EFFECT OF LOAD AND GRIT SIZE ON HIGH STRESS ABRASIVE WEAR OF Al-Mg-Si HYBRID COMPOSITES

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Abstract

In the present investigation, the two body abrasive wear behavior of Al-6082 alloy, Al 6082-10% SiC (Al-SiC) composites & Al 6082-5%SiC-5%Gr (Al-SiC-Gr) hybrid composites was studied at load of 5-15N, 75m sliding distance and abrasive grit size of 100-200μm by using pin-on-disc equipment. The composites were synthesized by stir casting technique, a liquid metallurgy route. It was observed that load and type of emery paper used would have profound influence on the abrasive wear characteristics in the present set of experiments. The results show that graphitic composites yielded better wear resistance compared to alloy and SiC alone reinforced composites. At higher load and abrasive grit size, 16.4% and 11.6% improvement was observed for Al-SiC-Gr and Al-SiC composites respectively when compared to unreinforced alloy. Worn surface analysis of tested samples and tested grit papers were observed by using scanning electron microscope (SEM).

Keywords— Two body abrasive wear, hybrid composites, wear resistance, worn surface analysis.

1. Introduction

Wear of the critical components like brake drums, cylinder blocks, cylinder liners, drive shafts etc was one of the serious concerns that affect the overall operational efficiency in automotive applications. In this regard, several experimental investigations have been made in adding individual reinforcements such as SiC, Al_2O_3, graphite etc to aluminium matrix metal. This lead to improvement in not only mechanical properties but also tribological properties of the materials. The aluminum metal matrix composites (Al-MMCs) have been successfully introduced in automobile, aircraft, space equipment and structural components [1-6]. Automobile companies like Honda, Nissan, Toyota, and General Motors etc have successfully implemented these Al-MMCs in different engine applications by using various particle and fiber type reinforcements [6].

Recent investigation studies show that attention has been given in reinforcing multiple reinforcements i.e. graphite and SiCp to aluminium matrix which produced by different techniques. This was done to know the synergistic effects of hard type and soft type of reinforcements in the sliding wear behaviour on the matrix material. It was proven that wear behavior of Al MMCs with multiple reinforcements was found to be superior compared to alloy and single reinforcement [7-11]. It was reported that the graphite addition was found to be advantageous in tribolayer formation, subsurface deformation and machining of Al-SiC composites [9]. However, it was observed that the abrasive wear behavior of single particle reinforced composites was well understood and investigation is required to study on abrasive wear behavior of Al-SiC-Gr hybrid composites.

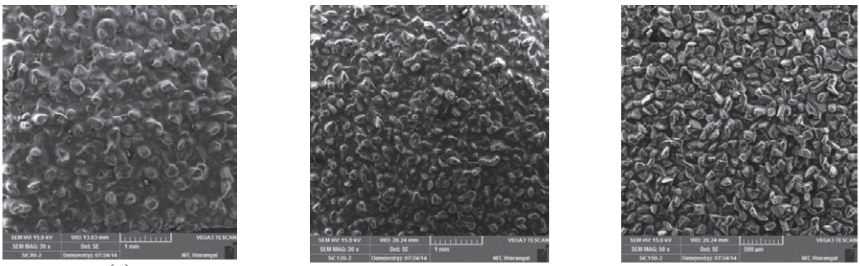
2. Materials & Methods

2.1 Composite Preparation

An Al-Mg-Si (6082) alloy and Al 6082-10%SiC and Al 6082-5%SiC-5%Gr composites were used for present investigation. The chemical composition of alloy has Cu-0.06%, Mg-0.77%, Si- 0.95%, Fe-0.32%, Mn-0.532%, Zn-0.016%, Ti-0.037%, Cr-0.038% and Al-balance. The composites were synthesized by stir casting technique i.e. liquid metallurgy route using SiC and graphite particles of size 20-40µm. The process involves melting of alloy, adding of preheated SiC and graphite particles in the melt through mechanical stirring and pouring of composite melt into stainless steel mould of size: 170 mm length & Ø40 mm. Similarly the alloy melt and SiC reinforced composites were synthesized. The wear testing samples of 27mm length & Ø 8mm were prepared from casted ones by machining process.

2.2. Microscopy

The morphology of fresh emery papers before abrasive testing was observed under scanning electron microscopy (SEM) (Model: TESCAN, Vega LMU 3) shown in Fig 1. The worn surfaces of specimens and emery papers were also observed which were discussed later in this work.



(a) (b) (c)

Fig. 1: Morphology of emery papers used in the abrasion tests (a) 200µm abrasive grit size (b) 125µm abrasive grit size (c) 100µm abrasive grit size

2.3 Wear Testing

The two body abrasive wear tests were conducted on a pin-on-disc machine (Magnum make, model: TE-165-SPOD, Bangalore). The parameters such as load of 5N, 10N & 15N and constant 75m sliding distance on different 100µm, 125µm, 200µm abrasive grit size silicon carbide emery papers. The desired grit paper was cut to size and fixed on a wheel diameter: 50 mm, thickness: 12 mm to serve as an abrasive medium. The specimens were cleaned before and after the wear tests using acetone. The each test was conducted for three times and average weight loss was noted. The wear rates (mm^3/m) were calculated from the weight loss measured.

3. Results & Discussions

The two body abrasive wear rate (mm^3/m) of the materials was plotted as a function of grit size at different loads and constant sliding distance of 75m. This was shown in Fig. 2(a)-(c). The wear characteristics were found to be having profound influence by load and type of emery paper used.

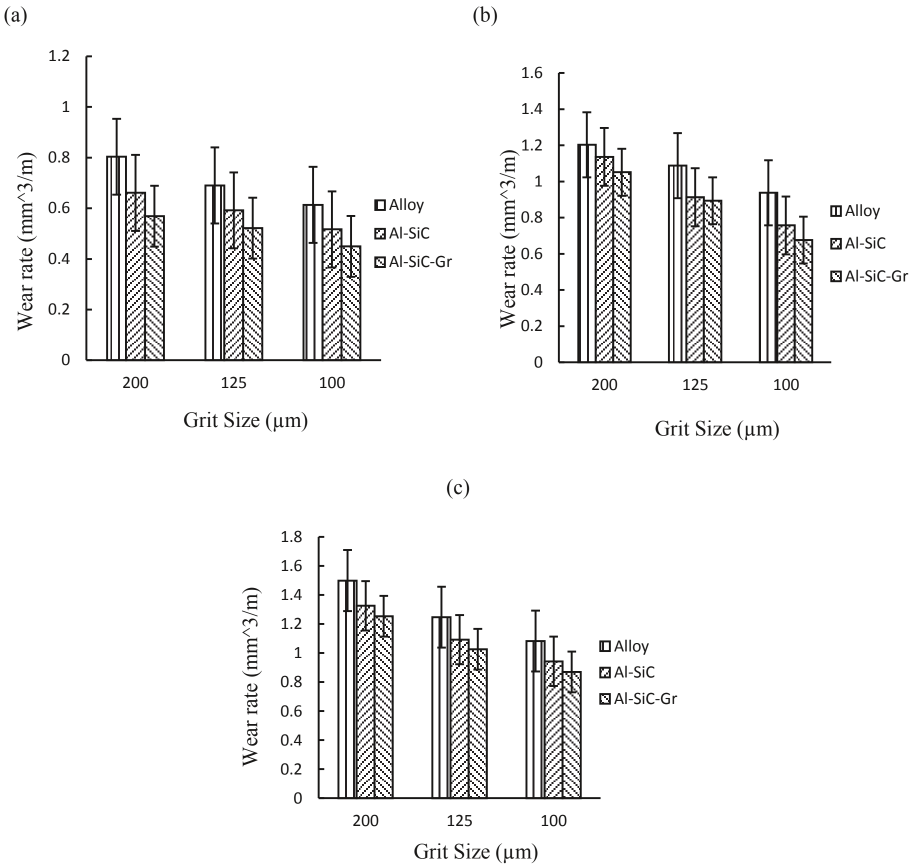


Fig. 2: Variation of wear rate of alloy and its composites at load (a) 5N (b) 10N and (c) 15N on abrasive grit size 100µm to 200µm at 75m sliding distance.

At 5N load and 200µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 0.8036, 0.6608 and 0.5684 respectively. This indicates the percentage improvement of wear rate is around 17.7 and 29.3 for Al-SiC and Al-SiC-Gr respectively. But on 100µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 0.6133, 0.5166 and 0.4496 respectively. This indicates the percentage improvement of wear rate is around 15.8 and 26.7 for Al-SiC and Al-SiC-Gr respectively. At 10N load and 200µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 1.2025, 1.1359 and 1.0511 respectively. This indicates the percentage improvement of wear rate is around 5.5 and 12.6 for Al-SiC and Al-SiC-Gr respectively. But on 100µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 0.9378, 0.7570 and 0.6759 respectively. This indicates the percentage improvement of wear rate is around 19.3 and 27.9 for Al-SiC and Al-SiC-Gr respectively. At 15N load and 200µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 1.4998, 1.3257 and 1.2539 respectively. This indicates the percentage improvement of wear rate is around 11.6 and 16.4 for Al-SiC and Al-SiC-Gr respectively. But on 100µm grit size, the wear rate of Al 6082 alloy, Al 6082-SiC composite and Al 6082-SiC-Gr composite was found to be 1.0825, 0.9429 and 0.8696 respectively. This indicates the percentage improvement of wear rate is around 12.9 and 19.6 for Al-SiC and Al-SiC-Gr respectively.

The worn surface analysis was done on tested pin sample surfaces as well as grit papers. Fig. 3 (a) and (b) shows the abraded surfaces of alloy pin at load of 5N and 15N respectively at 200µm grit size whereas Fig. 3 (c) and (d) shows the abraded surfaces of alloy pin at load of 5N and 15N respectively at 100µm grit size. Fig. 3 (e) and (f) shows the abraded surfaces of Al-SiC-Gr hybrid composite pin at load of 5N and 15N respectively at 200µm grit size whereas Fig. 3 (g) and (h) shows the abraded surfaces of Al-SiC-Gr hybrid composite pin at load of 5N and 15N respectively at 100µm grit size.

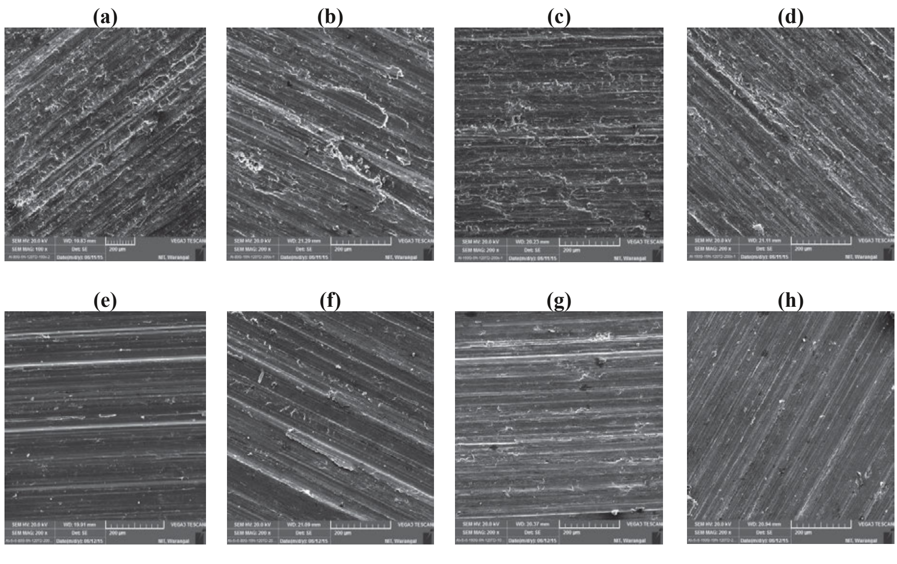
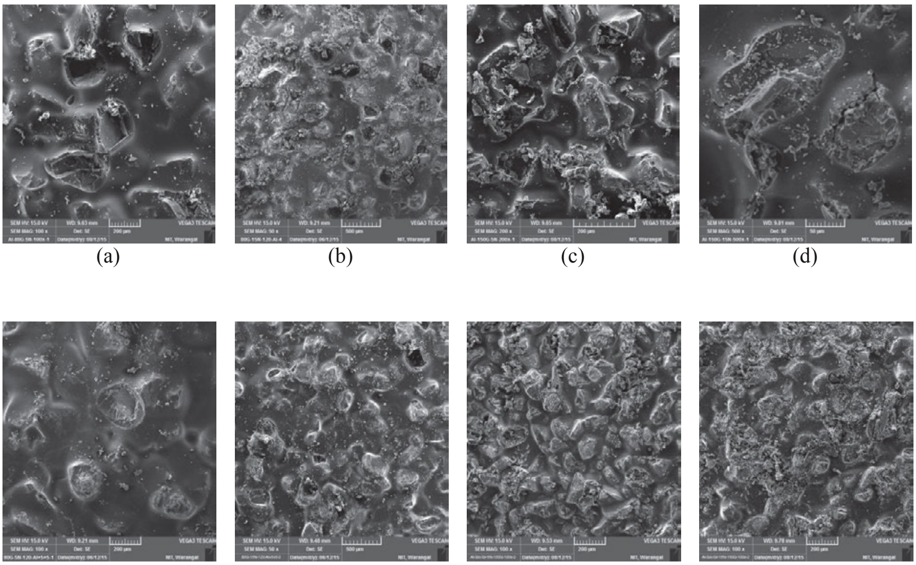


Fig. 3: Worn surface analysis of samples (a)Al 6082 alloy at load 5N and 200µm grit size (b)Al 6082 alloy at load 15N and 200µm grit size (c) Al 6082 alloy at load 5N and 100µm grit size (d)Al 6082 alloy at load 15N and 100µm grit size (e)Al 6082-SiC- Gr composite at load 5N and 200µm grit size (f)Al 6082-SiC- Gr composite at load 15N and 200µm grit size (g)Al 6082-SiC- Gr composite at load 5N and 100µm grit size (h)Al 6082-SiC- Gr composite at load 15N and 100µm grit size

Fig. 4 (a) and (b) shows the abraded surfaces of 200µm grit size paper tested on Al 6082 alloy at load of 5N and 15N respectively whereas Fig. 4 (c) and (d) shows the abraded surfaces of 100µm grit size paper tested at load of 5N and 15N respectively. Fig. 4 (e) and (f) shows the abraded surfaces of 200µm grit size paper tested on Al-SiC-Gr hybrid composite pin at load of 5N and 15N respectively whereas Fig. 4 (g) and (h) shows the abraded surfaces of 100µm grit size paper tested on Al-SiC-Gr hybrid composite pin at load of 5N and 15N respectively.



(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 4: Worn surface analysis of grit papers (a)Al 6082 alloy at load 5N and 200µm grit size (b)Al 6082 alloy at load 15N and 200µm grit size (c) Al 6082 alloy at load 5N and 100µm grit size (d)Al 6082 alloy at load 15N and 100µm grit size (e)Al 6082-SiC- Gr composite at load 5N and 200µm grit size (f)Al 6082-SiC- Gr composite at load 15N and 200µm grit size (g)Al 6082-SiC- Gr composite at load 5N and 100µm grit size (h)Al 6082-SiC- Gr composite at load 15N and 100µm grit size

The composite material typically will wear away by ploughing or cutting action of abrasive particles or asperities on the hard counter face. This will expose the protrusions of second phase particles present in the composite material. The further abrasion process will be hindered by the hard phased protrusions rather than soft one. The importance of the matrix material lies in the level of support given to the second phase particles. The more the capacities of the upholding capacity, the better wear resistance of the composite material.

The SEM characterization of abraded surface revealed that long continuous grooves have been formed. It was similar to that abraded surfaces during preparation of the metallographic specimens. The abrasive particles plough across the surface by displacing the material into ridges along groove sides. The worn surfaces of the composites show the shallow scratches when compared to alloy material. The wear tracks of the composite specimens exhibited a worn surface which is relatively smoother. This could be due to the tendency of microploughing is less on the surface of composite material. For the Al-SiC-Gr composites graphitic film would be formed and it would act as a lubricating layer [12,13,16]. During this eventual process of the abrasive wear, this layer could be removed first and after that hard SiC reinforcement particles takes role in further reduction of wear process. This indicates that the graphitic films tend to behave as a sacrificial layer in the initial wear process. Hence it was observed that the wear resistance was improved in the case of graphitized Al-SiC composites.

4. Conclusions

Based on the experimental investigation carried on materials the following conclusions were drawn:

- The composites were prepared using liquid metallurgy route.
- Two body abrasive wear tests were carried at load 5-15N and sliding distance 50-75m on 200µm grit size emery paper.
- As the load increases to 15N, the improvement of wear rate of Al-SiC and Al-SiC-Gr was 11.6% and 16.4% respectively when compared to alloy at 75m sliding distance.
- The Al-SiC-Gr composites yielded better abrasive wear resistance properties when compared with single SiC reinforced composite and alloy materials. The combination of SiC (hard) and graphite (soft) reinforcements found to beneficial due to formation of graphitic film which acts as an self-lubricant in Al-SiC-Gr composites.
- SEM analysis of worn surfaces revealed that shallower grooves were observed in graphitized composites when compared to alloy and un-graphitized composites.
- Lesser fragmentation of matrix material was observed on the surface of pin in case hybrid composites compared to alloy material.

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