A STUDY ON MECHANICAL PROPERTIES OF REINFORCED AL6061 USING REINFORCING MATERIALS OF Al_2O_3 AND SiC COMPOSITE

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ABSTRACT: The development of AA6061 aluminum matrix composites is of great interest in industrial applications for lighter materials with high specific strength, stiffness and wear resistance. In this paper we examine the effects of reinforced Al6061 alloy with 2 wt%, 4 wt%, 6wt% of SiC and 5 wt % Al_2O_3; being fabricated by liquid metallurgy (stir cast) method. The mechanical properties including hardness and wear resistances of the unreinforced alloy and reinforced have been measured. It has been observed that the addition of reinforced materials significantly improves wear resistances and hardness properties as compared with that of unreinforced matrix.

KEYWORDS: *AA6061 Aluminum Matrix, StirCast, Mechanical Properties*

1.0 INTRODUCTION

In the last decades, there is an increasing trend towards using composite materials, in order to achieve better performance in engineering materials [1]. Different reinforcing materials like SiC, TiB_2, Al_2O_3, B_4C, zircon sand, SiCrFe and CrFeC, and cerium oxide have been used to reinforce the metal-based matrices in an attempt to improve their mechanical and wear properties [2-9]. The strengthening of aluminum alloys with a reinforcement of fine ceramic particulates such as Al_2O_3 and SiC has greatly increased their potential in wear resistant and structural applications [10–20].

The incorporation of hard reinforcing particles like Al_2O_3 into the matrix alloys improves their mechanical and tribological behavior, but may result in deteriorated machinability together with rapid counter face wear [21]. These composites possess excellent wear resistance in addition to other superior mechanical properties such as strength, modulus and hardness when compared with conventional alloys [22-28]. Hardness of composite depends on hardness of reinforcement and matrix .Hardness of the composites increase with increases in the filler content [29].

Investigation of mechanical behavior of aluminum alloys reinforced by micro hard particles such as Al_2O_3 and SiC is an interesting area of research. Therefore, the aim of this study was to investigate the effect of Al_2O_3 and SiC content on hardness and abrasive wear of Al6061 matrix alloy, made by stir casting method.

2.0 EXPERIMENTAL

The matrix material used in the experimental investigation was an aluminum alloy (6061). Thechemical composition is listed in Table 1. The composition of aluminum alloy (6061) was determined by means of chemical analysis in (Ministry planning / Central Organization for Standardization and Quality Control), The cleaned metal ingots were melted to the desired temperature of 740°C in graphite crucibles. The addition of the silicon carbide particles in the matrix alloy was varied from 2–6 wt% and added keeping 5wt% Al_2O_3 constant as reinforcement was added as shown in Table 2.

Table 1: Chemical composition of Al6061 by weight percentage

Alloy	Si	Mg	Cu	Ti	Fe
Al (6061)	0.76	0.92	0.22	0.1	0.28
	Mn	V	Cr	Zn	Al
	0.12	0.01	0.31	0.08	Bal

Table 2: Sample characterization was used in this work

Sample No	Specimen Name	Characterization
1	Al6061	A
2	Al6061+5%Al2O3	B
3	Al6061+5%Al2O3+2%SiC	C
4	Al6061+5%Al2O3+4%SiC	D
5	Al6061+5%Al2O3+6%SiC	E

The molten alloy was stirred for a duration of 10 min using a mechanical stirrer possessing ceramic coated steel impeller. The speed of the stirrer was maintained at 400 rpm. Hardness, and wear tests were conducted for Al6061 alloy and Al6061 alloy reinforced. Hardness test was using a load of 1 N for a period of 10 s. The abrasive wear test was conducted for loads 10 N and 15 N within 10 min for Al6061 alloy and Al6061 alloy reinforced. Metallographic scanning was realized on an optical microscope. Samples for the microscopic examination were prepared by standard metallographic procedures etched with killer's agent and examined under optical microscope.

In this project , experimental and theoretical density values were in line with each other and confirmed the suitability of the liquid metallurgy techniques for a successful composite preparation. An actual density of the samples was evaluated by weighting the test samples using a high precision electronic weighting balance and dividing the measured weights in each sample by the volume of the respective samples. Then these densities were compared using theoretical density. The theoretical density was evaluated by using the rule of mixtures given by:

$$pAA6061/ Al_2O_3\ p/SiC$$
$$= Vol.\ AA\ 6061 \times pAA6061 + Vol.\ Al_2O_3 \times p\ Al_2O_3$$
$$+ Vol.\ SiC \times p\ SiC \qquad (1)$$

Where:
$pAA6063/ Al_2O_3\ p/ SiCp$ = Density of Composite,
Vol. AA 6061 = Volume fraction of AA 6061,
pAA6061 = Density of AA 6061,
Vol. Al_2O_3 = Volume fraction Al_2O_3,
pAl_2O_3 = Density of Al_2O_3,
pSiC= Density of SiC,
Vol. SiC = Volume fraction SiC.

3.0 RESULTS AND DISCUSSION

3.1 Density Measurements

Figure 1 shows the density measurements of the prepared composites. The density increased furtherwith increased percentage of filler content in the composites. The higher density of sample (E) composites have the highest filler content and can reasoned for the higher density values of SiC.

3.2 Result of Microstructures Test

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using an optical micrographs to study the distribution pattern of the filler content in the matrix. Figure

2 shows micrographs of unreinforced alloy and of reinforced alloy. The microstructure of the prepared composites contained primary α-Al dendrites and eutectic silicon, while Al_2O_3 particles were separated at inter-dendritic regions and in eutectic silicon. Figure 2b reveals the distribution of alumina particles in specimen and it can be observed that there is a fairly uniform distribution of particles. Figure 2b-e shows that the silicon carbide particles are uniformly distributed in the matrix. The reinforcements appeared darker than AA 6061 Aluminum alloy matrix. Further the microphotographs revealed a good bond between the matrix alloy and the reinforcement particles.

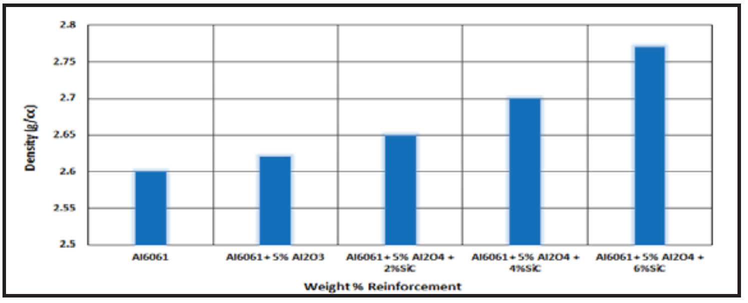

Figure 1: Effect of reinforced wt % on density of composites

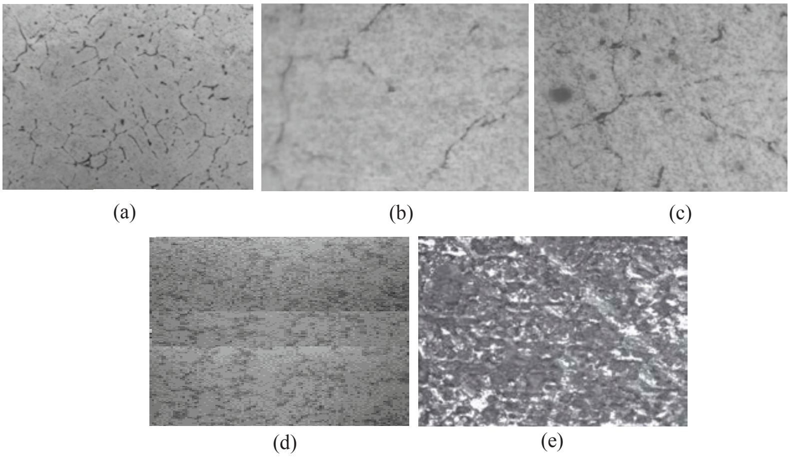

Figure 2: Microphotograph of Al6061 alloy with and without reinforced particles at 125X a) Cast Al6061 alloy, b) Al6061+5% Al_2O_3, c) Al6061+5%Al_2O_3+2%SiC, d) Al6061+5%Al_2O_3+4%SiC ,e) Al6061+5% Al_2O_3+6%SiC composites

From Figure 2 above, the distribution of reinforcement in the respective matrix is fairly uniform. These figures revealed the homogeneity of the cast composites. The microphotograph also clearly revealed the increase of filler contents in the composites.

3.3 Hardness Results

Hardness of Al6061 alloy base composite and Al6061 alloy reinforced is shown in Figure 3. There was a significant improvement in hardness with an addition of reinforcement. The hardness value was influenced by a volume fraction of SiC. Maximum hardness was observed in the case of Al606+5% Al_2O_3 + 6% SiC composite. Diffusion of carbide into the matrix increased the hardness of composite. Figure 2 shows the significant improvement in the hardness of the Al6061 alloy and Al6061 alloy reinforced reinforced Al6061 matrix alloy when compared with the unreinforced Al6061 matrix alloy exhibited higher hardness when compared with the matrix alloy. The effect of Al_2O_3 and SiC of sample as shown in privies paragraph.

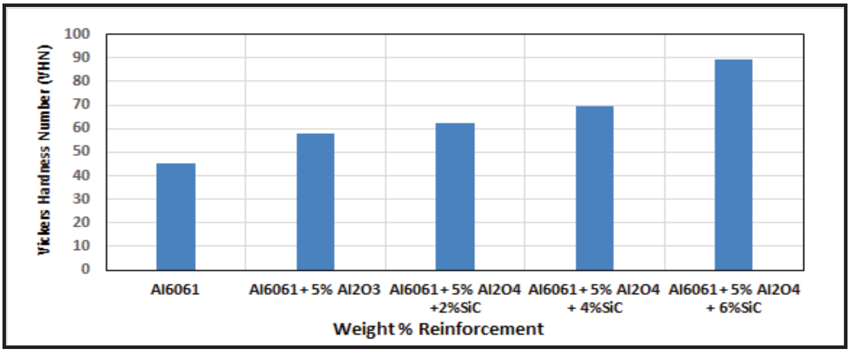

Figure 3: Variation of hardness with increase in weight % of reinforcement for as cast Al6061

3.4 Abrasive Wear

Figure 4 shows the effect of applied load on wear rates of unreinforced Al6061 and Al6061– reinforced composites. The wear rates of both unreinforced Al6061 and Al6061– reinforced composites specimen steadily increase with the increase of the applied load. It may be noted that the composite specimens exhibited significantly lower wear rates than the matrix. It is observed that the wear rates of both matrix alloy and its composites increase steadily with increase in load up to 15N.

It is observed that the amount of reinforcement in the matrix alloy has a profound influence on the abrasive wear behavior of matrix alloy. Increased content of SiC in the matrix alloy enhances the abrasive wear resistance of composites which can be attributed to the fact that SiC itself being hard can combat the abrasion, thereby resulting in lower material removal and more wear-resistant than the presently available commercial materials. Metal matrix composites (MMCs) are regarded as excellent materials to obtain properties that are superior to those of the constituent phases and also to satisfy the above requirements [30]. The higher the hardness of composites, the better is its abrasion resistance. For a given load, the abrasive wear tended to be higher for both the matrix alloy and its composites. excellent wear resistance of Al6061– reinforced composites specimen can also be attributed to improved surface hardness and high load bearing capacity of alumina particles with the increase in the percentage of reinforcement. Increase in hardness results in improvement of wear and seizure resistance of materials [31].

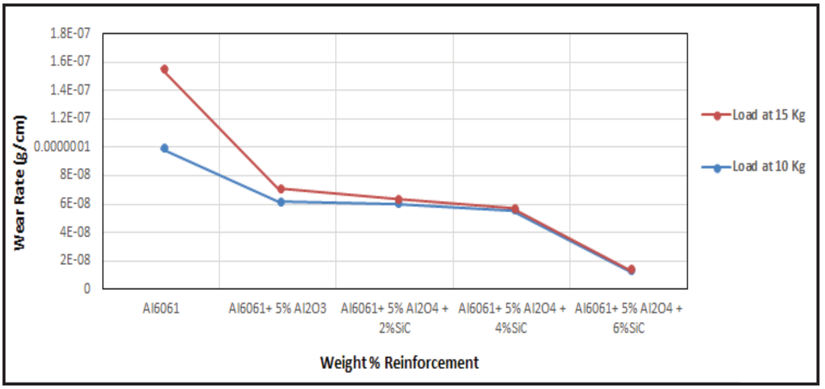

Figure 4: Variation of wear rate with increase in weight % of reinforcement for as cast Al6061

4.0 CONCLUSIONS

1- Aluminium based metal matrix composites have been successfully fabricated by melt stir method of four-step addition of reinforcement particulates.

2- The densities of the composites improve than their base matrix and they increase as addition of reinforcement particulates increase.

3- Sample (E) composites have shown higher hardness when compared to the hardness of sample (A). Hardness of composites also increases with the increase of wt% of reinforcement found in(46 to 89)VHN .

4- The optical microphotographs of composites produced by melt stirring method shows a fairly uniform distribution of reinforcement particulates in the Al6061 alloy.

5- Higher wear rate is observed as in cast sample (A) alloy when compared to sample (B) composites.

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