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Effect of silicon carbide particulates on characterization and mechanical properties of Al 7075 metal matrix composites

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ABSTRACT

Aluminium metal matrix composites is a metal or an alloy matrix, strongly embedded with hard ceramic reinforcements which is used to enhance the mechanical properties and exhibits high strength to weight ratio. This experimental study focuses on the mechanical behaviour of Al 7075 reinforced with X wt. % SiC (X= 3, 6, 9 and12) by powder metallurgy route. All composite specimens were prepared by mechanical milling of Al 7075-X wt. % SiC composite powders, followed by blending-compacting-sintering. Detailed metallurgical examination and energy dispersive analysis were carried out to assess the effect of SiC particles on AI 7075. The Scanning Electron Microscope (SEM) is used to characterize the sintered specimens, that have Al 7075 and different SiC reinforced particulates uniformly distributed throughout the matrix alloy. The experimental outcomes revealed that metal matrix composites retain the mechanical behaviour up to 9 wt. % SiC. The enhancement of mechanical properties with small amount of SiC is accomplished by collaborating the effect of reinforcement particulates.

KEYWORDS: Powder metallurgy, Metal matrix composites, Mechanical properties, Al 7075, SiC.

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INTRODUCTION

Current Engineering applications require materials that are more grounded, lighter and more affordable. Aluminium Metal Matrix composites (AMC) were identified as good material for automobile and space application[1]. The AMC are used in various industries for its lightweight, cost effective, energy efficient and high stiffness. The wear behaviour of aluminium metal matrix composite has been studied[2]. It states that small amount of reinforcement, produces greater amount of wear resistant properties. Moreover, the processing route adopted for synthesizing AMCs depends on the nature of the matrix alloy and reinforcing materials which also influence the final properties of AMCs[3]. This is because most of the parameters put into consideration during the design of AMCs are linked with the reinforcing materials. A few of such parameters are reinforcement type, size, shape, modulus of elasticity, hardness, distribution in the matrix among others. AMCs with different synthetic ceramic materials are developed basically for performance optimization with less consideration on the production cost. Silicon carbide (SiC), Alumina (Al_2O_3), boron carbide (B_4C),Tungsten carbide (WC), Graphite (Gr), carbon nanotubes (CNT)and silica (SiO_2) are some of the synthetic ceramic particulate that has been studied but silicon carbide and alumina are mostly utilized compared to other synthetic reinforcing particulates[5,6]. Conventional AMCs reinforced with SiC or Al_2O_3 have shown improved strength and specific stiffness over the monolithic alloys[7]. The principle objective of this research work is to synthesize a metal matrix composites using Powder metallurgy route, to examine the influence of SiC on the mechanical behavior of Al 7075-X wt. % SiC (X=0, 3, 6,9 and 12), composites. All composite specimens were prepared by powder metallurgy route. PM processes can avoid, or greatly reduce, the need to use metal removal processes, thereby drastically reducing yield losses in manufacture and often resulting in lower costs.Powder metallurgy process consists preparation of powders, followed by blending-compacting-sintering. The basic mechanical properties of this composite have been evaluated. Furthermore, SEM morphology of the developed composites was evaluated for deep understanding of their characterization.

MATERIALS AND METHODS

Materials

In the present work Al7075 alloy has been selected as the base matrix and SiC(27–33 µm) as reinforcing material with the composition of Al 7075 - X wt.% SiC (X = 0, 3, 6, 9 and 12 wt. %). The Matrix material (supplied by Prabhu Copper Restricted, Mumbai, and Maharashtra, India, 99.8% purity) used in the present experimental investigation is Aluminium 7075 (Al 7075). The composites were processed by powder metallurgy route. At first, the received powders were dried at 110 ºC in a muffle furnace for 1 hr to remove the moisture and other contaminations present. Blending of the powders was performed in a high energy planetary ball mill machine in the Laboratory. Mechanical alloying performed for 10 hrs. with suitable boundary parameters such as ball to powder weight proportion of 10:1, speed 300rpm and cycle time for 5 min. The varied weight portions of SiC particles (0, 3, 6, 9 and 12 wt. %) were blended in the ball processing machine with the Al 7075 matrix powder. The mixed powders were compacted under the uni-axial load with 35kN. Zinc stearate was used as die wall lubricant[8]. The green compacted sample were set in a controlled furnace for sintering at which the temperature steadily increase up to 420ºC, and is withheld at 420ºC for 120 min with quenched water, and continue to stay with the same condition at room temperature for 72h. The prepared samples were examined using Scanning electron microscope (SEM), which is an essential investigative apparatus and performs qualitative metallographic examination. The micro graphs produced by SEM reveal grain structures, particles' size, shape and their dispersion.

Density

The density of the composites specimens was analyzed by the Archimedes' principle. The specimens were measured first in air and afterward water and density values were calculated[9, 10].

Hardness

Hardness test was performed on Rockwell hardness analyzer. Every specimen was subjected to hardness test with 1/16th ball indenter, 100 Kgf load and 20 seconds of dwell time. Trials were directed for varying weight percentage of SiC reinforcement.

Table 1: Experimental values of density and hardness of the composites.

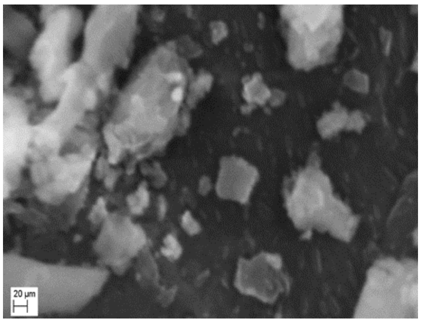
Sample no.	Composition	Density (g/cm^3)	Hardness (HRB)
1	Al 7075 - 0% SiC	2.810	65.30
2	Al 7075 - 3% SiC	2.8221	68.30
3	Al 7075 - 6% SiC	2.8918	72.00
4	Al 7075 - 9% SiC	2.9825	75.66
5	Al 7075 - 12% SiC	3.1109	73.66

RESULTS AND DISCUSSIONS

The morphology, density, type of reinforcing particles used and its distribution shows major influence on the particulate composites. Uniform distribution of particles throughout the matrix is essential for the production of composites.

Microstructure analysis

The SEM micrographs of the as-got powder mixture containing aluminium, and coarse SiC particles is appeared as shown in Fig. 1(a–d). The micro structural examination reveals the existing and uniform distribution of SiC particulates throughout Al7075 matrix in each specimen. The SiC particles are with ellipsoidal, cube-like structures and Al related with a circle and round and hollow shapes can be seen from the acquired micrographs. The absenteeism of breaks can also be observed from the micrographs.



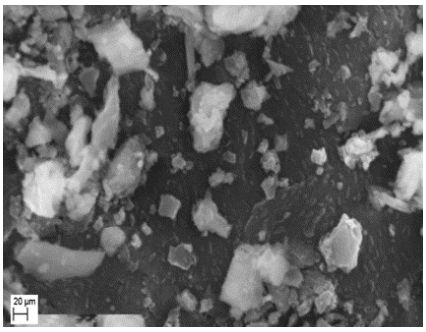


Figure (a) **Figure (b)**

Figure (c) **Figure (d)**

Figure. 1 (a-d) shows SEM micrographs of sintered composites (a) Al 7075/3%SiC composite, (b) Al 7075/6% SiC composite and (c) Al 7075 /9%SiC (d) Al 7075/12% SiC composite.

Density and hardness

The variation of density of composites at SiC content, it was observed that increase in density causes increase in SiC reinforcement composition. This can be attributed to the addition of higher density reinforcements of SiC. It can be understood that the hardness of the composites was improved with the increase in weight percent of SiC reinforcements. The increase in hardness of composites is attributable to the accompanying reasons (i) high hardness of SiC reinforcement particles. (ii) Uniform appropriation of SiC in the composites. (iii) The increased density that contributes to the increase in hardness.

CONCLUSION

- Al 7075–SiC composites have been effectively produced by powder metallurgy route. From the SEM morphologies, it was observed that the SiC particles are homogeneously dispersed throughout the Al 7075 matrix; simultaneously it authorizes non-appearance of cracks in the micrographs of the specimens.

- From the obtained results, it can be determined that the effect of 9 wt.% SiC has shown improved mechanical properties, addition of SiC particle increases the density and hardness of the composites and it was higher than that of base alloy.
- Addition of SiC to Aluminium alloy is known to decrease the hardness at the 12% wt. SiC, Consequently, these composites could be utilized in sectors such as automobile and aerospace industries, which demands light weight and great mechanical properties.

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