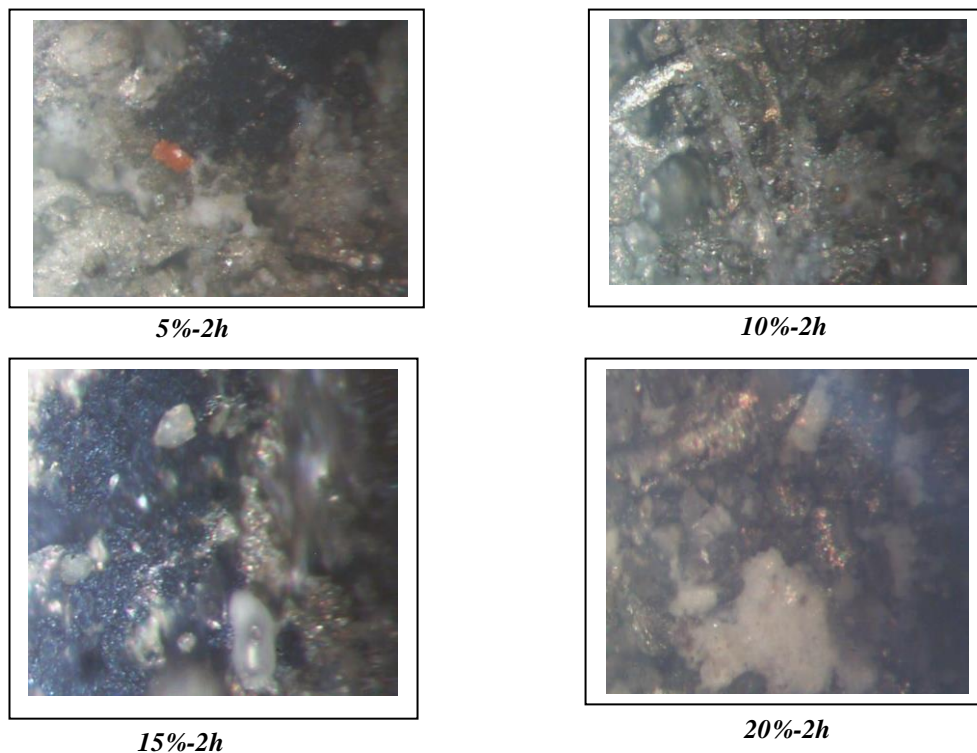


Fig.(4) Optical Microscopy.

Conclusions

From this research it has been found, Wetting between Al and SiC is present in all cases investigated. The open pores are the main source to the alternative results, the relation ship between the sic composition ratio which was proportional with the thermal conductivity as well as the impact strength. Due to the mechanical properties as this research used to deal with the wear rate, it is observed that the increase in addition of sic particle ratio lead to decrease in wear rate which has been clearly noticed at 25% sic. While the impact test showed a proportional relationship with increment of sic particle ratio.

References

- [1] Charles, D.; J of Met. And Mat., 6 (1990), PP.78.
- [2] Tawfeeq, S.S.; "Development and Characterization of Al-SiC Composites", PhD. thesis university of technology, 2004.
- [3] Alberto, B.; Gaspar G.D; J of Mat.Sci. and Eng., A245 (1998), PP.10.
- [4] Liu, Y.L.; Hansen, N. J. D.; J of Metal. Trans. 20A (1989), PP. 1743.
- [5] Little, J. A.; Mcracken, D.; Simms, N. ;J of Mat. Sci. Lett., 7(1988); PP.1037.
- [6] Burnay; "New Materials and their Applications", Proceedings of The Institute of Physics Conference held at the University of Warwick, 22-25 September 1987.
- [7] Al-Rubaie K.S.J; "Abrasive wear of Al-SiC Composite", Wiley Interscience Journal Abstract, Vol. 31, Issue 4, (2000) PP. 300-311. [Internet].
- [8] Taminger .K.M.B.; "Analysis of Creep Behavior and Parametric Models of 2124 Al and 2124 Al+SiC_w Composite", M.Sc. Thesis, Materials Science and Engineering, Faculty of the Virginia polytechnic Institute and State University, (1999).
- [9] Sultani,I ;"studying the properties of al-sic composite material (%) by using stircasting method" technology university metal and engineering department,2001.
- [10] Majeed. S.M.; "The effect of particle size of reinforcement material on the properties of metal matrix composites", Msc thesis; material dept., technology university"2008.
- [11] Tawfeeq. S. S.; "Development and Characterization of Al-SiC Composites", PhD. thesis, technology university, 2004.

الخلاصة

لقد تم في هذا البحث تحضير مجموعتين من المتراكبات: المجموعة الأولى وقد تم تليدها لمدة ساعة واحدة في حين تم تلييد المجموعة الثانية في زمن تلييد مدته ساعتان وتمت معاملة العينات حراريا في درجة حرارة ٥٥٠ °م . ولقد تمت دراسة عدد من الخواص الميكانيكية مثل المعدل الزمني للبلبي ،قوة الصدم وبعض الخواص الحرارية للعينات . استنتج الباحث بانه وبزيادة نسبة كاربيد السيليكون في العينات فقد ازدادت التوصيلية الحرارية الى ١٥٠ (واط/م.كلفن) بالنسبة للعينات التي تم تلييدها لمدة ساعة واحدة و ١٥٥ (واط/م.كلفن) بالنسب للعينات التي تم تلييدها لمدة ساعتان في حين قلت كل من قوة الصدم الى ٩,٨ جول للعينات التي تم تلييدها في زمن ساعة عنها في زمن ساعتين الى مقدار ٩,٥ جول في حين كان المعدل الزمني للبلبي لزمن تلييد ساعة واحدة عند نسبة 25%SiC هو $1 * \exp(-8) \text{ gm/cm}$ ولساعتان من التلييد $0.5 * \exp(-8) \text{ gm/cm}$.