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Influence of single and multiple particle size variation on mechanical and wear behaviour of aluminium silicon carbide composites

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ABSTRACT – Lightweight aluminium composite possesses the potential requirement for modern technological applications due to its inherent and superior properties over monolithic materials. This study compares both mechanical and wear behaviour of single particle size (SPS) and multiple particle size (MPS) reinforced 6061 Al-20 wt% SiCp composite. The composite is produced using a bottom pouring stir casting set up. Standard impact and hardness test was conducted to ascertain the energy absorbed before fracture failure and resistance to plastic deformation of the composite. Pin-on-disc test was also investigated at room temperature under dry sliding wear condition. It was observed that the MPS-AMC exhibited superior hardness compared to the SPS-AMC because coarse particle size (CPS) support a greater fraction of applied load while the fine particle size (FPS) and intermediate particle size (IPS) sustain hardening due to dislocation.

1. INTRODUCTION

Composite materials constitute the combination of two or more material phases in order to achieve a multiphase material with desired properties which cannot be attained by the individual material phases. Recent research [1, 2] have shown that aluminium matrix composite (AMC) possesses the desired potential properties such as high specific strength and stiffness, required wear resistance to withstand various in the automotive and aerospace industries. Bhandare and Sonaware [3] showed that silicon carbide (SiC) is an ideal candidate because of its significant ability to enhance the strength, modulus, thermal stability, and abrasive wear resistance of the matrix.

Generally, the wear and mechanical properties of composites can be influenced by the particle size variation and volume fraction. Huang et al. [4] reported that the wear resistance of MMCs with 3µm SiC particles is considerably lower compared to 20µm SiC particles. This phenomenon is attributed to the tendency of finer reinforced particles to be easily gouged out and machined away by abrasive particles. Bindumadhavan et al. [5] studied the tribological behavior of a low volume fraction dual particle size (DPS) SiCp reinforced composite and compared with single particle size (SPS) reinforced composite. They found that the DPS composite exhibited better wear resistance properties compared to same volume fraction of SPS composite. Due to the possibility to influence the AMC properties with reinforcement particle size, this study aims to investigate the mechanical and wear behaviour of the MPS-SiC variation on AMC considering higher percentage of CPS when compared to SPS-SiC AMC.

2. METHODOLOGY

2.1 *Materials and Methods*

The matrix and reinforcement phase material utilized for this study are Al 6061 alloy and silicon carbide particulate (SiCp) in the ratio 80:20 respectively. The SiCp comprises of three different particle sizes of mean sizes; 15 µm, 40 µm and 80 µm as described in Table 1. The composite was synthesized using the liquid metallurgy route through the bottom pouring stir casting technique. The SiCp was preheated to 900 °C maximum temperature of 1000 °C. The Al 6061 alloy was superheated to a temperature of 800 °C. The AMC was prepared into four different variation of 20 wt% SiCp phase. The ratio of the MPS-SiC for the mixed composition comprises of 5:5:10 with the coarse particle consisting of 50% of the 20 wt% SiCp.

Table 1 Variation of AMC with different particle sizes.

Matrix Alloy	Mean particle size of SiCp (µm)	Designation
6061 Al	15 (fine)	*AMC I
6061 Al	40 (intermediate)	*AMC II
6061 Al	80 (coarse)	*AMC III
6061 Al	15-80 (mixed)	*AMC IV

*AMC: Aluminium Matrix Composite

The stirrer speed was maintained at 550 rpm as the stirring continued for a period of 3 minutes after the complete incorporation of the preheated SiCp powder. Metallographic analysis of the sample surface was conducted using standard technique to achieve a better microstructural observation.

3. RESULTS AND DISCUSSION

3.1 *Microstructure Studies*

Figure 1 shows the morphology of the as received SiCp for different particle sizes and the ball milled SiCp for the MPS using SEM. The MPS-SiC shows a uniform distribution of particulates after mixing.

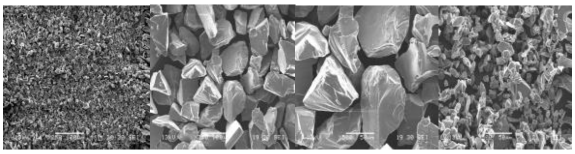

Figure 1 SEM view of as received single SiCp (a) 15µm (b) 40µm (c) 80µm and (d) mixed SiCp (15-80µm).

3.2 Hardness Test

The Rockwell hardness test was performed in accordance with ASTM E18 - 14a at room temperature condition. Based on the average results, AMC IV had the highest hardness value of 98 HRB as shown in Figure 2. Maximum hardness is achieved as a result of the combined influence of the three sizes. The coarse particle size influences the AMC because larger particles support a greater fraction of the applied load.

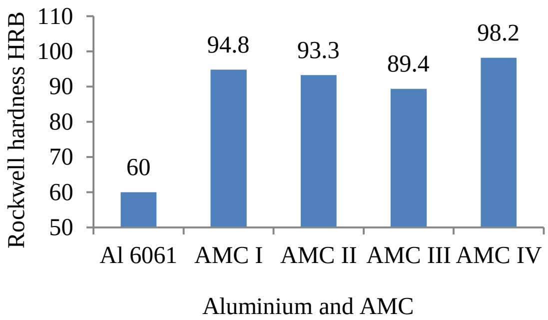

Figure 2 Hardness value for different AMC variations.

Moreover, the fine particle sizes (FPS) possess greater amount of particle matrix interface which enhances more hardening due to dislocations. Also, IPS provides additional support for the resistance to deformation by bridging interparticle spacing gap for the CPS and FPS to improve the hardness of AMC IV.

3.3 Impact Toughness

Impact test was conducted using the Charpy impact tester. The test is performed according to ASTM E23 procedure. Compare to other AMC variations, the energy absorbed by AMC IV is 3J indicating a brittle nature compared to the matrix alloy of 18J. The brittleness occurred due to strain energy been lowered thereby inducing brittle fracture. The impact toughness increases with the SiC particle size. This is as a result of alumina carbide (Al_3C_4) formation during composite processing. CPS experiences minimum contact with the matrix when compared to the FPS, thereby producing less Al_3C_4, unlike the FPS which have maximum contact thereby catalyses the higher formation of Al_3C_4.

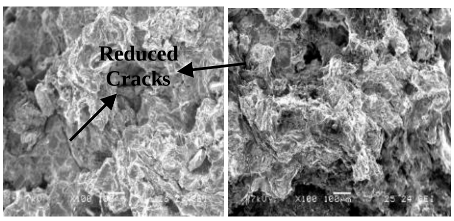

Figure 4 SEM facture surface of AMC IV.

However, the CPS has the tendency for particle cracking due to possible weak bonding and particle fragmentation, but this effect is reduced (Figure 4) with the addition of the IPS which compensates for the variation between the coarse and fine particle sizes. However, the FPS influences good bonding effect between the reinforcement and matrix due to its maximum contact.

3.4 Wear rate analysis

The wear test was conducted in order to study the effect of the particle size variation on AMC. The wear rate was analyzed from the equation below;

$$W_r = \frac{\Delta w}{2\pi rnt} \qquad (1)$$

Where, Wr is the wear rate, Δw is weight loss, n is revolution per minute, r is radius of steel disc, t is time.

AMC IV, exhibited high wear resistance when compared to other AMC variations. This is as a result of the load bearing capacity of the coarse particle size. The high interfacial strength which exists between the matrix and CPS is achieved due to large surface bonding which makes it difficult for particle pull out from the matrix. This strong bonding provides a shielding effect for the IPS and FPS which provides toughness and strength respectively. Figure 5 shows the SEM image of the worn surface characterized by localized narrow/shallow grooves and less fragmented particles. The smooth surface on the worn AMC IV could be ascribed to the load bearing capacity demonstrated by the CPS providing multiple shielding for the matrix.

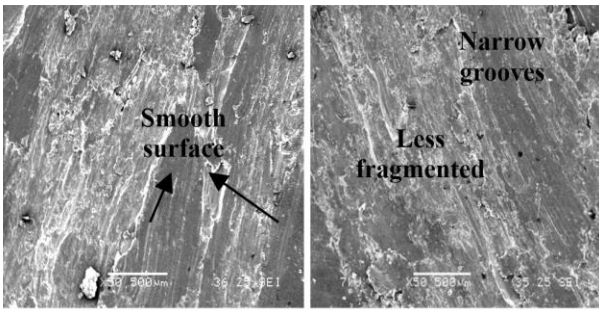

Figure 5 SEM micrograph of worn AMC IV surface.

4. CONCLUSIONS

1) The MPS-SiC shows the possibility to tailor its properties to meet engineering requirements by suitable choice of particle size variations.
2) The MPS-SiC AMC was found to have higher impact energy than SPS composites with same quantity of reinforced phase.
3) Study reveals that the presence of higher percentage of CPS influences the MPS-SiC AMC by enhancing the wear resistance and hardness properties as compared to SPS-AMC.

5. REFERENCES

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