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Dry-Sliding Wear Behavior of Aluminum Metal-Matrix Composites Produced by Modified Stir Casting Method

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Abstract

Light weight high strength materials like Aluminum Metal Matrix Composites (AMMC) are very useful in automobile and industrial sectors. Out of different method of composite manufacturing, modified stir casting method is very efficient and least cost in liquid route. The wear behavior of Al-2Mg and SiC Composite with different composition were tested in dry sliding condition using pin-on-disc tribometer. The composites (AMMC) are manufactured by modified stir casting in liquid route with three different compositions such as 4%, 8% and 12% SiC. The samples are cut to size for wear test in dry sliding condition. The results show that wear rate decreases with increase in silicon carbide content. As the normal loads increases, the cracks and combination of abrasions, delimitation andwear of the adhesives of silicon carbide particles were observed.

Keywords: Aluminum metal matrix composites / modified stir casting / Reinforcement / Wear

1. Introduction

Ideally, there is a common-practice to fully replace the present structural material to a higher yield strength material with possible inclusion of reinforcements. The introduction of light-weight, high-performance metal-matrix composites for the aero space, consumer and automotive sectors has been difficult due to the high-cost of the components or even negligibly complex shape. Modified stir casting can be the key technique to trounce these problems, although there have been several technical problems. Achieving with a smooth distribution of reinforcements within the metal-matrix is one of these problems which directly affect the quality and properties of the composite material. Continuous reinforced aluminum metal-matrix composites have required properties like low density, high specific stiffness and strength, controlled co-efficient of thermal expansion, resistance to increased fatigue and excellent dimensional fastness at a very high temperature [1–4]. The most frequently used matrix- composite system consisting of an Al alloy rein-forced with solid-carbide particles i.e. silicon carbide and others [5–6]. These composites have various amplification methods compared to continuous reinforced-composites or traditional materials [7–10].

Wear is a material removal process from a solid body from its surfaces by solid state contact. As it is a surface removal phenomenon and occurs mainly at the level of external surfaces, it is more eco- nominal and appropriate to modify the surface materials to wear resistant materials. The presence of hard reinforcing elements gives the composite to an excellent tribological characteristic (wear and friction) of the material. Properties as well as good specific modulus and resistance make the compo- site to a suitable material for different technical applications in sliding contacts where it is expected. All the mechanical members that roll or slide are subjected to wear. Wear acts in the surfaces that oc cur when the material is moved or torn off, as it usually involves progressive weight loss and resizing over a period of time. An indepth study is required for the dry sliding wear characteristic which influences the volume-fraction reinforcements and its size, applied load, sliding distance, sliding speed, phase, and hardness of the surface of the work [11, 12]. The study has been reported that different wear parameters affect sliding speed and wear characteristics [13–16]. The tribological characteristics of Al Mg/silicon carbide metal-matrix composite indicate with increase in mechanical properties, the wear-resistance increases sharply and it affects the surface predominately [17–20].

Based on the above description, the study attempted to enhance the dry sliding wear behavior of aluminum composites reinforced with silicon carbide particles at varying speeds and sliding distance, so that this will more appropriate and adapted to difficult conditions

2. Experimental procedures

2.1 Apparatus

The modified stir casting apparatus (Shown in Fig-1) is used to produce Aluminum- 2% Mg and 4%, 8% and 12% SiC composite. Here the feeding of Magnesium turnings and SiC particles to the Aluminum melt was done by plunger rods. The plunger rods are the perforated mild steel capsules which has wrapped with Aluminum foil containing SiC particles and Mg turnings.

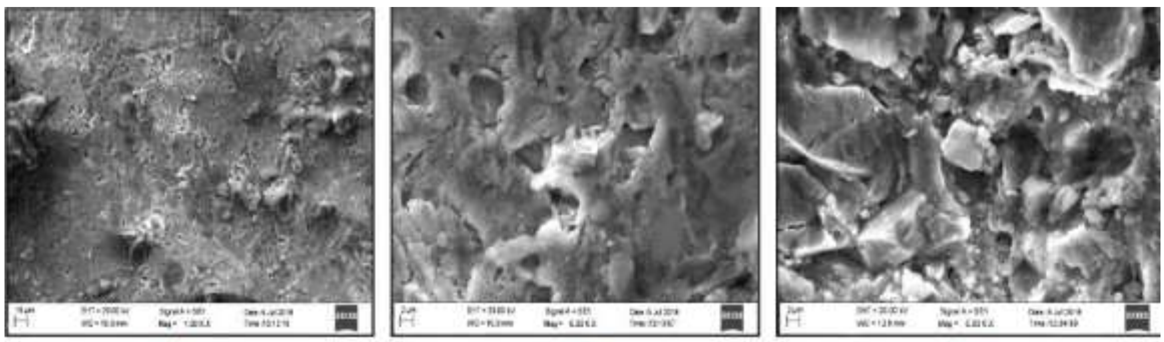
Fig-1: Modified Stir Casting Apparatus

2.2 Preparation of the composites

First commercially pure Aluminum ingot was taken in the furnace of apparatus which was set to the temperature of 800^0C. Then plunge rods containing Mg turning and SiC particles of required compositions were fed to Aluminum melt to produce Aluminum- 2 % Mg and 4%, 8% and 12% SiC by weight. The manufactured composites are cut to size to get different testings.

2.3 Microscopic study

Aluminum matrix-composites produced through modified stir casting process were subjected to a scanning electron microscope (Brand: Zeiss) to determine their micro structural characteristics. Composite samples of 10 mm × 10 mm were cut from samples for micro-structural studies. The microscopic views of the aluminum matrix composites with 4 percent, 8 percent and 12 percent silicon carbide reinforcements were studied by the scanning electron microscope; *Figure 2*a–c. Non-homogeneous dispersal of the reinforced particles was clearly detected inside the composites and was evenly distributed over the composites.



(a) (b) (c)

Fig-2: Scanning electron microscopic view of sintered aluminum metal matrix composite with (a) 4 wt.% silicon carbide reinforcement (b) 8 wt.% silicon carbide reinforcement (c) 12 wt.% silicon carbide reinforcement

2.4 Density

The density of AMMC produced was calculated as per the following formulae.

Density of aluminum metal matrix composite with silicon carbide 4 wt. % reinforcement

Density of composite (ρ_4) = Mass/Volume = 2.574 g/cm^3

Density of aluminum metal matrix composite with silicon carbide 8 wt.% reinforcement

Density of composite (ρ_8) = Mass/Volume = 2.783 g/cm^3

Density of aluminum metal matrix composite with silicon carbide 12 wt. % reinforcement

Density of composite (ρ_{12}) = Mass/Volume = 2.876 g/cm^3

2.5 Hardness

The composite sample hardness was measured with a Vickers hardness-testing instrument with a load of 10 kg-force, retention time 10 s. In the Vickers hardness of aluminum metal matrix composites with 8 percent, 10 percent and 12 percent silicon carbide particles reinforcement were found to be 174.5 HV 10, 206.5 HV 10 and 226.5 HV 10 respectively, It is established that the hardness is greater than that of aluminum. This was due to the fragile solid silicon carbide particles presence in the aluminum alloy matrix. The hardness of the material exhibits its better wear resistance.

3. Dry sliding wear test

Fig-3: Ducom-Pin-On-Disc Apparatus

The dry sliding wear test was performed using a pin-on-disc tribometer (DUCOM-PIN-ON-DISC) for aluminum metal matrix composite, *Figure3*. Before the test, the pin and the surface of the disc were polished with sandpaper, so that the contact would be smooth. All wear tests were carried out in accordance with ASTM-G99 standards under non lubricated conditions at normal atmospheric temperature (30°C) and 70 percent relative humidity. Weight loss in the composite sample after each wear test was calculated by electronic weighing device. Measures have been taken to ensure that the test samples are constantly cleaned to avoid trapping of residual wear and uniform receipt in the experimental procedure.

The cylindrical pin samples were cut to a size of 10 mm in diameter and 30 mm in length. Tests were performed for various axial load of 25 N and the sample (pin) was located on a certain track diam. During the experiment, the samples remain stationary and the disc spins. Loads were applied via the dead loads to compress the pin onto disc. Rotational speed of the disc via motor can be modified through the controller, and then the wear test parameters have been tabulated. The cumulative mass loss and the wear rate at different sliding distances under different loads were measured for the aluminum metal matrix composite samples.

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4. Results & Discussions

4.1 Mathematical calculations

The different wear parameters are calculated up to three decimal points as:

- Cumulative volume loss = $\frac{\text{cumulative weight loss}}{\text{density}}$
- Wear rate (Wr) == $\frac{\text{cumulative weight loss}}{\text{sliding distance}}$
- Specific wear rate = $\frac{\text{wear rate}}{\text{load}}$

4.2 Wear test with the load of 25 N

The cumulative weight loss, cumulative volume loss, wear rate and specific wear rate for aluminum based metal matrix composite produced with theload 25 N *Tables 1–5*.

Table 1. For sliding speed – 2 m/s, load –25 N, sliding distance – 500 m.

Sl. No.	Silicon carbide (%)	Cumulative Weight loss (g)	Cumulative Volume loss (m^3)	Wear rate (m^3/m ($\times 10^{-3}$))	Specific Wear rate (m^3/MN)
1	4	0.0051	1.981	3.962	0.158
2	8	0.0034	1.221	2.442	0.097
3	12	0.0021	0.730	1.460	0.058

Table 2. For sliding speed – 1.5 m/s, load – 25 N, sliding distance – 1000 m.

Sl. No.	Silicon carbide (%)	Cumulative weightloss (g)	Cumulative Volume loss (m^3)	Wear rate (m^3/m ($\times 10^{-3}$))	Specific Wear rate (m^3/MN)
1	4	0.0069	2.680	2.680	0.107
2	8	0.0054	1.940	1.940	0.077
3	12	0.0028	0.973	0.973	0.038

Table 3. For sliding speed – 1.5 m/s, load – 25 N, sliding distance – 1500 m.

Sl. No.	Silicon carbide (%)	Cumulative weightloss (g)	Cumulative Volume loss (m^3)	Wear rate (m^3/m ($\times 10^{-3}$))	Specific Wear rate (m^3/MN)
1	4	0.0091	3.535	2.356	0.094
2	8	0.0072	2.587	1.724	0.068
3	12	0.0046	1.599	1.066	0.042

Table 4. For sliding speed – 1.5 m/s, load – 25 N, sliding distance – 2000 m.

Sl. No.	Silicon carbide (%)	Cumulative weightloss (g)	Cumulative Volume loss (m^3)	Wear rate (m^3/m ($\times 10^{-3}$))	Specific Wear rate (m^3/MN)
1	4	0.0121	4.700	2.350	0.094
2	8	0.0096	3.449	1.724	0.068
3	12	0.0061	2.121	1.060	0.042

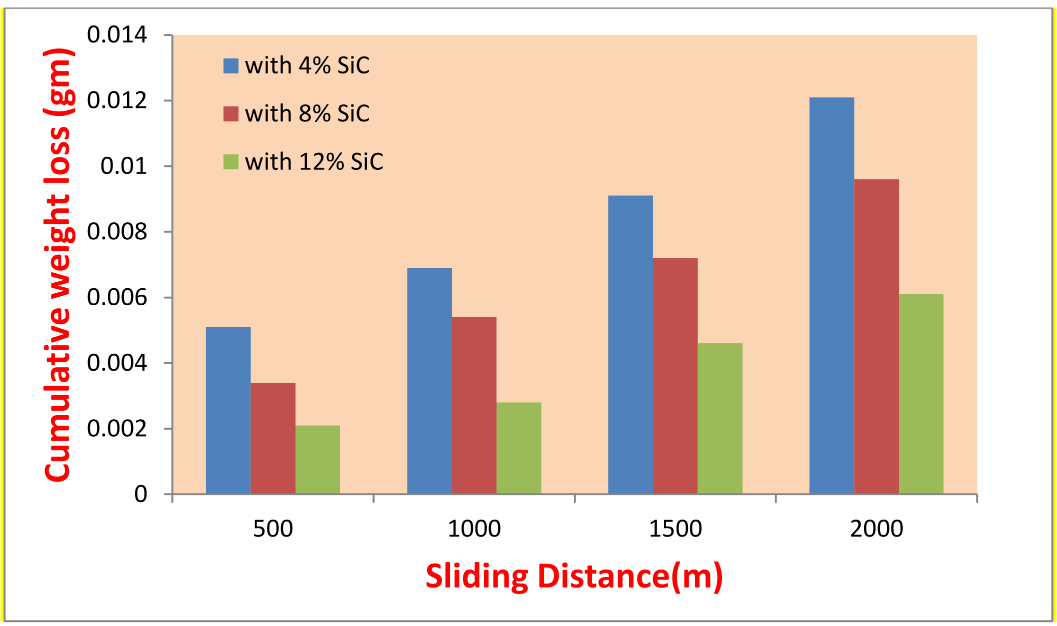

Fig-4: Silicon carbide percentage (%) vs. cumulative weight loss at load 25 N.

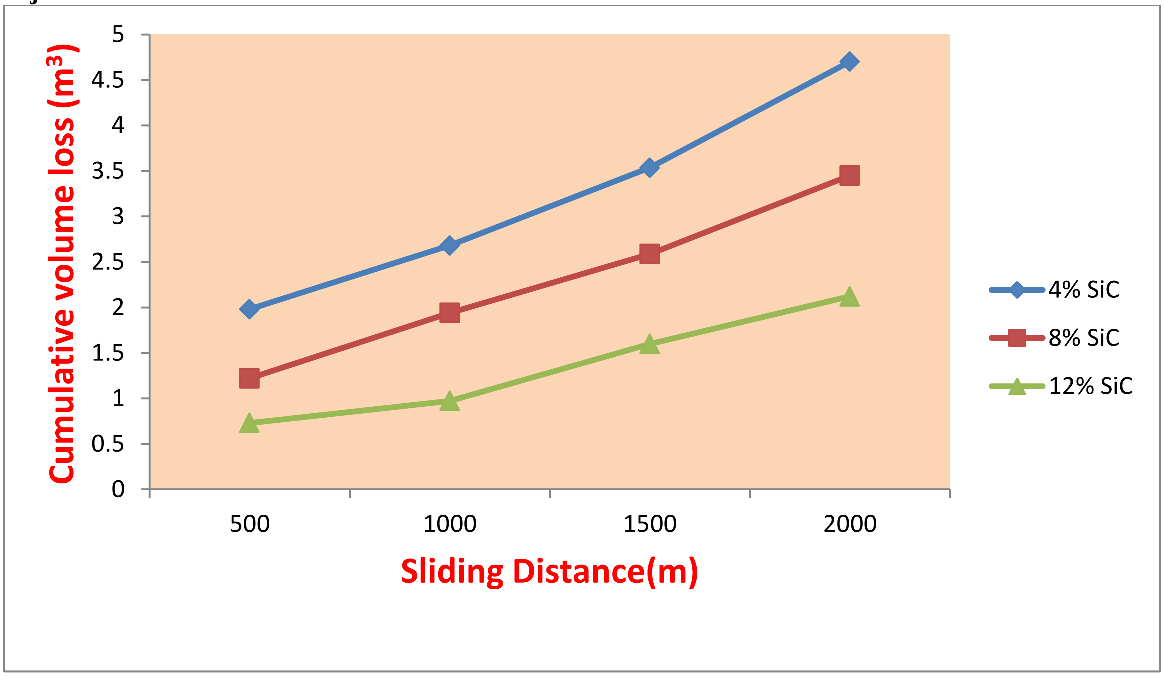

Fig-5: Sliding distances vs. cumulative volume loss

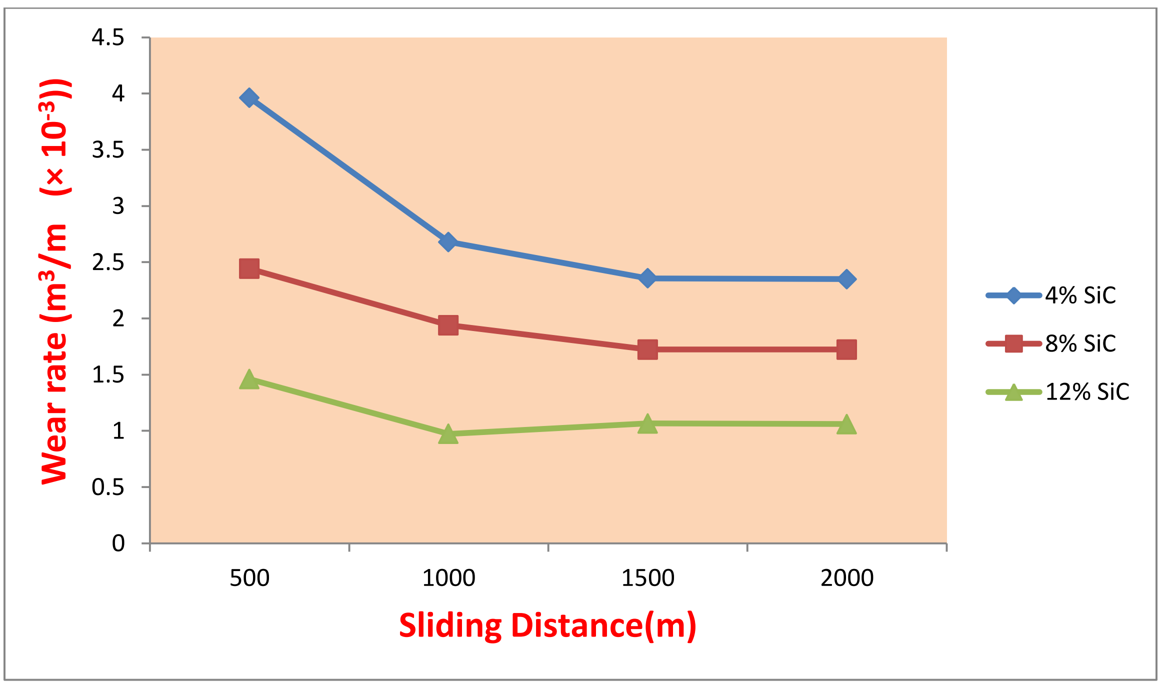

Fig-6: Sliding distances vs. wear rate.

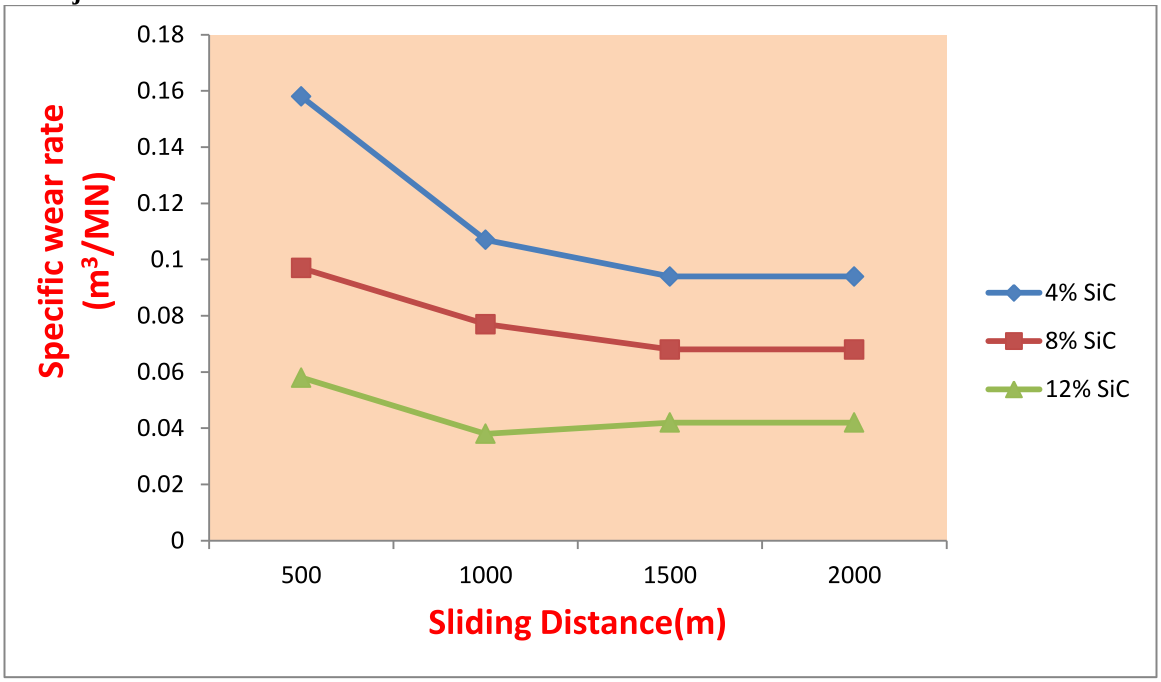

Fig-7: Sliding distances vs. specific wear-rate.

The graphs have shown that with increasing sliding-distances during tests the cumulative weight-loss of the composite would increase. The sliding distances increased, the cumulative volume-loss also increased, and then it was almost the same for the entire tests.

5. Conclusion

The wear rate decreases with an increase in the sliding speed for the loads of 25N because the surface hardening of the sample i.e. formation of iron oxide and crushing of silicon carbide particles. This shows that of wear volume loss increases with increasing sliding distance and decreases with increasing particle contents of silicon carbide. The loss of wear volume in Al-2% Mg and 4%, 8% and 12% SiC composite was higher with increasing order of SiC. From the results it is concluded that the composite material having silicon carbide content 12 percent shows greater wear resistance compared with other two composite materials 4 percent and 8 percent silicon carbide. So, the silicon carbide particles may be used as a reinforcing material to increase the properties of aluminum based metal matrix composites which can be used in different automobile applications.

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