Influence of Ceramic Particles Reinforcement on some Mechanical Properties of AA 6061 Aluminium Alloy

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ABSTRACT

This paper is to investigate the influence of adding 5,10 and 15 weight percentage silicon carbide particles on some mechanical properties of 6061 Aluminium alloy. The composites Al6061/SiC were prepared by stir casting technique.

The results revealed that as the reinforcement content was increased, there were significant increases in the ultimate tensile strength, yield strength and hardness of composites accompanied by a reduction in its percentage of elongation. Microstructural studies have been carried out to understand the nature of structure.

Keywords: AA6061 /Sic, MMC, Al 6061, Silicon Carbide Particles, Mechanical Properties.

تاثير التقوية بالدقائق السيراميكية على بعض الخواص الميكانيكية لسبيكة الالمنيوم (AA 6061)

الخلاصة

تناول البحث التقصي عن تاثير اضافة دقائق كاربيد (5,10,15%) على بعض الخواص الميكانيكية لسبيكة الالمنيوم (6061) . وتم تحضير المواد المركبة المؤلفة من سبيكة الالمنيوم (AA 6061) كمادة اساس وكاربيد السليكون كمادة تقوية بتقنية السباكة بالمزج.

وأظهرت النتائج تحسناً واضحاً في الخواص الميكانيكية للمواد المركبة، إذ ارتفعت مقاومة الشد القصوى ومقاومة الخضوع والصلادة رافقها انخفاض بالاستطالة النسبية. ولفهم طبيعة البنية الدقيق فُحصت عينات البحث مجهرياً.

INTRODUCTION

Considerably scientific research has been carried out in recent years to develop stronger, stiffer and wear resistant engineering materials than the available commercial materials presently. Metal matrix composites (MMC) are regarded as excellent materials to obtain superior properties to those of the constituent phases and also to satisfy the above requirements. However, the use of some MMC is limited by the high cost of their processing [1]. The impressive widespread of the use of composite materials at present could be explained, among other arguments, by the possibility to predict the composite's properties, on the basis of the volumic content and the corresponding properties of the matrix and the

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reinforcement [2]. In fact, the user can get new material that is tailored by his demands.

The reinforcement of metallic alloys with ceramic particles has generated a new family of material called discontinuously reinforced metal matrix composites (DRC_s). Among the DRC_s the most common particulate composite is aluminium reinforced with silicon carbide. Aluminium is light weight and moreover it is less expensive in comparison with other light metals such as titanium and magnesium. Therefore, there has been an increased interest to use DRC_s based on aluminium matrix for applications that demands high strength to weight ratio. The technically viable methods available for the production of aluminium matrix based DRC_s include solid and liquid state processing techniques. Owing to economic constrains, the bulk production of aluminium matrix based DRC_s are usually restricted to liquid state processing. Out of the various liquid state processing methods, stir casting technique is promising route for the mass production of aluminium matrix based DRC_s with reproducible properties [3,4]. The composite consisting of Al 6061 matrix alloy reinforced with SiC, Al2O3, TiO2, MgO and Zr_2O has found wide application. Therefore, the mechanical properties of materials of this kind have received much attention.

There is much reinforcement characteristic that influence the mechanical properties of the composites, such as the volume fraction and the shape, size and µµincreased modulus and wear endurance, but reduced tensile strength and high cycle fatigue resistance by comparison with small particles reinforced composites. As for low cycle fatigue life, that of large particles reinforced composites raises at higher strain amplitude, but decreased at lower strain amplitudes. However, investigations of the effect of particle size on low cycle fatigue behavior of composite are still limited [5]. Pervious studies have shown that mechanical properties of aluminium and aluminium alloys matrix composites would be enhanced with particles reinforcement [6,7,8,9,10].

The present research is an attempt to test and analyze the mechanical properties of Al 6061 alloy reinforced with (5,10,15 Wt %) of SiC particles.

EXPERMENTAL PROCEDURE

Aluminium alloy 6061 was used as the base matrix and SiC particles of average size 15µm as reinforcement [supplied from BDH Chemicals Limited. Poole England and checking in particle size by sieve analysis]. Table (1) gives the chemical composition of Al 6061. Some property of silicon carbide is listed in table (2). The stir casting (vortex technique) was adopted to fabricate the specimens.

The master alloy 6061 was melted at 700°C which slightly more than 30°C above liquids temperature in an electric furnace and then the reinforcement particles were added according to the required quantity. After that, the molten was stirred by 250 rpm speed for three minutes by using vortex technique to ensure optimal distribution of SiC particles. A small amount of Mg was added to ensure good wettability of particles with molten metal[10]. Then melt was poured into a preheated melt molds. Composites ingots were T_6 heated treated in furnace to accuracy of ±1°C for two hours at 530°C, followed by ice quenching and then aged at 200°C for six hours.

Aluminium alloy 6061 composites containing various SiC contents, namely 5, 10 and 15% by weight were fabricate and tested, and their properties were compared with those of unreinforced matrix. All tested were conducted in accordance with ASTM standards. Tensile tests were performed at room temperature using machine in accordance with ASTM E8-95 standards [11] and ductility (in terms of percentage elongation) was measured. The tensile specimens of diameter 12.5 mm and gauge length 62.5mm were machined from the composite with gauge length of specimen parallel to longitudinal axis of the casting. The hardness tests were conducted in accordance with ASTM E10 standards [12]. A Brinell hardness tester was used which has ball indenter diameter of 2.5mm, minor load 10 Kg and major load of 62.5 Kg. The load was applied for 15 seconds. The Brinell hardness number is calculated as: $BHN = 2P / (\pi D (D - (D^2 - d^2)^{1/2}))$ where BHN = Brinell hardness number, P = load on the indenting tool (kg), D = diameter of steel ball (mm) & d = measure diameter at the rim of the impression (mm). Samples for the microscopic examination were prepared by standard metallographic procedures etched with killer's agent and examined under optical microscope.

RESULTS AND DISCUSSIONS

Microstructure

The optical micrographs of unreinforced alloy and of the composites with 5,10 and 15 weight percentage of reinforcement are shown in Figure (1). It was observed that the silicon carbide particles are uniformly distributed in the matrix. The reinforcements appear darker than AA 6061 Aluminium alloy matrix. Further the microphotographs reveal well bonded between the matrix alloy and the reinforcement particles.

Hardness

The Figure (2) explains the effect of particulate reinforcement on Brinell hardness number (BHN). The hardness of Al 6061/SiC_P increased about 107 percentage as the reinforcement content of silicon carbide 15 weight percentage. This increase in hardness is to be expected since SiC particles being a very hard dispersoid contribute positively to the hardness of the composite. As is well known, hardness is resistance to indentation, wherein there will be localized plastic deformation under standardized conditions. This increased hardness is attributable to the hard SiC particles acting as barriers to the movement of dislocations within the matrix Al 6061[3,5].

Ultimate Tensile Strength

The Figure (3) reveals that the ultimate tensile strength of composite increases about 93 percentages by addition the reinforcement. Similarly Figure (4) shows the increase in yield strength of Al 6061/SiC about 58 percentage as the reinforcement carbide silicon content increases from 0 to 15 weight percentage. In both cases the addition of SiC to Al 6061 matrix is increasing the tensile properties of composite material. Dispersion of hard ceramic particles in soft ductile matrix results in improvement in strength. This may be attributed to large residual stress developed during solidification and due to mismatch of thermal expansion between ceramic particles and soft aluminium matrix [4, 6]. This resulting in misfit strain due to the differential thermal contraction at the interface between the matrix and the reinforcements. The misfit strain and resultant misfit stress, generates dislocations. This increased dislocation density, generated to accommodate the misfit strain provides a significant contribution to strengthening of metal matrix. The increase in UTS may be due to the SiC particle acting as barriers to dislocation in the microstructure. This dislocation increases the dislocation density, which provides a positive contribution to strength of Al 6061/SiC composite. There is decrease in the interparticle distance between the reinforcement particles, which causes increased resistance to dislocation motion as the particulate content is increased. During the deformation either the matrix material has to push the hard particulate further or it has to bypass the particles for deformation, during the process the dislocation piles up. This restriction in the plastic flow in the matrix provides enhanced strength in composite [3, 5].

The similar conclusions were obtained by other researchers when Aluminium alloy was reinforced with ceramic particulates [6, 7, and 9].

Percentage Elongation

Figure (5) is a graph showing the effect of reinforcement content on the percentage elongation. It can be seen that as the carbide silicon content increase, the percentage elongation of the composite material decreases. Quantitatively as SiC content is increased from 0% to 15% there is a reduction in percentage elongation 75%. There is an embrittlement effect due to the hard SiC particles which cause increased local stress concentration sites. These SiC particles resist the passage of dislocations either by creating stress fields in the matrix or by inducing large differences in the elastic behavior between the matrix and the dispersoid. All these results are in agreement with the conclusion made by other researchers [5, 9, and 10].

CONCLUSIONS

The conclusions derived from this study are as follows:

a)Using stir casting method, silicon carbide can be successfully introduced in Al 6061 alloy matrix to fabricate composite material.

b)Hardness of composites found increased with increased SiC content.

c)The tensile strength of composite found increasing with increased reinforcements in the composites.

d)The percentage elongation of the composite decreased with increase in weight percentage of SiC.

e) The microstructural studies revealed the uniform distribution of the particles in the matrix system.

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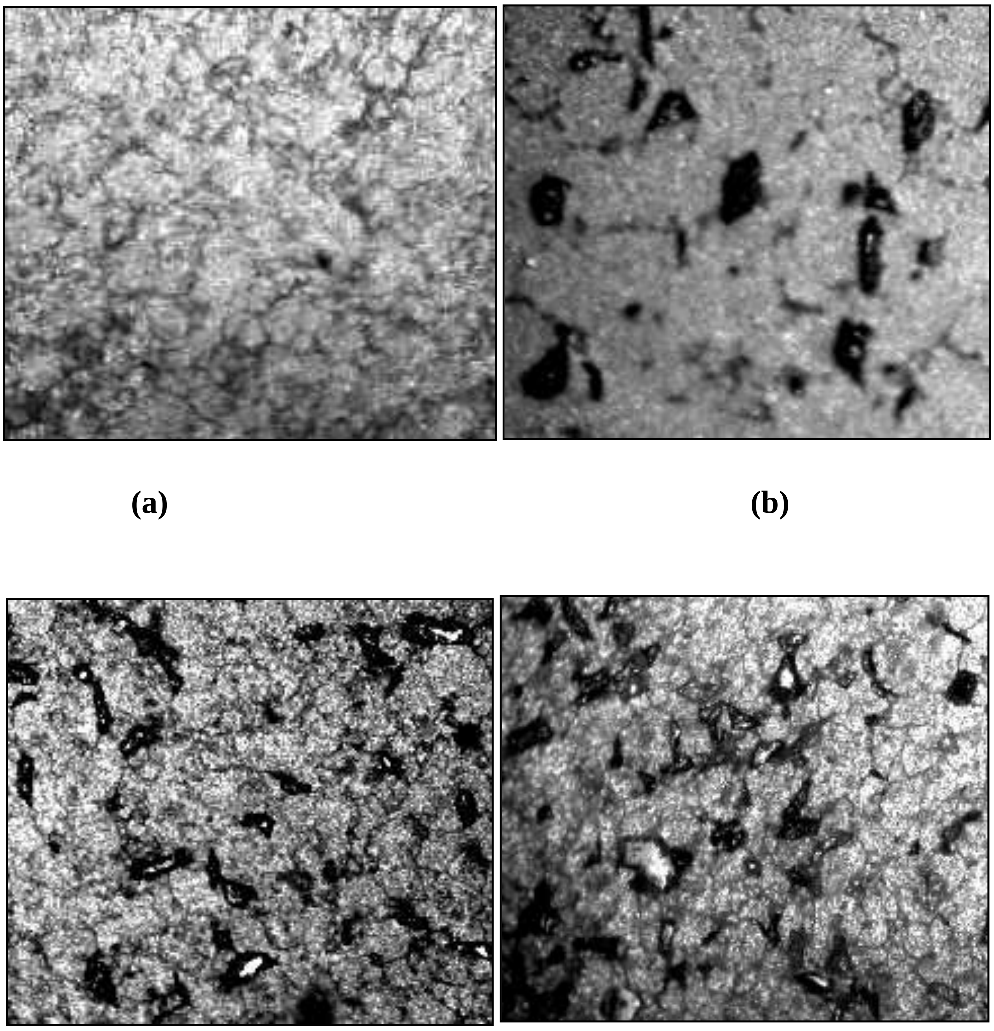
Table (1) Chemical composition of A1 6061 by weight percentage.

Mg	Si	Fe	Cu	Mn	Zn	Ti	Cr	Al
0.90	0.75	0.23	0.25	0.03	0.10	0.10	0.22	Balance

Table (2) some property of Silicon carbide.

Elastic Modulus(GPa)	Density(g/cc)	Poisson's Ratio	Hardness (HB500)	Compressive Strength(MPa)
410	3.1	0.14	2800	3900



(a) **(b)**

(c) **(d)**

Figure (1) optical micrographs (40X) of (a) unreinforced Al 6061 alloy,(b) Al 6061 alloy+5%wt. SiC, (c) Al 6061 alloy+10%wt. SiC & (d) Al 6061 alloy+15%wt. SiC.

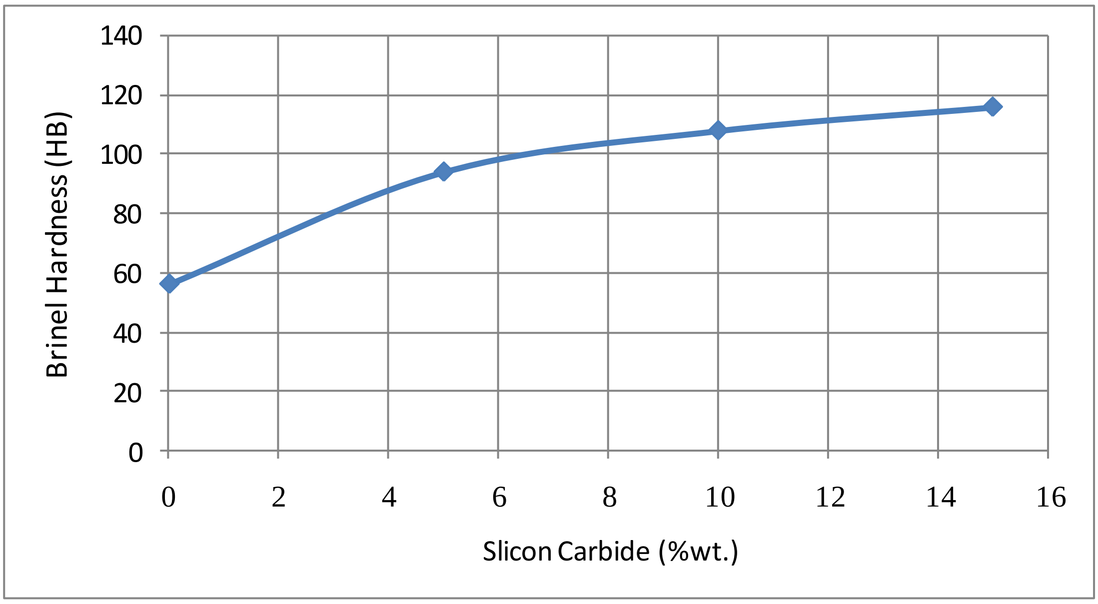


Figure (2) Effect of silicon carbide on hardness of Al 6061.

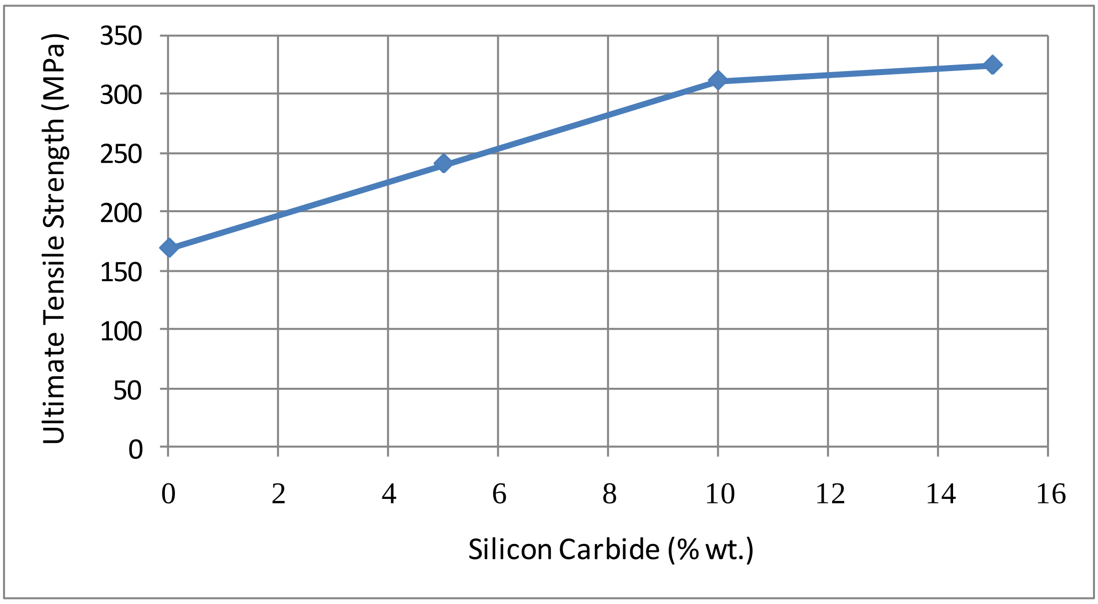


Figure (3) Effect of silicon carbide on ultimate tensile strength of Al 6061.

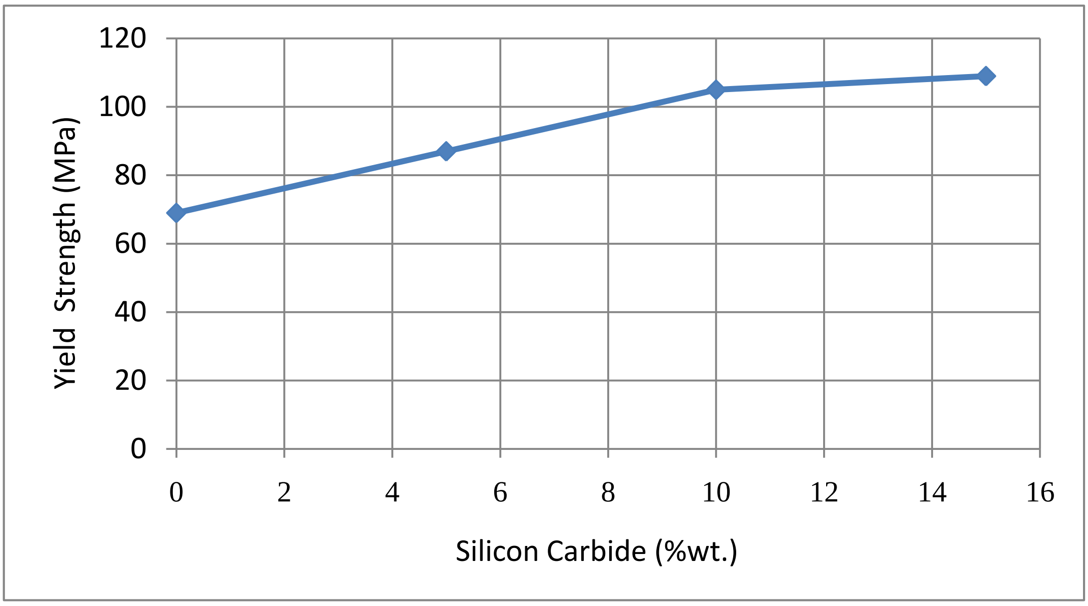


Figure (4) Effect of silicon carbide on yield strength of Al 6061.

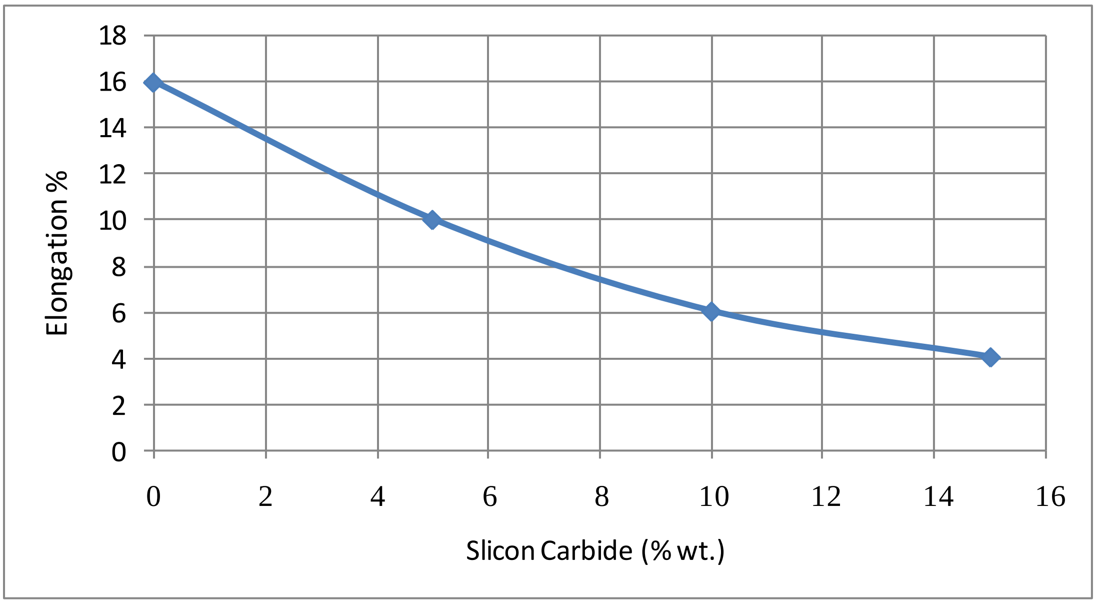


Figure (5) Effect of silicon carbide on percentage elongation of Al 6061.