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The Effect of Nanoparticles Additives on Impact Strength of Metal Matrix Composites

Abstract- The impact strength of Al6061/SiC metal matrix composites reinforced with nanoparticles of weight percentage (3%, 6%, 9% & 12%) was studied. The composites were fabricated using liquid metallurgy technique. The results revealed that the Al6061/SiC metal matrix composites exhibited better hardness and impact strength than the Al 6061 alloy. Such improvement in the mechanical properties was observed with increasing the weight percentage of SiC nanoparticles and this increase both the hardness and impact strengths of the composites. The impact strength of 12 wt% nano SiC_p aluminum composites showed the maximum strength. The effect of the nanoparticles was acted as barriers to dislocation motion. It is seen that the impact energy of the composites increase gradually with filler content increasing from 3 to 12 wt%. SEM were carried out to identify the uniform distribution of nanoparticles in composites.

Keywords-(AA6061) Aluminium alloy, Nano (SiC) particles, liquid metallurgy technique, Hardness test, Impact strength.

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1. Introduction

Metal matrix composites (MMCs) are manufactured by distributing a reinforcing material into a material into a metal matrix[1], and materials will achieve high tensile strength, high compression and young modulus, economic efficiency, thermal stability, good process ability, low density, higher operating temperatures and high strength to Weight ratios [2,3].

In nowadays, metal matrix composites like aluminum (Al) are used as matrix materials. Widely used reinforcements in MMCs are nano particles such as nano silicon carbide (SiC)_p, nano alumina particles (Al₂O₃)_p and nano titanium dioxide particles (TiO₂)_p to improve and changing the physical and mechanical properties such as wear resistance, toughness, thermal conductivity, hardness and creep resistance. These nano composites may be utilized at many applications used in drive shaft, diesel pistons for automobile, biotechnology, aerospace applications, electronic, nuclear and sporting goods industries [4-6].

The objective of the present investigation is to study the impact strength of Al6061/SiC composites. The effect of nanoparticles weight percentages on the impact strength of the composites was investigated. SEM were carried out to identify the distribution of nanoparticles in composites.

2. Experimental procedure

2.1. Materials

Metal matrix composites are containing different weight percentages (0, 3, 6, 9 & 12) % of □-silicon carbide particles were produced by liquid metallurgy technique.

Production of metal matrix composites, (AA6061) aluminum alloy used as matrix material while nano silicon carbide particles with an average size of 25 μm used as reinforcement. The chemical composition of aluminium alloy (AA 6061) is shown in Table 1 and nano silicon carbide was selected as given in the Table 2.

Table 1: The composition of aluminium alloy (AA 6061)

Cu	Si	Mg	Cr	Fe	Mn	Al
0.2	0.6	0.9	0.2	0.2	0.0	Balanc
5	2	2	2	3	3	e

Table 2: Silicon carbide ceramic nanopowders properties

properties	Silicon Carbide
Purity	99+%
Particle size	30 nm
Color	Green powder
Density	3.22 g/cm ³

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Morphology	nearly spherical
Crystal Phase	SiC nanopowder (β)

II. Composite preparation

A liquid metallurgy technique has been adopted to fabricate the cast composites. Aluminium alloy melt and Preheating of Silicon Carbide particle mixture at 750°C was done for one hour to remove moisture and gases to scape from the surface of the particulates [7]. The stirrer speed lowered vertically up to 3 cm from the bottom of the crucible. Speed of stirrer was raised gradually to 800 rpm the preheated silicon carbide particle powder was added (3%, 6% , 9% and 12%) with a spoon at the rate of 10- 20g/min into the melt. After the addition of nano silicon carbide powder, stirring was continued for 10 min. get better distribution. The melt was kept in the crucible for one minute in static condition, the slag were removed and aluminium melt poured in the graphite moulds.

III. Hardness Test

Micro hardness tests were carried out after the specimens were polished to get smooth surface. Vickers hardness testes was evaluated hardness by using 9.8 N loading at 15 seconds as a penetration period and recording the average of three readings were taken for each sample.

Micro hardness was calculated according to the following equation [8]:

$$H_v = 1.854 \left[\frac{L}{(d_{av})^2} \right] \tag{1}$$

Where

H_v = Vickers hardness (kg/mm^2).

L = Applied Load (kg).

d_{av} = The average diameter of the two diagonal length of the rhombus indentation (mm).

IV. (Charpy impact) test

This test is measured the energy absorbed in a notched Charpy test. Figure 1 shows the dimensions of specimens used for the Charpy impact test as per ASTM Standard E23 [9].

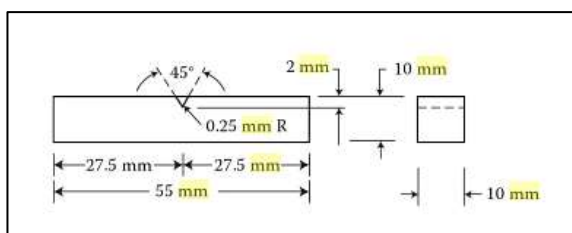


Figure 1: The impact specimen(dimensions in mm).

3. Results and Discussions

I. Micro hardness Test

Figure 2 shows hardness values of the composites with nano silicon carbide. It has been shown that the hardness increases with increasing weight percentage of the reinforcement. The hardness of all composites is higher than that of the aluminum matrix. This is because of the presence of hard SiC nanoparticles. This behavior is explained by reduced amount of porosity in the all samples and more homogenous distribution of SiC nanoparticles in the aluminum matrix [10].

II. Impact Energy Absorption

The test results revealed that the impact energy of Al alloy and Al/SiC composites are mainly depended on the distribution of the particles in the matrix. The increase of impact values for composites can be attributed to the presence of brittle (SiC)_p which may act as stress concentration area especially when the stresses on the particles are distributed uniformly.

The addition of nanoparticles have small grain sizes and large grain boundary, results in restriction to dislocation movements. Figure 3 shows impact energy strength values of the composites with nano silicon carbide.

The increasing addition of nano SiC particulates in the aluminum matrix were gradually increase impact strength. A reason for the increasing impact strength for nano SiC particles reinforcement composites lies in the hardness of the ceramic to fracture as result of the impact. In MMCs, the matrix absorb damage caused by plastic deformation. The plastic deformation is in fact beneficial; the matrix will be harder as a result [11].

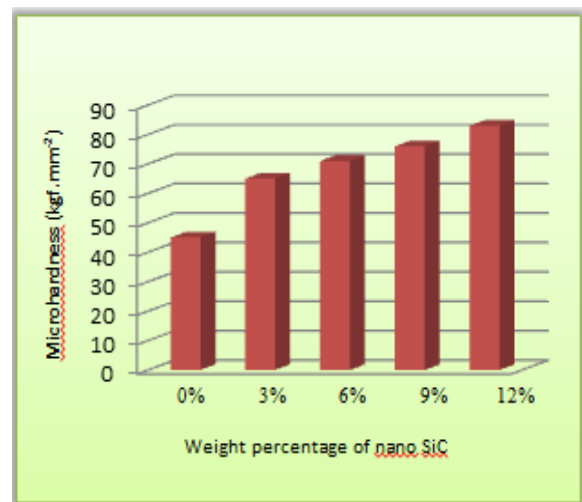


Figure 2: Hardness values of the composites

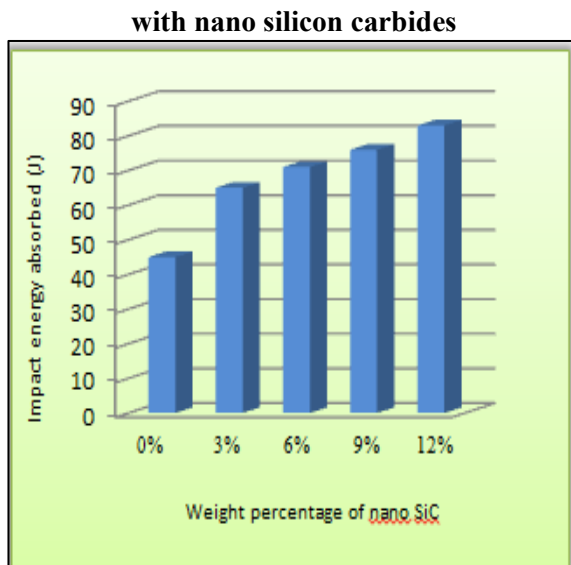


Figure 3: Impact Energy Absorbed During Charpy Impact Test

III. Morphological investigations using SEM

Scanning electron microscopy images of the reinforcement SiC particles are shown in Fig.4. The SEM images of Al 6061 matrix alloy and its SiC (3%, 6%, 9% & 12%) composites after the casting process, are presented in Fig. 5.

The combination of reinforcement inclusions and structural flaws/ defects formed at the time of MMC fabrication.

From the SEM images show uniform distribution of the nano silicon carbide particles in the aluminum matrix except very tiny of agglomerates of the powders.

It is indicating for a good interfacial between the matrix and the SiC particulates where it leads to uniform distribution.

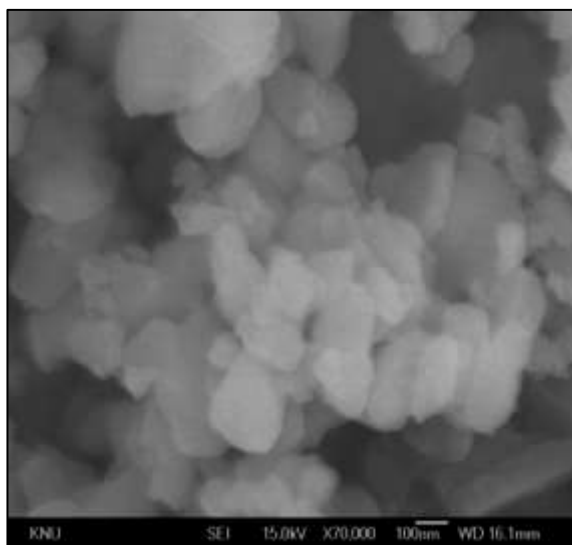


Figure 4: SEM micrographs nano SiC particles.

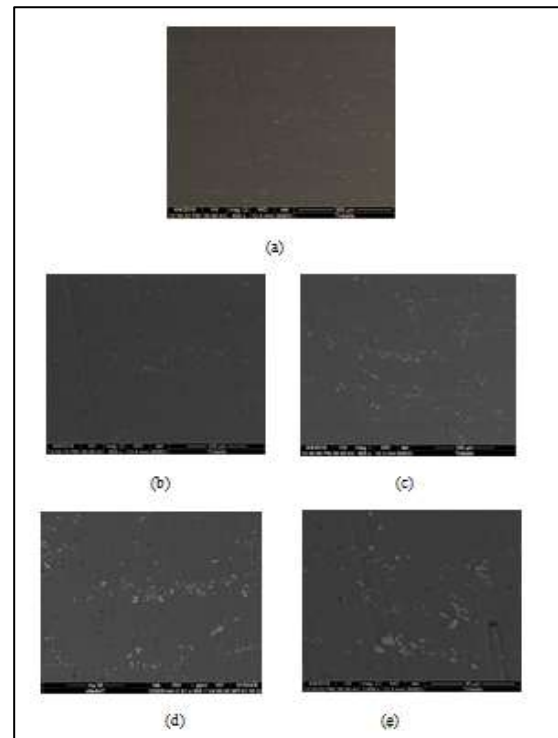


Figure 5: SEM micrographs of (a) Al 6061 matrix alloy, (b) Al 6061-SiC (3 wt %) composite, (c) Al 6061-SiC (6 wt %) composite, (d) Al 6061-SiC (9wt%) composite and (e) Al 6061-SiC (12 wt %).

4. Conclusions

The following conclusions were achieved from the current study:-

- 1) Hardness of aluminum metal matrix composites improved with the addition of nano SiC particles compared with base metal due to grain refinement and particle strengthening effects.
- 2) The impact strength of the metal matrix composites were improved by the addition of the nano SiC particles results in restriction to dislocation movements.
- 3) The metal matrix nano composites have more homogeneous microstructure with the increase of weight percentages of nano SiC_p content.

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