EVALUATION OF MECHANICAL PROPERTIES AND FRACTURE BEHAVIOR OF Al-ALLOY/SiC AND Al-ALLOY/Al_2O_3 METAL MATRIX COMPOSITES

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ABSTRACT

Composites are materials in which two or phases are combined, usually with strong interfaces between them. They usually consist of a continuous phase called the matrix and discontinuous phase in the form of fibers, whiskers or particles called the reinforcement. In particulate reinforced metal matrix composites (MMCs), the matrix is the major load bearing constituent. The role of the reinforcement is to strengthen and stiffen the composite by preventing matrix deformation by mechanical restraint. This restraint is generally a function of the inter-particle spacing-to-diameter ratio.

Particulate reinforcement MMC materials exhibit higher strength and stiffness, in addition to isotropic behavior at a lower density, when compared to the unreinforced matrix material. The main contribution to the strengthening of particulate reinforcement MMC composites is particle addition. The important particle parameters, which affect the mechanical properties of MMC composites, include volume fraction, size, shape, and distribution of the reinforced particles within the metal matrix. The most important among these parameters are the volume fraction and particle size. Therefore, it is essential to determine the effects of volume fraction and particle size on the mechanical properties of MMC composites.

The need for satisfying high fuel-economy goals in the automobile industry is a major challenge. The metal matrix composites based on lightweight alloys will play a significant role. While few studies have focused on establishing an understanding of the influence of particulate reinforcements on matrix microstructure and concurrent fracture behavior for particulate reinforced metal matrix composites is limited and there does exist a critical need to examine and understand the aspect of mechanical consideration for automobile applications.

The objectives of this research work are to characterize Al-alloy/SIC and Al-alloy/Al_2O_3 metal matrix composites. In this research work, the effect of type of aluminum alloy matrix and type of reinforcement materials, and volume fraction and particle size of the reinforcement on the mechanical behavior have been evaluated. The fracture mechanisms in Al-alloy/SIC and Al-alloy/Al_2O_3 metal matrix composites have also been characterized.

Al-alloy/SIC and Al-alloy/Al_2O_3 metal matrix composites were prepared by the stir casting method. Several test samples of these composites were prepared with reinforcement content of 12, 16 and 20% volume fraction, different type of aluminum matrix Al6061, Al6063 and Al7072, and different particle sizes (such as 10, 20 and 30

μm) of Al_2O_3, and SiC reinforcements. The design of experiments was planned according Taguchi's techniques. The mechanical behavior of the metal matrix composites was evaluated in terms of yield strength, ultimate tensile strength, ductility (in terms of tensile elongation), hardness, and bending force. The microstructural examination of the test samples was carried out to reveal and study the distribution of reinforcement particles, grain structure, the matrix-particle interfaces, and the formation of intermetallics in the metal matrix composites. The fractured surfaces of the tested specimens under tensile loading were examined using scanning electron microscope (SEM).

The major conclusions drawn from the current research work: are as follows:

1. Mg improves the wettability between Al and SiC particles by reducing the SiO_2 layer on the surface of the SiC.

2. The elements of Si, Fe, Cu, Mn, and Mg in Al-alloys increase the tensile properties by forming precipitates during the solidification process.

3. The ductility of Al-alloy/SiC and Al-alloy/Al_2O_3 metal matrix composites is much lower than that of un-reinforced Al-alloy.

4. The ultimate tensile of Al-alloy/SiC and Al-alloy/Al_2O_3 metal matrix composites is only marginally higher than yield strength indicating that the work hardening rate past yielding is low.

5. The SiC particles are distributed unevenly in the as-cast composite with no distinct evidence of clustering but very little agglomeration.

6. In the as-cast condition, Al is present both in solid solution with the matrix and precipitated as $Al_{12}Mg_{17}$ phase along the grain boundaries. MgO and $MgAl_2O_3$ are also formed along the grain boundaries.

7. The ductility decreases with increasing amount of reinforcement in Al-alloy/SiC and Al-alloy/Al_2O_3 metal matrix composites.

8. The decrease in the particle size increases the yield strength, ultimate tensile strength, bending force, hardness, and ductility (tensile elongation). The larger ceramic particle size is detrimental to composite strength.

9. Al_2O_3 particles aggregated to form coarse clusters in the matrix. The degree of agglomeration increases with the particulate volume fraction in the case Al 6063 and Al 7072 matrix alloys.

10. The tensile fracture behavior of Al-alloy/SiC and Al-alloy/ Al_2O_3 metal matrix composites is observed to be ductile in nature.

11. The fracture of SiC particles is not seen when the particles are of 10μm. As the volume fraction increases the failure mode is predominantly by the particle-matrix interface cracking in the case of Al-alloy/SiC composites.

The fracture surfaces of fractured Al-alloy/Al_2O_3 MMC specimens reveal dimple morphology. There is an occurrence of interface or near interface debonding in the Al-alloy/Al_2O_3 composites. Void formation takes place either by particle fracture or by decohesion of the particle-matrix interface in the case of Al-alloy/SiC composites with coarser particles.

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