Investigation of Mechanical and Morphology of Al-SiC composites processed by PM Route

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Abstract: This experimental work is based on the effect of the addition of SiC particles in the pure aluminum matrix synthesized by powder metallurgy technique. The SiC reinforcement is varied form 0 % to 15 % in a step of 5 %. The morphology of the worn out surface were also analyzed to recognize wear mechanism. The impact of filler reinforcement, sliding distance and sliding speed on the wear were studied with the help of pin on disc wear tester. The hardness of fabricated composites increases with the increases in SiC percentage. Finally, through this experimental work it can be concluded that reinforcement of SiC enhances the hardness and wear resistance of aluminum composite.

Keywords: AMCs, Morphology, Powder metallurgy, Rockwell hardness, Wear

1. INTRODUCTION

In the category of metal matrix composites, Aluminum matrix composites are one of the most preferred material excellent mechanical and tribological properties. Due to possessing light weight these composites are extensively used in automotive and aerospace industries [1]. The properties of metal matrix composites greatly influenced by filler material and their synthesis technique [2]. Powder metallurgy is generally used method for synthesis of AMCs because the most serious issue of dispersing reinforcement particle in the matrix can be easily resolved by this route [2]-[3].

The silicon carbide (SiC) reinforced AMCs have considerable potential as an engineering material. SiC retains room temperature ductility and increases the stiffness and high temperature strength of Al-SiC alloys and provide wear resistance at ambient temperature. Among dispersions, reinforcements such as SiC, graphite and alumina SiC maintain good thermal and chemical stability during synthesis and good strength at severe service conditions [4]. SiC reinforced AMCs also gives superior strengthening by ways of higher modulus, strength, wear resistance and hardness in the composite [5]. Garcia et al. reported that specific wear rate of AA6061-SiC decreases with the rise in volume fraction and particle size of reinforcement. Sahin et al also claimed that wear resistance is maximum when SiC is added to
10% synthesized by vacuum infiltration [6]. Thus, in this research Al-SiC micro-composites have been fabricated by mechanical milling and powder metallurgy. The morphology of composites were analyzed by optical microscope. Mechanical properties of composites were analyzed by Pin on disc wear tester and Rockwell hardness.

2. MATERIALS AND METHODS

Pure aluminum powder and silicon carbide powder with average mesh size 400, purchased from Otto Company, Maharashtra, India. To carry out the experimental analysis following composites were synthesized: 1. Pure Al, 2. Al + 5% SiC, 3. Al + 10% SiC, 4. Al + 15% SiC. The above composites were synthesized through PM route. The prerequisite amount of powder were weighted with the help of electronic balance having accuracy of 0.1 mg. The powders were mixed in planetary mixer with steel balls of 8 mm diameter having 10:1 ball to powder ratio. The compaction of samples were done in uniaxial press at 390 MPa. The die wall was lubricated by zinc stearate after each run to get finished samples. The green compacts were sintered under argon environment in electric muffle furnace at 450°C for 45 mints and then allowed to cool in the furnace to room temperature. The size of each sample is taken as 12 mm height and 8 mm in diameter.

Hardness test
The hardness test were carried out using digital Rockwell hardness tester with 1/8” ball indenter and a load of 60 kgf. with dwell time 8 sec. The hardness test have been performed at room temperature (30°C) and readings were taken at five different place on each composites to obtain the mean value of hardness.

Wear test
A pin on disc test equipment (Ducom, model No: ED-201, Bangalore, India) was used to investigate the dry sliding wear behavior of Al-SiC composites. Pin specimens of diameter 8 mm and 12 mm height for wear test was prepared. The counter disc material was EN31 steel of 60HRc was used for the test. The test was performed with various sliding distance of 200m, 400m and 600m at a sliding speed of 1.5, 2.0 and 2.5 m/s at fixed load of 3 kg. The wear test was performed at room temperature (30 °C) and relative humidity of 60 – 65%. The weight of the samples was measured in an electronic weighing machine having 0.0001 g least count. In each test after performing the experiment specimen was removed from the sample holder, washed with acetone and then dried and weighed to find the loss of weight due to wear.

3. RESULTS AND DISCUSSION

Effect of reinforcements on hardness
The effect of SiC addition on the hardness of the specimen obtained from Rockwell hardness tester is shown in Fig. 1. The hardness of the samples increases with the increase in SiC addition as shown in figure. Hardness of all composites increases with the pure aluminum is due to hard nature of SiC particles. SiC particle is acting as an obstacle to the moment of dislocation causing increase in hardness. Hamid Abdulhaqq et al. also claimed that incorporation of rigid ceramic reinforcement increases the bulk hardness of the aluminum alloy [7].
Sliding Wear behavior
Effect of filler reinforcement
The effect of different weight percentage of SiC in Al matrix on wear loss is shown in Fig. 2. It has been inferred that as the percentage of SiC is increased the wear resistance of the composites also increased. This enhanced wear resistance of composite materials is because of the presence of SiC which works as load-retaining element. It is also seen that the dispersion of silicon carbide, a hard face in the soft aluminum matrix leads to diminish the wear loss of composites. An increase in hardness results in the improvement of wear resistance of materials [8]-[9].

Effect of sliding distance
The effect of different sliding speed on wear loss on composites is shown in Fig. 3. Fig. 3 is showing that wear is directly related to the sliding distance. It is noted that an increase in sliding distance results in increased wear loss of all the composites. This effect is caused due to the
hard SiC particles, which are released during sliding and form a mechanically mixed layer at the contact surfaces [8].

**Effect of sliding speed**

The variation of wear loss of composites with sliding speed is shown in Fig. 4. It is noted that an increase in sliding speed results in decreased wear loss of all the materials. Since the nature of SiC is hard so it prevents the composites during sliding wear and toughen the aluminum matrix. SiC also resist the dispersion and cutting of the slider into the surface of composites, thus controlling the delamination. Due to this reason, the wearing of aluminum matrix composites is improved [5]-[10].

![Fig. 3 Wear loss versus sliding distance](image)

![Fig. 4 Wear loss versus sliding speed](image)
Morphology and wear analysis
The worn out surface of pure aluminum under 3 kg load at 2.5 m/s is shown in Fig 5 (a-b). The matrix is much softer than the counter body material, and during sliding the counter body penetrates into the matrix causing plastic deformation of the surface, which results in great material loss and significant wear rate [11]. The worn surface of pure aluminum also shows presence of deep permanent grooves, micropits and fractured oxide layer, which may have caused the increase of wear loss. However, the worn surface of Al-SiC composites were rough with more grooves indicating abrasion effect of hard SiC particles as shown in Fig. 5(c-h). The worn surface also contains the evidence of adhesive wear in the form of adhesive pits [3].
CONCLUSION

In the present study, Al-SiC composites have been prepared by powder metallurgy technique. The mechanical and morphological analysis have been investigated. The results can be summarized as follows:

1. The PM is suitable method for MMCs synthesis because distribution of reinforcing particle is easy as compared to other method.
2. The incorporation of hard SiC in matrix material increases the hardness of the composites.
3. The SiC reinforcement improves the wear resistance of Al metal in all changing variables of distance and sliding speed.

REFERENCES

[1] M.K, S. (2003). Aluminium matrix composites: Challenges and opportunities. Sadhana, 319-334.
[2] Fathy A, O. E.-K. (2015). Effect of iron addition on microstructure, mechanical and magnetic properties of Al-matrix composites produced by powder metallurgy route. Transactions of Nonferrous Metals Society of China, 46-53.
[3] Ravindran P, M. K. (2013). Investigation of microstructure and mechanical properties of aluminium hybrid nano-composites with the additions of solid lubricants. Materials and Design, 448-456.
[4] V, U. (2014). Experimental evaluation of the influence of processing parameters on the mechanical properties of SiC particles reinforced AA6061 aluminium alloy matrix composites by powder processing. Journal of Alloys and Compounds, 380-386.
[5] Sursha S, Sridhara B. K. (2010), Wear characteristics of hybrid aluminium matrix composites reinforced with graphite and silicon carbide particulates. Composites science and Technology, pp. 1652-1659.
[6] Sahin Y, A. M. (2003). Production and properties of SiC reinforced aluminum alloy composites. Composites, 709-718.
[7] Hamid A, G. P. (2014). The influence of porosity and the particle content on dry sliding wear of the cast in situ Al( Ti)-Al2O3(TiO2) composites. Wear, 464-471.
[8] Ramesh CS, N. A. (2009). Development and performance analysis of novel cast copper-SiC-Gr hybrid composites. Material Design, 1957-65.
[9] Savaskan T, B. O. (2010). Dry sliding friction and wear properties of Al-25Zn-3Cu(0-5) Si alloys in the as-cast and heat-treated conditions. *Tribology letter*, 327-36.

[10] Alpas AT, Z. J. (1992). Effect of SiC particulate reinforcement on the dry sliding wear of aluminum-silicon alloys(A356). *Wear*, 83-104.

[11] Ali MAZAHERY, S. M. (2013). Microstructural and abrasive wear properties of SiC reinforced aluminum-based composites produced by compocasting. *Transaction of Nonferrous metals society of china*, 1905-1914.

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