METALLURGICAL CHARACTERISTICS OF FRACTURE BEHAVIOUR IN Al/SiC METAL MATRIX COMPOSITE

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Abstract: Aluminium based metal matrix composite reinforced with particles of SiC exhibit higher strength and stiffness, in addition to isotropic behavior at a lower density, when compared to the un-reinforced material. The aim of this paper is to study the damage and fracture processes of particle reinforced metal matrix composites caused by tensile loading. This paper through the use of SEM fracture analysis shows that the main fracture mechanism is based on void nucleation, and the test result shows that the strength increased with the increase in volume fraction (Vf) and decrease particle size (Ps).
Keywords: silica, fracture, metal matrix composite,
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1. INTRODUCTION

Metal-matrix composites (MMCs) are engineered combinations of two or mote materials (one of which is a metal). MMCs consist of continuous or discontinuous fibres, whiskers, or particles as reinforcement. MMCs provide significantly enhanced properties over conventional monolithic materials, such as higher strength, stiffness, and weight savings [1, 2]. While continuous fibres reinforcement provides the most effective strengthening (in a given direction), particle reinforced materials are more attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials. The mechanical properties of aluminum alloys reinforced with ceramic particulates are known to be influenced by the particle size and the volume fraction [1-21]. It is also generally found that 0.2% proof stress and tensile strength tend to increase and toughness and ductility decrease with increasing volume fraction of particulate or decreasing particles. Some investigations have indicated that commercial particulates generally have a size ranging from a few micrometers to several hundred micrometers. The fracture mechanism of composites is controlled by the ability to form cavities and voids around particles in the matrix, which in turn depends on the particle size of the particles. For optimum strength, the second-phase dispersion strengthened particles must be fine and inter particulate spacing small.

In the present work, we attempted to fabricate aluminum 6061 matrix composites with different volume fractions and different particles. The aim

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has been to study the effect of volume fraction and reinforcement particle size on the tensile properties and fracture behavior of the composites.

2. Experimental Procedure and Materials

For the present investigation, aluminum alloy 6061 was reinforced with 12%, 16% and 20% (V_f) of SiC particles with average particle diameter (10, 20 and 30 μm). Table 1 shows the composition of the matrix Al-6061. Al-6061 alloy was melted in an oil-fired furnace. The melting losses of alloy constitutes were taken into account while preparing the charge. The charge was fluxed with coverall to prevent dressing. Figure 1 shows Al-6061 alloy ingots. The composites were prepared by stir casting process. The preheated reinforcement particles were added to the liquid melt. The molten alloy and reinforcement particles were thoroughly stirred using a mixer to make the melt homogenous as shown in figure 2.

Table 1: Chemical composition of alloys

Al	Composition determined spectrographically, %								
	Al	Si	Fe	Cu	Ti	Mg	Mn	Zn	Cr
6061	97.6	0.68	0.61	0.02	0.053	0.92	0.044	0.072	0.005

Figure 1: Aluminum 6061 alloy ingots

The samples were machined to get dog-bone specimen for tensile test. The computer-interfaced UTM (Universal Testing Machine) was used for the tensile test. The specimens were loaded hydraulically. The loads at which the specimen has reached the yield point and broken were noted down.

Metallographic samples from 12%, 16% and 20% (V_f) SiC reinforced composites were cut with a low speed diamond-blade wheel. They were wet ground on 320, 400 and 600 grit SiC abrasive paper using water as lubricant, followed by polishing on diamond slurry (1μm), followed by cleaning in deionized water. The specimens were coated with electrically-conductive metal (gold) which would ground the specimen to the stub and drain off electrons. The specimens were coated with gold by Vacuum Evaporator Toshiba in IICT. Fracture behavior was analyzed using scanning electron microscope (SEM) of Hitachi S-3000N in Indian Institute of Chemical Technology (IICT).

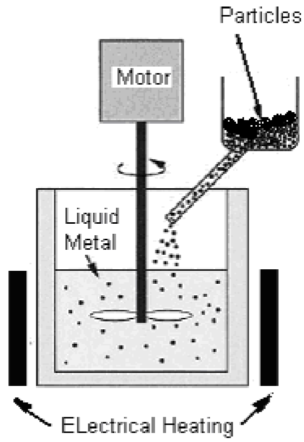


Figure 2: Charge preparation in the stir casting process

3. RESULT AND DISCUSSION

The tested tensile specimens are shown in figure 3. Three samples were tested for each trial. The average values of yield strength, ultimate tensile strength.

Figure 3: Tested tensile Al/SiC Composite specimens

3.1Effect of Volume Fraction on Mechanical Properties

Figure 4-5 shows the influence of volume fraction on the ultimate tensile strength (σ_u) and yield strength (Ys) of Al-SiC composites respectively. As expected, the σ_u and Ys values were substantially influenced by the addition of SiC particles. Experimental results show an increase in σ_u and Ys with an increase in reinforcement.

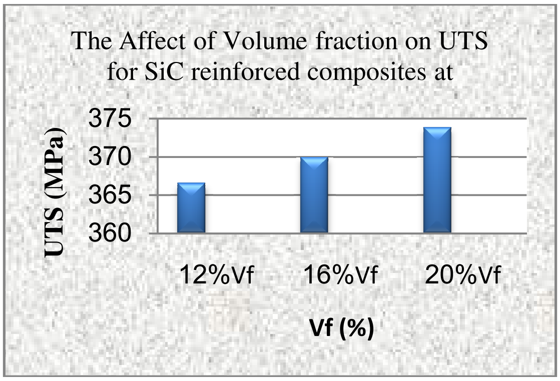


Figure 4: Influence of volume fraction on the ultimate tensile strength of Al/SiC composite

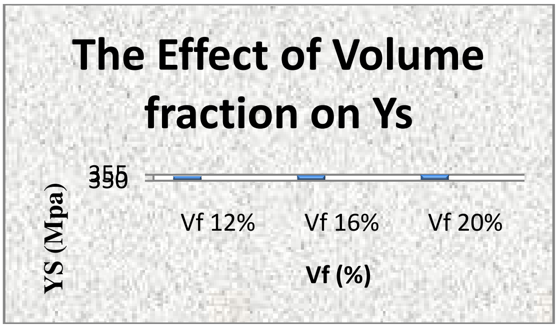


Figure 5: Influence of volume fraction on the yield strength of Al/SiC composite

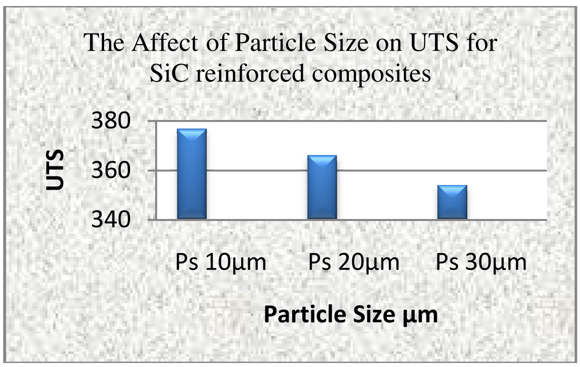
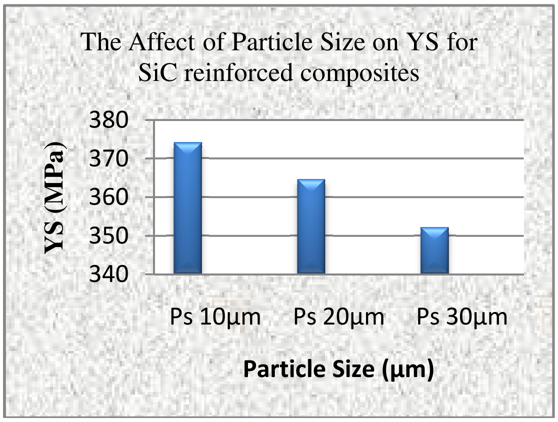


Figure 6: Influence of particle size on the ultimate tensile strength of Al/SiC composite

3.2 Effect of Particle Size on the Mechanical Properties

The effect of the particle size on σ_u and Ys can be noticed in the figure 6-7. The ultimate tensile strength σ_u and yield strength Ys have been influenced by particle size, decrease the particle size increase σu and Ys because increase in dislocation density depends upon size of the reinforcement. As the particle size increase for constant volume fraction, the inter-particle spacing increase and the dislocation due to the coefficient of thermal expansion mismatch decrease [5].



igure 7: Influence of particle size on the yield strength of Al/SiC composite

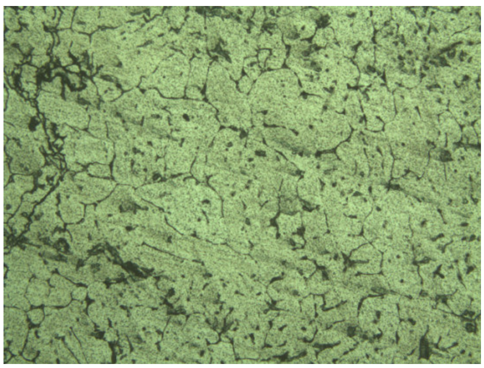


Figure 8: Microstructure of Al 6061/SiC metal matrix composite,12%V_f , 200X.

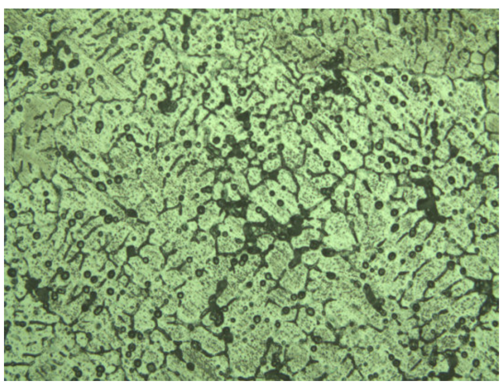


Figure 9: Microstructure of Al 6061/SiC metal matrix omposite,16% V_f 200X

3.3 Microstructure

The various intermetallics can be revealed in the microstructures shown in figure 8-10. Figures also show the distribution of the SiC particles in the composites. Microstructure of 6061/SiC metal matrix composite of 12% V_f shown in figure 8 reveals near uniform distribution and shaped, few clustering and agglomeration. There is less of agglomeration of aluminum oxide in 6061 aluminum matrix. While in the figure 9 shows higher degree of agglomeration and clustering. Figure 10 shows irregularly shaped agglomeration and these are dispersed randomly through the metal matrix. If compare these figures we can observe that the degree of clustering and agglomeration increases if volume fraction increased. An agglomeration site consisted of a few large SiC particulates intermingled with the smaller, uniform and more regularly shaped particles. It may be concluded that as a result of particles agglomeration, the inter-particle distance hindered uniform matrix infiltration by the particles and as a result porosity may be elevated in these regions.

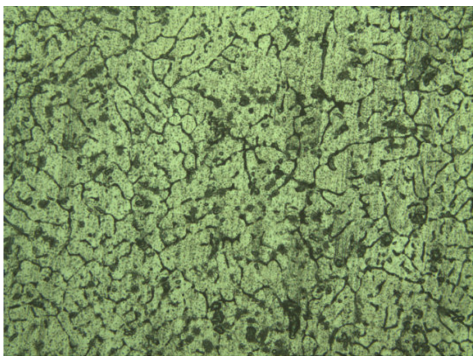


Figure 10: Microstructure of Al 6061/SiC metal matrix composite,20% V_f 200X

Figure 11: SEM tensile fracture surface of the 12% V_f Al/SiC composite

3.4 Fracture Behaviour

The influence of SiC particles clustering and the micro structural effects on ductility and fracture properties of the composites are analyzed by examining SEM fracture surface of the tested specimens. Two factors appear to control the ductility of these composites: distribution of the SiC particles and deformation characteristics of the metal matrix [6]. While the figuure 11 shows ductile fracture for the Al 6061/SiC, 12% V_f composite, with no extensive diameter contraction. Figure 12 shows the SEM of the same composite revealing medium size dimples with tear ridges, and most of the particles are firmly embedded in the matrix.

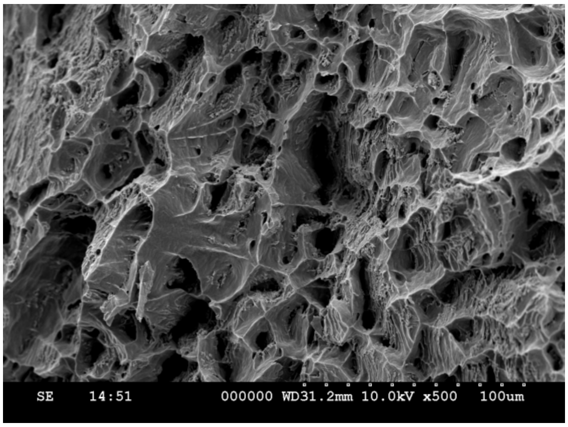


Figure 12: SEM tensile fracture surface of the 12% V_f Al/SiC composite

Figure 13 shows that the fracture is intermediate between the ductile and brittle fracture. The dimples in the figure 14 for Al 6061/SiC, 16% V_f are same to that in figure 12 but greater percentage matrix-particle decohesion than previously was observed for the 12% SiC composite.

Figure 13: SEM tensile fracture surface of the 16% V_f Al/SiC composite

Figure 15 shows the fracture surface of the Al 6061/SiC 20% V_f, the fracture surface appears to be flat and normal to stress axis on macroscopic scale. The fracture surface appears to contain many macrovoids (figure 16) in the matrix. With much different from those observed for smaller volume fraction. The matrix-particle decohesion was also observed but more extensively than those observed for 12% and 16% volume fraction composites. The brittle fracture of these composites indicates that void growth and coalescence occurred rapidly. Voids

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nucleation, growth, and coalescence contributed to final fracture in the matrix.

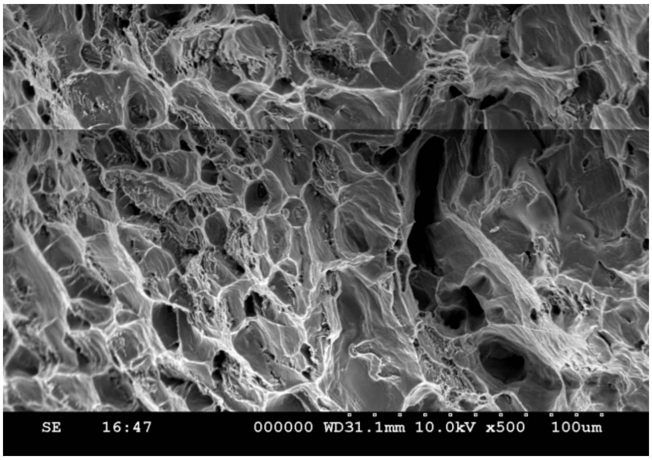

Figure 14: SEM of fracture surface of 16% V_f Al 6061/SiC composite

Figure15: SEM tensile fracture surface of the 20% V_f Al/SiC composite

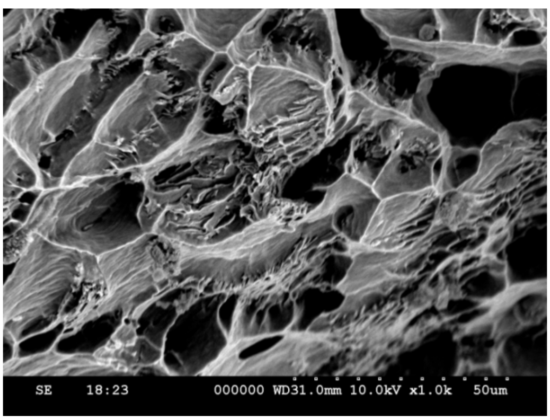

Figure 16: SEM of fracture surface of 20% V_f Al 6061/SiC composite

4. CONCLUSION

The geometrical constraints imposed on deformation cause by the presence of the hard and brittle SiC particles in the soft and ductile Al 6061 metal matrix. It is required a high value of stress to initiate plastic deformation in the matrix. This result in increase σ_u and Ys for the composites and it is increase with increase of volume fraction and decrease the particle size. The degree of clustering and agglomeration in Al-6061/SiC increases and the ductility decreases with increase the reinforcement.

5. ACKNOWLEDGMENT

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