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Effect of Silica on Sliding Wear Behavior of Silica reinforced Aluminium Alloy based Composites

Mallikarjuna G. B [1*], E. Basavaraj [2]

[1,2,3*]Department of Mechanical Engineering, JNN College of Engineering, Shimoga-577 204

mallikarjun.gb06@gmail.com, basavaraj@jnnce.ac.in

Abstract

This paper gave an insight on the effect of Silica (SiO_2) reinforcement particles on wear characteristics of Al LM13 alloy matrix based composites, Different combinations of composites reinforced with SiO_2 of different size (106µm, 150µm, 250µm & 355µm) and weight content (3, 6, 9 and 12%) were fabricated using stir casting route. Microstructural Characterization of fabricated composites indicates uniform distribution of SiO_2 particles in matrix material. Wear studies are conducted on ASTM standard Al LM13 alloy based composite specimens reinforced of different size and weight content of SiO_2. Effect of wear parameters (sliding speed, Load and sliding distance) on wear characteristics of Al LM13 alloy-SiO_2 composites have been investigated. Results indicated that wear resistance of fabricated composites are significantly improved with the addition of SiO_2 particles as compared to Al LM13 alloy matrix.

Keywords: *SiO_2 Particles, Al LM13alloy, Stir Casting, Wear*

1. Introduction

In recent days, industry demands for newer materials. Advanced materials like particulate reinforced composites are more popular due to simple processing method and cost factors leading to prospects for future applications [1]. Metal matrix composite (MMC) reinforced with hard ceramic particles results with tailored properties for electronics, space shuttle, commercial airliners, automobile applications [2]. High specific modulus, specific strength, damping and good wear resistance properties of MMC's significantly higher than compared to unreinforced base matrix alloys. [3-6].Particulate reinforced aluminium alloy matrix composites (AMC's) are more attractive materials due to their toughness, ductility and strength. These composites are produced by conventional casting methods like stir-casting. The aluminium alloy matrix material can be strengthened by reinforcing with hard ceramic particles materials like SiO_2, Al_2O_3 and SiC etc. The composite properties can be optimized by proper selection of process variables [7-8].

Significant properties of Al alloys improved the structural properties of composites reduces in fuel consumption because of less weight. Hence demand for automobile industry is more. The requirement of advanced materials are growing with specific tailor made materials fuelled research activities for further development of aluminium alloy based composites [9-10].

2. Materials and Methods

In this work, MMCs are fabricated through stir-casting, using Al LM13 aluminium alloy as matrix material which possesses good formability and toughness properties. Silica (SiO_2) of 106µm, 150µm, 250µm and 355µm are added as reinforcement with different weight content (3, 6, 9 and 12%) which is a hard particle combined with the soft lead-alloy provides excellent hardness. Al LM13 alloy composites test specimens were prepared as per ASTM standard. Composition and properties of Al LM13 alloy and SiO_2 reinforcement are given in Table 1and 2. Al LM13 is eutectic alloy having the low melting point in the Al-Si phase which is about 85 to 90% and silicon of 12% to 13%. Following objectives were planned in the experimental study.

1. To process light weight advanced material used in Automobile parts.

2. To fabricate Al alloy LM13-SiO_2 composite by stir-casting method.

3. Microstructural Characterization of fabricated composites using optical microscope.

4. Evaluation of wear properties by varying wears parameters.

5. SEM analysis to know the surface damage and bonding.

Table 1: Al LM13 alloy chemical Composition

Elements	Zn	Mg	Si	Ni	Fe	Mn	Al
Wt.%	0.5	1.4	12	1.5	1.0	0.5	Balance

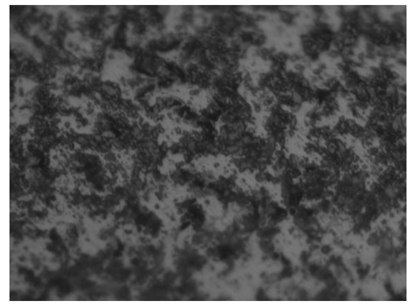
Table 2: Physical and Mechanical Properties of Al LM13 alloy and SiO_2

Properties	**Al alloy LM13**	**SiO_2**
UTS(MPa)	220	25
Density (g/cc)	2.7	2.65
Melting Temperature(°C)	695	1830

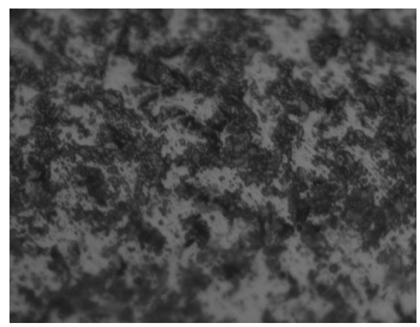
3. Results

3.1 Microstructure

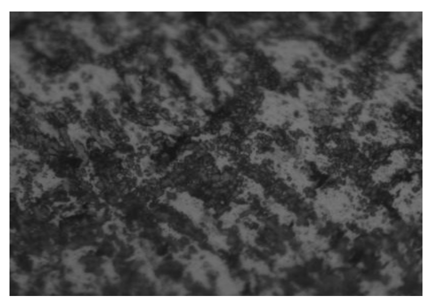
Microstructure images of Al alloy LM13-SiO_2 as cast composites, indicates the aluminium LM13 alloy dendrites and silicon eutectic phase in the regions of interdendritic and around the structure of dendrites. The micro structures of LM13 Al alloy with of 3 to 12 wt.% silica composites of different particulate size shows the uniform distribution of silica particles in aluminium matrix phase in as cast condition. Figure 1 shows the Micrographs of fabricated composites of different particle size and weight content of silica reinforcement.



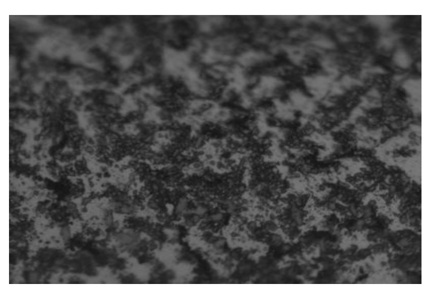
3%SiO_2 (106µm)



6%SiO_2 (150µm)



9%SiO_2 (250µm)



12%SiO_2 (355µm)

Figure 1: Optical Micrographs of Al LM13 alloy-Silica of different size (100X).

3.2 Wear Results

Wear studies are conducted using Pin-on Disc test type DUCOM make wear testing machine and ASTM G99 standards are used for test. Surface loss and progressive damage occurs as a result of relative motion with the counter surface. Sliding wear behaviour of Al- SiO_2 composite depends on the microstructure and mechanical properties along with wear parameters (load, speed and sliding distance along with temperature, environment and counter face material. Figure 2 shows the schematic diagram of the wear test specimen figure 3 shows wear machine set up used in the laboratory.

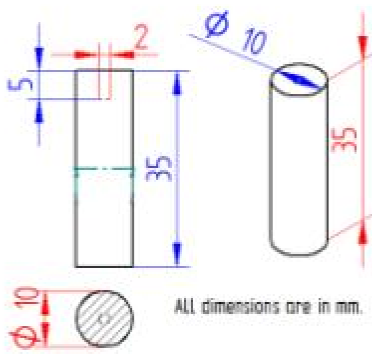


Figure 2: Wear Test Specimen

Figure 3: Wear Testing Machine

3.2.1 Effect of Sliding Speed

Figure 4 shows, wear in terms of weight loss of Al LM13 alloy, that increases with increase in sliding speed (400, 500 and 600rpm) under normal constant load of 10 N and sliding distance of 1000m.Wear was decreased by adding of inter metallic material into the base alloy. wear rate was increased as the sliding speed increases, less loss of material due to wear was found as the amount of reinforcement increases[11].

3.2.2 Effect of Sliding Distance

Effects of wear rate of Al LM13 alloy on sliding distance under constant sliding speed of 500rpm and load of 10N. Figure 5 indicates that, wear in weight loss of Al LM13 alloy increases with increase in sliding distance (800, 1000, 12000 m) in the entire testing. The addition of reinforcing particles shows that the wear in weight loss decreases.This reduction in wear due to reinforcement of hard silica particles that forms a layer between the surface of the sliding pin and the composites [11].

3.2.3 Effect of Load

The effects of wear rate on reinforced Al LM13 alloy by the varying load under normal constant sliding speed of 500 rpm and sliding distance of 1000 m It is well known that, as load increases, material wear also increases due to surface contact of the rotating disc. However, in reinforced Al LM13 alloy, wear rate is less due to hard particles of silica as reinforcement. It is clear that, the wear in weight loss increases with increase in load (10N, 20N, 30N, 50N and 70N) as shown in Figure 6. The results as shown in figure 6, reflects that the reinforcements in metal matrix composites are more useful to wear resistance at minor loads. Increasing wear loss of material is proportional to the increasing load. The addition of silica reinforcement in the base alloy will have an effect of reduction in weight loss due to the formation of oxide layer called glaze between particles[11].

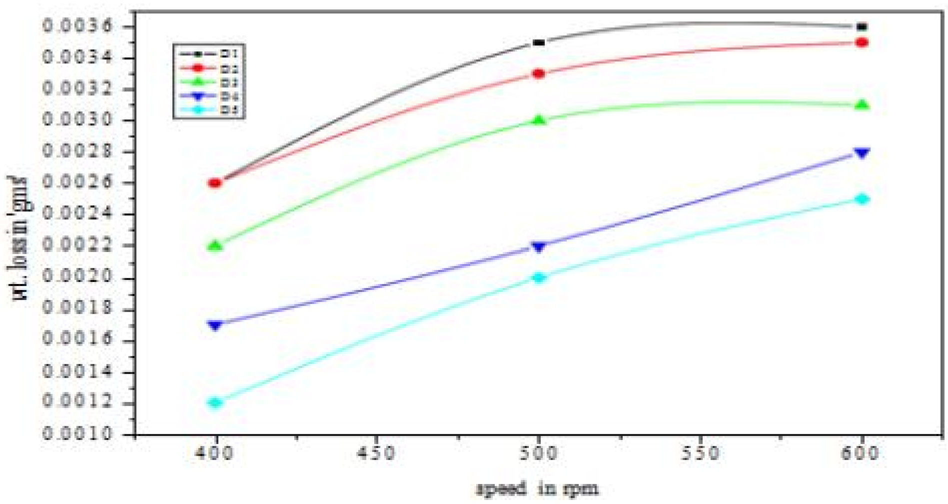


Figure 4: Sliding Speed v/s Wt. Loss at constant Load (10N) and Sliding Distance (1000m)

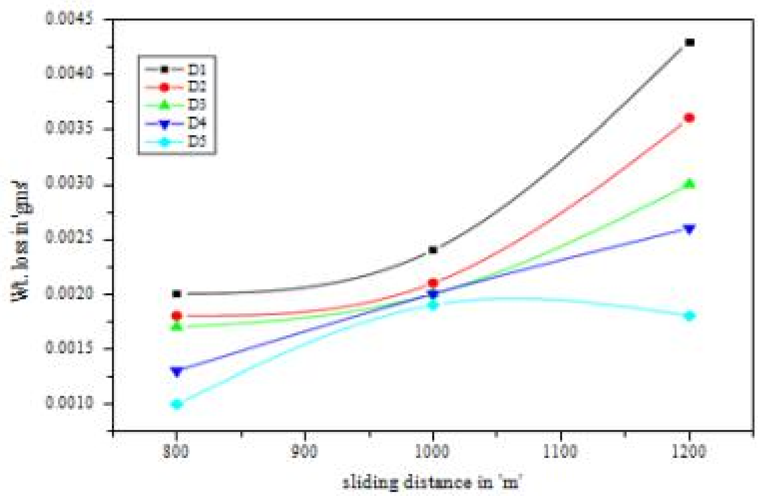


Figure 5: Sliding Distance v/s Wt. Loss at constant Sliding Speed (500rpm) and Load (10N).

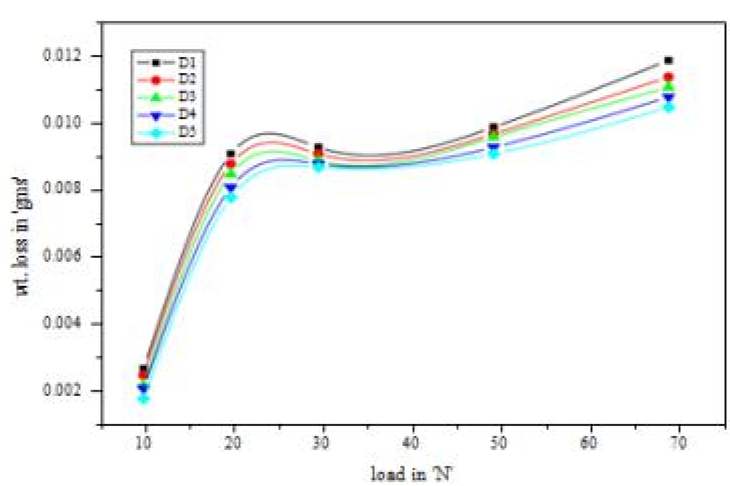
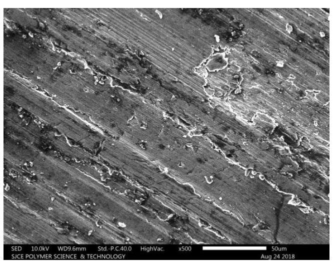


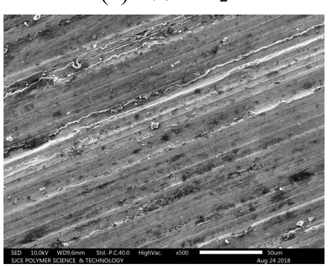
Figure 6: Load v/s Wt. Loss at constant Sliding Speed (500rpm) and Sliding Distance (1000m)

3.2.4 SEM Analysis

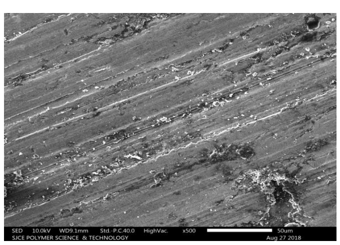
Worn out surfaces of tested composites are analysed using Scanning Electron Microscope (SEM). SEM images reveals surface damage and bonding of composite specimen under different tested conditions. Wear behaviour of tested composites indicates fracture surface with the presence of flake type debris with large amount of delamination. Due to higher temperature and the pressure on abrasive particles that leaves deeper indentations along the sliding direction with the delimitation exhibiting for higher wear rate [12]. Figure 7 shows the SEM images of fractured surfaces under different wear studies.



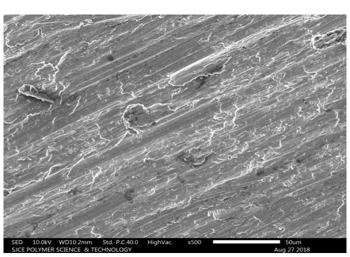
(a) 3% SiO_2



(b) 6% SiO_2



(c) 9% SiO_2



(d) 12% SiO_2

Figure 7: SEM Micrographs of Al LM13 alloy-Silica of 106μm

4. Conclusion

The wear studies on Al LM13 alloy-Silica MMCs results with significant contributions, which are as follows.

1. The microstructural graphs revealed that the distribution of reinforcement particles in the matrix alloy material is uniform.

2. The wear properties are considerably increases with the addition of inter metallic particles of SiO_2 particles and the wear resistance of reinforced particles.

3. Wear rate of Al LM13-SiO_2 MMCs strongly depends on composition of SiO_2 reinforcement.

4. Al alloy LM13-Silica composites exhibits superior wear properties compare to matrix alloy.

5. SEM images reveals nature of wear loss, surface damage and bonding of the composites.

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