Effect of Particle Size and Concentration of SiC on Al 6061 Metal Matrix Composite Produced by Stir Casting Method

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Abstract

The reinforcement of metals with ceramic particles have generated a new family of composite materials for the last two decades and are used widely for structural components subjected various loading. Cyclic loading draws attention because of resistance the material has to offer for fatigue failure. This work is carried out to understand the fatigue behavior of aluminium 6061 reinforced with various SiC particles size and weight% for varying stress levels. Stir casting method is used to prepare the specimen owing to its simple and economical aspects and expect isotropic properties. It is observed that increased percentage of reinforcement lead to decrease in the fatigue life, this is because the composites had lower cyclic ductility and the high local deformation occurrence in the matrix particles reinforcement interface, and this leads to the creation of fatigue damage region for the failure. Further larger size of the particles tend to increase the fatigue life.

Key words: Al MMC, Particle Size, Particle Concentration, Fatigue, SiC Particle.

1. Introduction

The ever demanding need for high-performance materials that can provide attractive combinations of high specific strength, specific stiffness, efficient and reliable, over the range of operating parameters, has impressed the manufacturing industry in the development and use of composite materials.. The reinforcement types may be continuous such as long fibers or discontinuous in the form of whiskers, short fibers, and particles. These material offer improvements in, reliability, stiffness and mechanical properties such as strength, hardness, wear resistance, abrasion resistance and fatigue resistance over monolithic counterpart [1-2].

Discontinuously-reinforced metal-matrix composites (DRMMCs) based on particulate reinforcement are gaining attention now a days. Driven initially by the demand for high performance military and space applications, the discontinuously reinforced metal–matrix composites (DRMMCs), with aluminum alloy metal matrices gain significant attention. Increased uses in the areas of automotive, aerospace [3-4] and in recreational goods [5-6]. Since they provide substantially improved modulus and strength properties compared to unreinforced matrix materials. While whisker reinforcements also an offer to make in terms of enhanced mechanical properties, but they are expensive and susceptible to break during secondary fabrication [7]. On the other hand, particulate-reinforced matrices are widely used since they offer near-isotropic properties compared to continuously reinforced matrix [8]. These materials are easier to produce by using standard metallurgical processes such as powder metallurgy, rolling and extrusion, casting and the conventional operation can be performed to get the required shape and size of the component by various machining operations using conventional machines [9]. Improvements in attainable properties are dependent on the intrinsic properties of the composite material constituents, along with size, shape, orientation, volume fraction and distribution of the reinforcing particles in the composite [10]. The fatigue behavior of particle reinforced aluminium metal matrix composites has been studied extensively in past decade [11]. It is observed that in A1/SiCp composites threshold levels and fatigue crack growth rates are influenced by the reinforcement particles [12-14].

Research shows a strong bonding for the AI/SiC metal matrix composite, although this bonding depends on the types of the SiC like whisker, short fiber, particle etc. and the method of production of composite, and cleanliness of the matrix [15]. Investigation on short-crack behavior in aluminium alloy 2124 reinforced with SiC_w shows crack initiation was generally associated with debonding at whisker poles, as such these sites act as stress concentrations, and followed by rapid crack propagation along the matrix-whisker interface. It is shown that the matrix-SiC_w interface is estimated site for crack initiation for the composite Williams and fine [16]. The subsequent short-crack growth was caused at matrix-whisker interfaces.

In fatigue test, crack initiation plays a vital role in determining fatigue life. For discontinuous metal matrix composites, this is more dominant because crack initiation may occur depending on the distribution of the reinforcement. The contribution of the reinforcement to crack initiation and subsequent crack growth depends on the reinforcement weight/volume fraction, shape, size and wettability between the matrix and reinforcement, as well as material strength [17].

Controlling various parameters like stirring time, holding temperature, stirring speed, stirring time, etc. and selection of matrix and reinforcements structurally sound quality of components can be produced [18]. In this work the effect of reinforcing SiC particles on the fatigue behavior of Al 6061 is discussed based on weight fraction and particle size. Specimen is prepared by stir casting method since it is simple and economical to use. Out of many processes stir casting process is very cost effective, simple and operating parameters can be controlled with more ease.

2. Materials and methodology

Round aluminium 6061 bars of 20 mm diameter are procured from standard vendors and heated around 800°C in electrically heated furnace.

The specimens were then precision machined from the casting produced by using a (HSS) single point cutting tool. The cylindrical specimens conformed to ASTM standards with straight sided collect grip ends and a gage section which measured 86 mm in length and 8 mm in diameter. To minimize the effects of surface irregularities and finish, final surface preparation was achieved by mechanically polishing the entire gage section of the test specimens through 600 grit silicon carbide paper to remove scratches on the circumference of the specimen. Tests were performed on a mechanically loaded test machine with a maximum loading capacity of 250 Kg. Reverse bending tests were performed at various stress levels. Load is applied perpendicular to the axis of rotation and the cycles were recorded by the digital recorder and the machine stops at the failure of the specimen. All tests were conducted at normal room temperature.

Mechanical properties of Al 6061

Density (ρ)	2.7 g/cm^3
Young's Modulus (E)	68.9 GPa
Tensile strength (σ_t)	290 MPa
Elongation (ε)	12-25%
Poisson's ratio (ν)	0.33

Chemical Composition of Al 6061

Elements	**Weight%**
Magnesium	1.2
Silicon	0.8
Iron	0.7
Copper	0.4
Manganese	0.15
Chromium	0.35
Zinc	0.25
Aluminium	Balance

3. Results and discussions

Particle size should not affect cyclic softening/hardening by the continuum theory. However, the observations made here are of the different case. For a constant volume fraction of the reinforcement, the composite containing fine (25microns) SiC particles has less interparticle spacing when compared to the composite with coarse (120micros) SiC particles. This leads to the presence of matrix material around the coarse SiC particle is more when compared to the smaller SiC particles. Therefore, the small particle reinforcements share more portion of loading giving rise to lower cyclic stress. On the other hand, it is understandable that the plastic deformation would be more constrained and the re arrangement of the dislocation of the structure in the matrix would then be more difficult as the particle size in the composite is reduced.

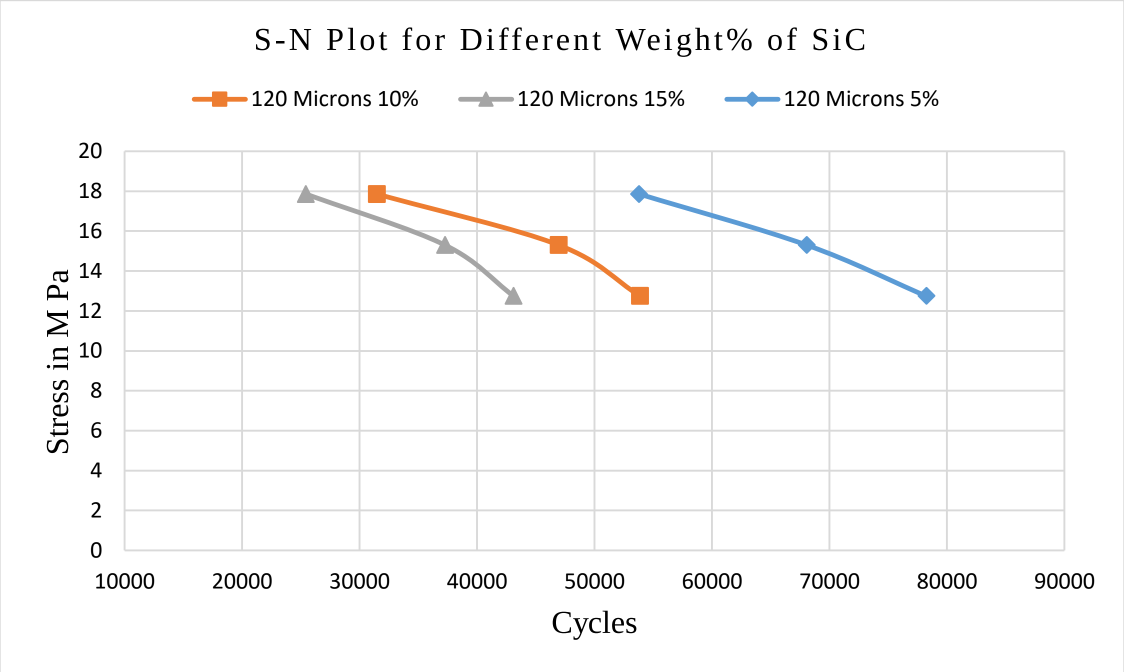

Figure 1: S-N Plot for Different Weight % of 120 Microns SiC Particles

Figure 1. shows the comparison of different weight % of 120 microns reinforcement with varying stress levels. Increase in the concentration of reinforcement, has reduced the fatigue life. It is observed that for a given stress value, the addition of reinforcement is led to decrease in the fatigue life. This is because the composites had lower cyclic ductility and the high local deformation in the matrix reinforcement interface, in this region fatigue damage was observed to be concentrated.

The medium SiC particle (60 Microns) shows lower levels of fatigue life when compared with 120 microns of SiC particles which is observed from Figure 2. The reason being as the particle size decreases, the greater the surface areas between reinforcement and the matrix. This gives rise to the voids in the composite material. Which is the major cause for decreased fatigue properties of the material. It is evident that amount of SiC particles in the material reinforced with small particles is more when compared to that of the large SiC particles for a given weight fraction of the reinforcement.

In figure 2, medium size particles (60 microns) with 10 % weight has seen sudden reduction in the fatigue life it is because the transition phase between larger to smaller size particle distribution.

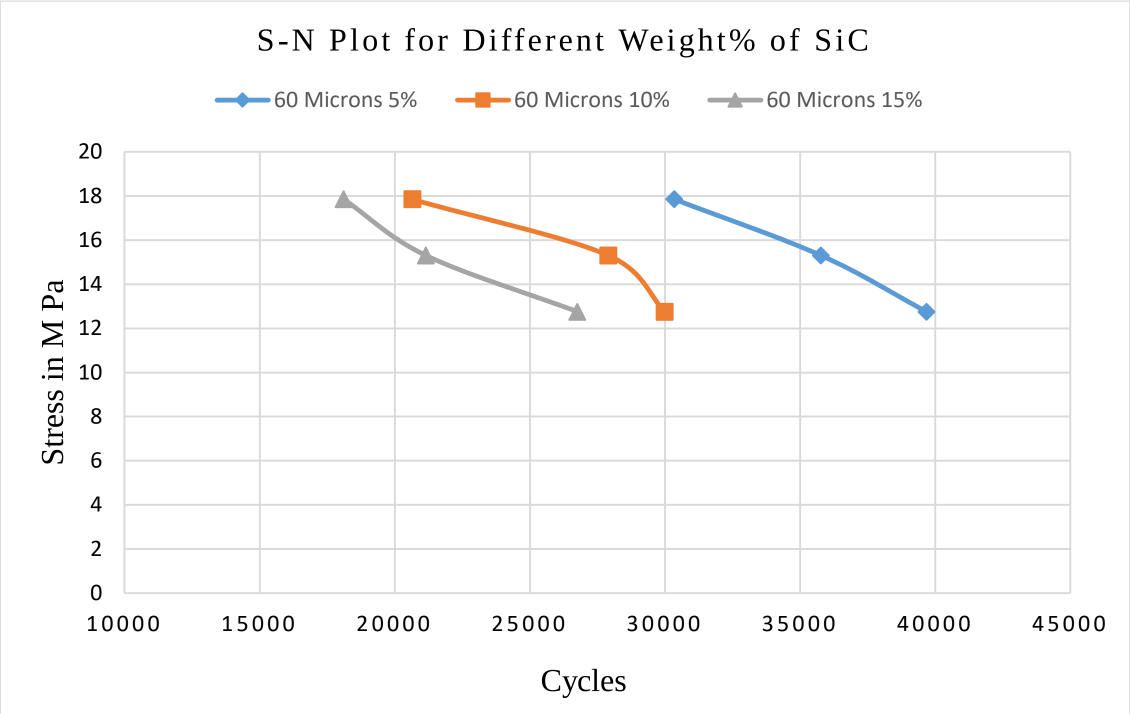

Figure 2: S-N Plot for Different Weight % of 60 Microns SiC Particles

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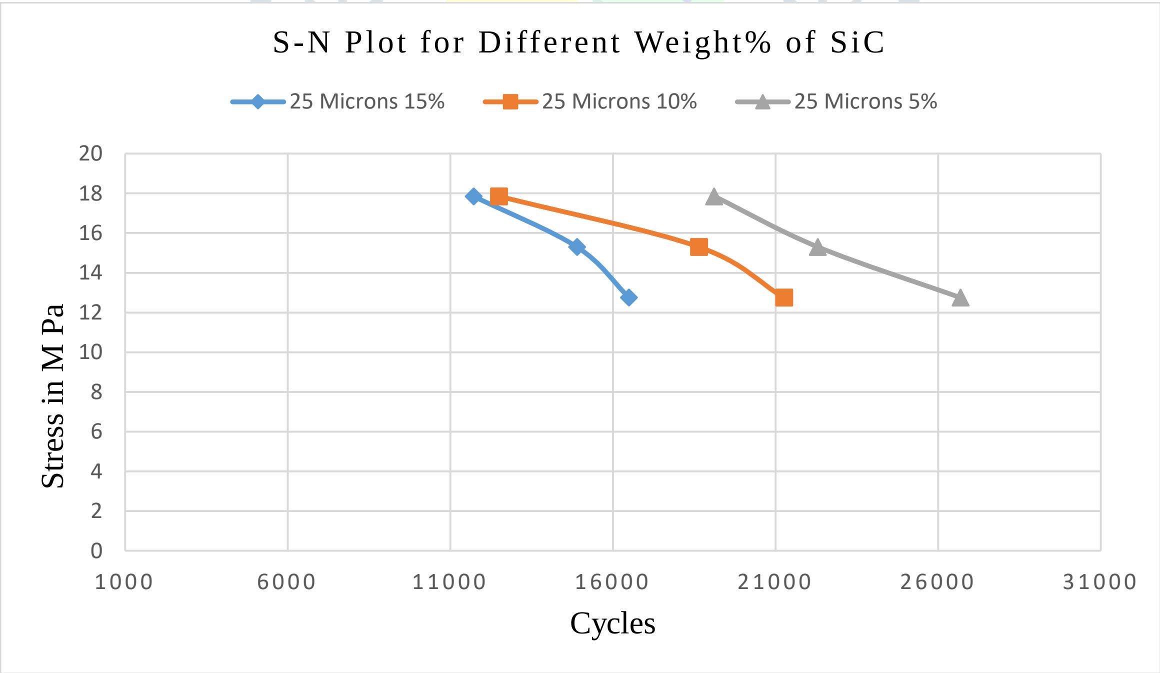

Figure 3: S-N Plot for Different Weight % of 25 Microns SiC Particles

. At higher loading conditions, the specimens were failed at few cycles. The effect of nucleation, growth and coalescence of voids played the major role in the failure of the materials at the lower cycles The small particle breaking and decohesion in the composites are the source for the creation of voids and the failure of the component at early cycles as shown in figure 3. Hence the failure easier than that of big particle composite at high stress values. At low stress values, fatigue limit of the composites mainly depended on its strength. It is evident from the results that the larger interface area between reinforcement and matrix the lesser the resistance for the fatigue life.

The comparison between the three sizes of SiC particle reinforcements are made, the bigger (120 Microns) SiC particles reinforcement has longer fatigue life when compared to 60 and 25 microns of SiC particles.

4. Conclusions

From the above conducted experiments, the effect of particle size and concentration of the reinforcement on the fatigue behavior of Al/SiCp composites, the following conclusions are drawn.

(1) Aluminium SiC composite displayed continuous cyclic softening after initial hardening for initial cycles.

(2) Higher weight % for the larger particles (120 microns) provides lesser fatigue life and the trend continues for reduced particle size for 60 and 25 microns of SiC particles. The evolution of cyclic softening became faster when the particle size is increased

. (3) Decrease in the particle size leads to lesser fatigue life owing to the fact that the particle clustering causes the brittle failure and higher surface interaction of reinforcement with matrix material which results in creation of voids.

(4) Stirring speed, holding temperature and the stirring time plays important role in uniform mixing the reinforcement particle in the liquid meal while preparing the specimen by stir casting method.

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