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Title: **THE EFFECT OF STRUCTURAL DEFECTS IN SiC PARTICLES ON THE STATIC AND DYNAMIC MECHANICAL RESPONSE OF A 15 VOLUME PERCENT SiC/6061-Al MATRIX COMPOSITE**

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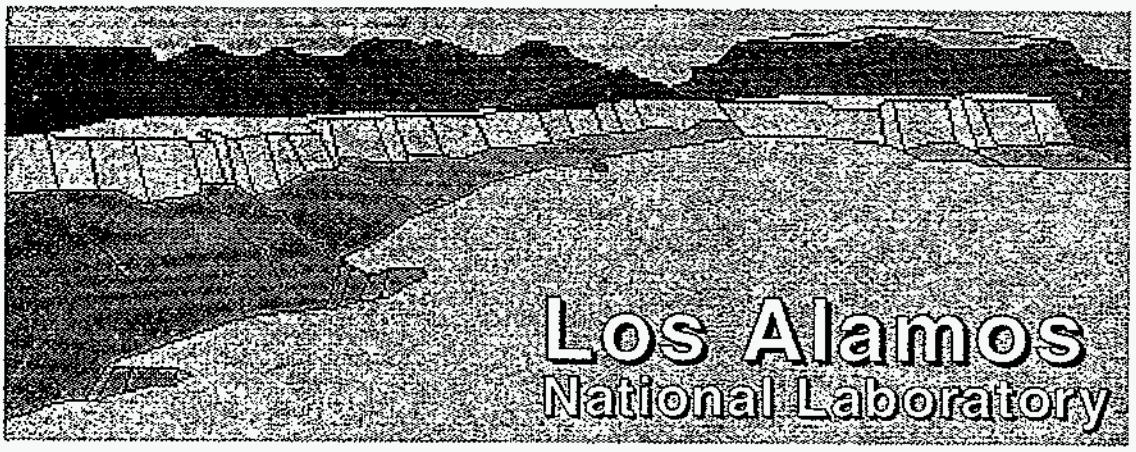

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THE EFFECT OF STRUCTURAL DEFECTS IN SiC PARTICLES ON THE STATIC & DYNAMIC MECHANICAL RESPONSE OF A 15 VOLUME PERCENT SiC/6061-Al MATRIX COMPOSITE

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Static and Dynamic mechanical tests, and microstructural examinations performed on a SiC particle reinforced 6061-Al matrix composite indicated that particle cracking significantly affected the strength, strain hardening, and failure mechanism of the composite. Cracks were observed to nucleate and propagate on stacking faults and interfaces between the various phases within the reinforcing SiC particles. Planar defects were the predominant artifacts seen in the SiC particles. Partial dislocations were also observed bounding the stacking faults within the reinforcement phase.

INTRODUCTION

Aluminum matrices reinforced with ceramic particles such as SiC and Al_2O_3 have been studied extensively because of their potential technological advantages over conventional aluminum alloys. These advantages include higher stiffness, wear resistance, and creep resistance over the alloys on which they are based [1-3]. Although the mechanical properties of these composite materials have been extensively studied and documented in literature, many recent studies have focused on correlating the observed properties to the properties of the constituents of the composite system viz. the matrix, reinforcements, and the interface. Changes in the properties of the components of the composite system can have a significant effect on the overall properties of the composite.

Our present study focuses on a 15 volume percent SiC particle reinforced Al 6061 matrix composite. The strength of the composite in tension and compression was significantly lower as compared to the value predicted by a volume fraction rule. We have correlated the observed mechanical behavior of the composite to stacking faults and other defects within the SiC particles.

EXPERIMENTAL PROCEDURE

Unreinforced Al 6061 alloy and SiC/Al 6061 composite samples were obtained in the form of spray cast extruded rods, 1 cm in diameter and 180 cm long. The aluminum alloy was a commercial grade alloy, and had the following composition: Al + 1.0% Mg + 0.6% Si + 0.28% Cu. The nominal volume fraction of the SiC particles was 15%, and the average size of the SiC particles was 15 μm. The particles asperity along the extruded direction was neglected since all of the samples were machined along that direction. All of the samples were annealed in air for 12 hours in a box furnace prior to testing.

Quasistatic and dynamic compression tests were performed on cylindrical samples, having a diameter of 0.5 cm and a height of 0.5 cm. The quasistatic compression tests were performed in an Instron machine, at a strain rate of 10^{-3} s^{-1}, while the dynamic compression tests were performed using a Split Hopkinson pressure bar at 6500 s^{-1}. Quasistatic tensile tests were also performed on samples having a gage length of 1.25 cm and gage diameter of 0.4 cm, in an Instron machine, at a strain rate of 10^{-3} s^{-1}.

Samples used for transmission electron microscopy (TEM) observations were prepared by dimpling 3 mm discs, followed by ion milling. TEM observations were conducted in a Phillips CM 30 microscope.

RESULTS AND DISCUSSION

Results of the compression and tension tests are shown in Figures 1, 2 and 3. Although the elastic

modulus of the composite samples was significantly enhanced over the unreinforced alloy samples, the composite samples fractured at significantly smaller strains in tension as compared to the unreinforced alloy. Furthermore, the compression strain hardening for the composite samples was not significantly enhanced as compared to the unreinforced alloy samples.

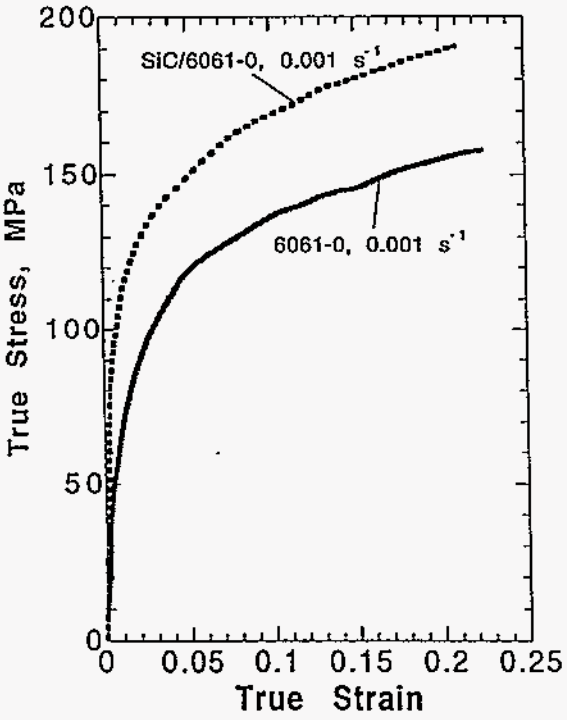

FIGURE 1. Compression responses for the unreinforced 6061 alloy and SiC/6061 composite samples at 10^{-3} s^{-1}.

A simplified volume fraction rule when used to calculate the theoretical tensile strength of the composite, gave a value of 171.5 MPa. The experimentally observed value was 147 MPa. Discrepancies between the experimental and theoretical strength values were resolved on the basis of fractographic observations conducted on the composite samples. Scanning electron microscopy (Figure 4) carried out on the fractured composite surfaces exhibited the presence of extensive particle matrix debonding. This debonding was attributed to the wetting characteristics of the SiC particles by the molten aluminum alloy [4-6]. Cracked SiC particles were also observed on the polished surfaces of the fractured composite samples, Figure 5. The nature of the cracking process was unclear, because the theoretical fracture strength of the SiC particles is significantly higher as compared to the strength of the aluminum matrix alloy [7].

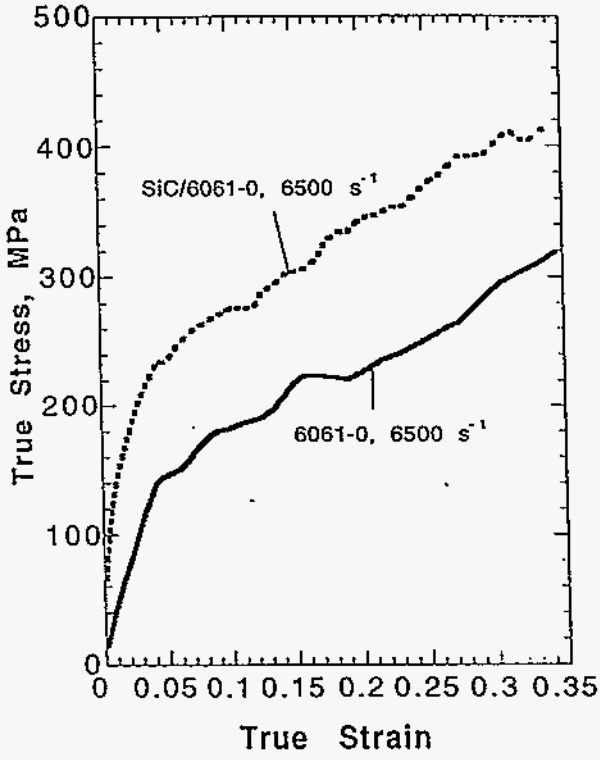

FIGURE 2. Compression responses for the unreinforced 6061 alloy and SiC/6061 composite samples at 6500 s^{-1}.

Transmission electron microscopy (TEM) was carried out to ascertain the nature of the particle cracking. The TEM micrograph in Figure 6 shows microcracks initiated within the reinforcing SiC particles. The microcracks appeared to propagate on specific planes within the particles. These planes were also observed to be parallel to one another. Detailed TEM analysis revealed that the cracking within the SiC particles occurred along stacking faults between various phases within the particles [8]. The vast majority of the stacking faults observed in the particles were interfaces between the hexagonal 6H and 4H (or cubic 4C) phases of the

SiC material. Such stacking faults are not uncommon in SiC particles, and are frequently a result of variability in their fabrication process.

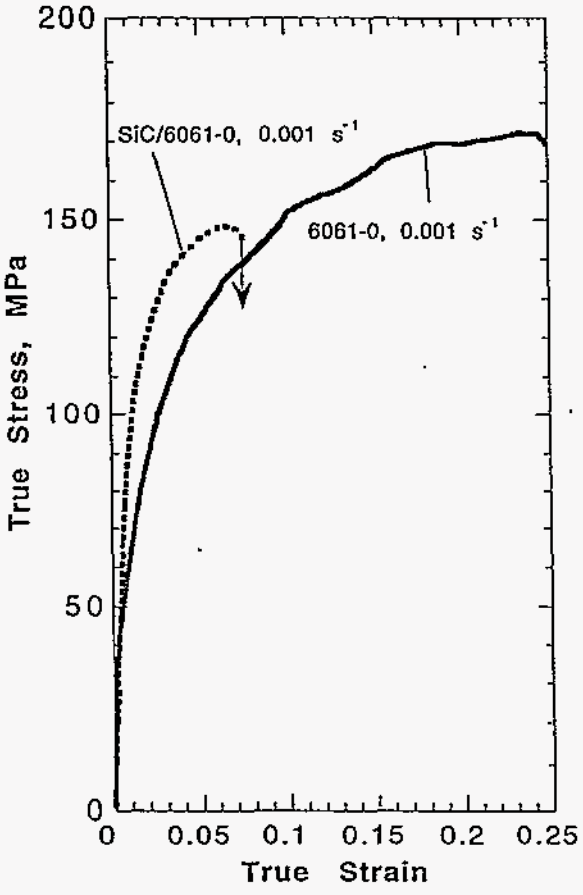

FIGURE 3. Low strain rate tension responses for the unreinforced 6061 alloy and SiC/6061 composite samples.

Particle fracture and debonding can occur in the early stages of plastic deformation in the SiC composite material as a result of stress concentration sites, and elastic discontinuities in the particles. Particle fracture is detrimental to the strength, stiffness, and fracture toughness of these materials.

CONCLUSIONS

The strength of a SiC particle reinforced Al 6061 matrix composite, measured in both compression and tension, was not significantly enhanced over that of the unreinforced alloy. This anomalous behavior was attributed to particle-matrix debonding and particle cracking in the composite samples. While the poor particle/matrix debonding was due to poor particle-matrix wetting, the cause of particle cracking was the presence of stacking faults within the reinforcing particles.

Microcracks were observed to nucleate on these stacking faults. The stacking faults were preferred sites for crack propagation because of the material weakness across the stacking fault. It is important to account for these heterogenities when making strength predictions on such materials.

ACKNOWLEDGMENTS

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FIGURE 4. Scanning electron micrograph of the fractured surface of the SiC/6061 composite illustrating extensive particle-matrix debonding.

FIGURE 5. SEM micrograph of cracked SiC particles in the polished surface of a fractured sample.

FIGURE 6. TEM micrograph of cracking within the SiC particles. Note that the cracks are parallel to the stacking faults within the particle

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