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Aluminum Metal-Matrix Composites Made by a Modified Stir Casting Method: Dry-Sliding Wear Behavior

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Abstract:
The automotive and industrial sectors can benefit greatly from lightweight, high-strength materials like Aluminum Metal Matrix Composites (AMMC). Modified stir casting is the most effective and affordable liquid route among the several composite manufacturing methods. Using a pin-on-disc tribometer, the wear characteristics of Al-2Mg and SiC Composites of various compositions were evaluated. The composites (AMMC) are produced using a modified stir casting method in a liquid medium with three distinct SiC compositions: 4%, 8%, and 12%. The samples are size-cut for the wear test in the dry sliding condition. The findings indicate that as silicon carbide content increases, wear rate reduces. The cracks and combination of abrasions, delimitation, and wear of the silicon carbide particle adhesives were seen as the normal loads increased.
Keywords: Aluminum metal matrix composites; Modified stir casting; Reinforcement; Wear

1. Introduction

The ideal situation would be to completely replace the current structural material with a material that has a higher yield strength, possibly with reinforcements. The high cost of the components or even a little complex shape has made it challenging to provide light-weight, high-performance metal-matrix composites for the aerospace, consumer, and automotive sectors. Although there have been a number of technical issues, modified stir casting can be the main way to overcome these issues. One of these issues that directly impacts the quality and attributes of the composite material is achieving with a smooth distribution of reinforcements within the metal-matrix. The needed features of continuous reinforced aluminium metal-matrix composites are low density, high specific stiffness and strength, controlled thermal expansion, resistance to increased fatigue, and outstanding dimensional fastness at very high temperatures [1-4]. The most popular type of matrix-composite system is one that uses silicon carbide and other solid-carbide particles to reinforce an aluminium alloy [5–6]. Compared to continuous reinforced composites or conventional materials, these composites have a variety of amplification mechanisms [7–10].

Wear is the process of material removal from a solid body from its surfaces through solid state contact. It is more ecologically and logical to adapt the surface materials to wear resistant materials since it is a surface removal phenomenon that mostly affects exterior surfaces. The composite has good tribological properties (wear and friction) because to the strong reinforcing components included. The composite is a suitable material for many technological applications in sliding contacts where it is predicted due to its good specific modulus and resistance properties. Wear can occur on any mechanical component that

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rolls or slides. When the material is shifted or pulled off, wear affects the surfaces because it often entails gradual weight loss and resizing over time. An in depth 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 AlMg/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. Experimentalprocedures

2.1 Apparatus

The modified stir casting apparatus (see Figure 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.

Figure 1: Modified Stir Casting Apparatus

2.2 Preparationofthecomposites

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.

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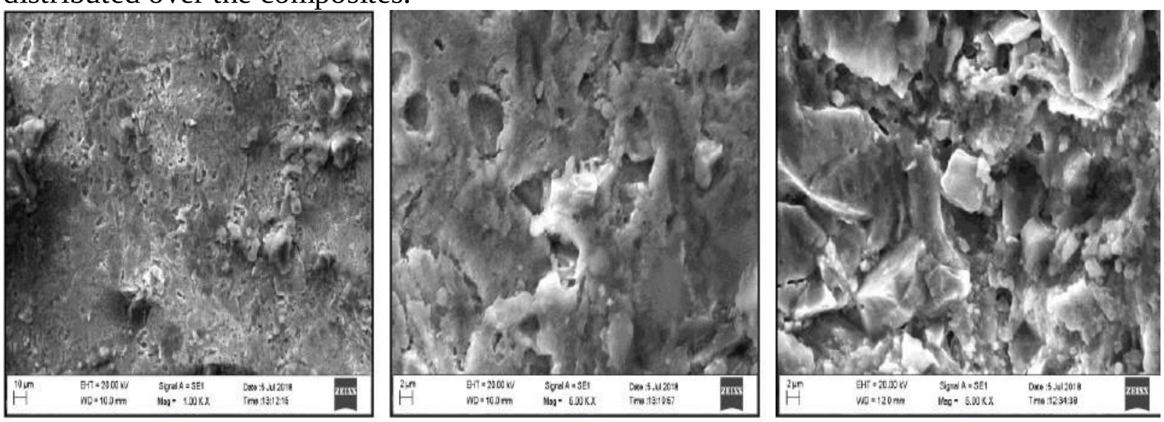
2.3 Microscopicstudy

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 of10 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)

Figure 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 carbide12 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 HV10, 206.5 HV 10 and 226. 5HV 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 weartest

Figure 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.

4. Results & Discussions

4.1 Mathematicalcalculations

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 Weartestwiththeloadof25 N

The cumulative weight loss, cumulative volume loss, wear rate and specific wear rate for aluminum based metal matrix composite produced with the load 25 N *Tables1–5*.

Table 1: For slidingspeed–2m/s, load–25N,sliding distance–500m

Sl. No.	Silicon carbide (%)	Cumulative Weight loss (g)	Cumulative Volume loss (m^3)	Wear rate(m^3/m (×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 (×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 (×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 slidingspeed–1.5m/s, load–25N,sliding distance–2000m

Sl. No.	Silicon carbide (%)	Cumulative weightloss (g)	Cumulative Volume loss (m^3)	Wear rate (m^3/m (×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

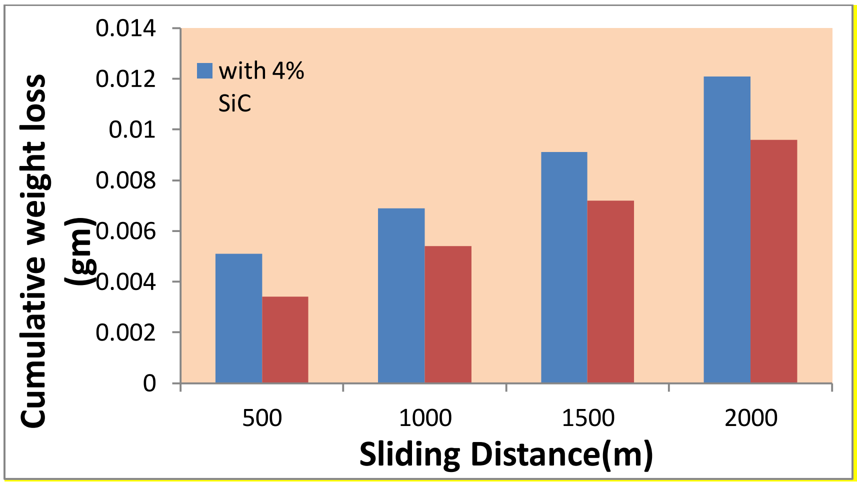


Figure 4: Silicon carbide percentage (%) vs. cumulative weight loss at load 25 N

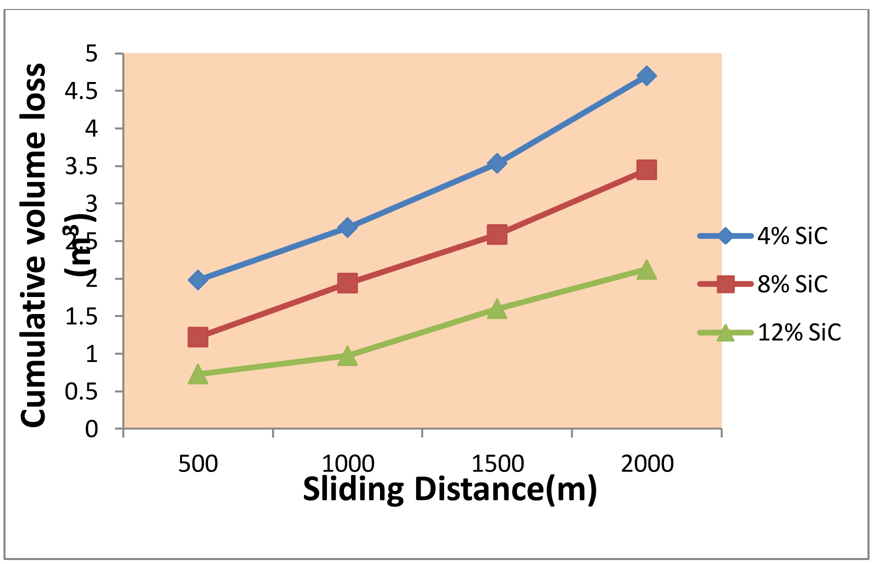


Figure 5: Sliding distances vs. cumulative volume loss

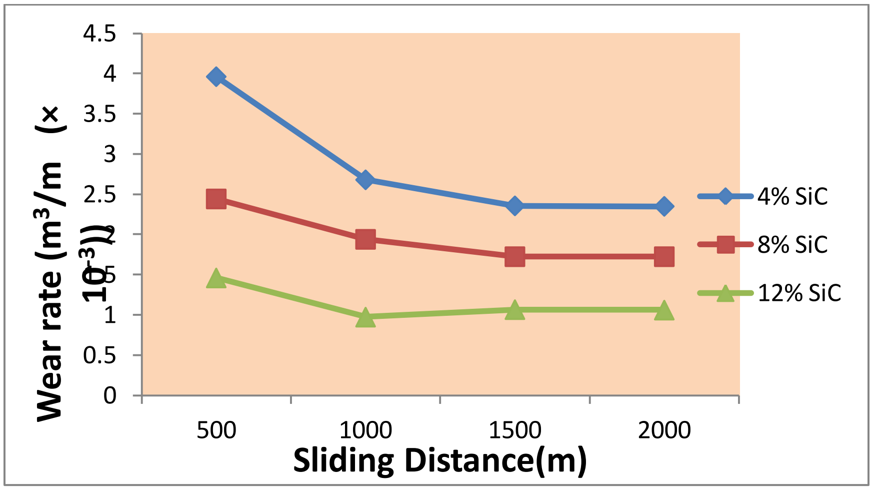


Figure 6: Sliding distances vs. wear rate

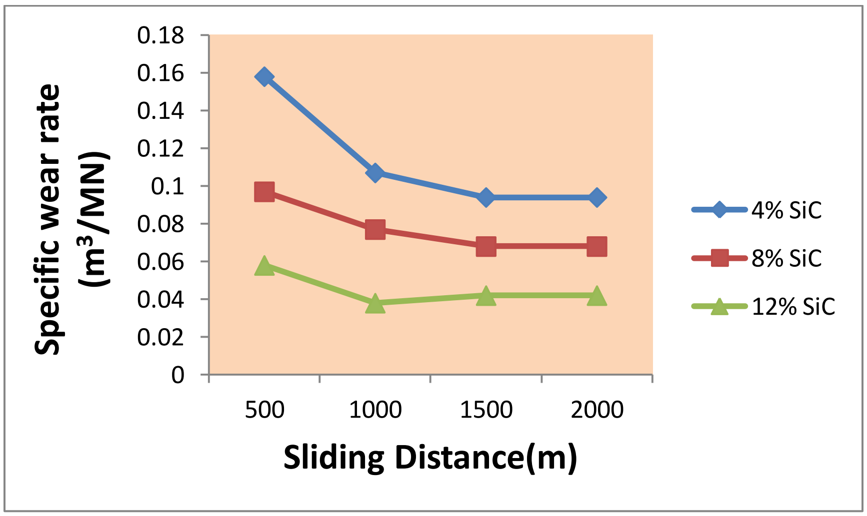


Figure 7: Sliding distances vs. specific wear-rate

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

With loads of 25N, the wear rate reduces as the sliding speed rises due to the sample's surface hardening, which includes the development of iron oxide and the crushing of silicon carbide particles. This demonstrates that wear volume loss rises with increasing sliding distance and falls with rising silicon carbide particle concentrations. The loss of wear volume in the Al-2% Mg and 4%, 8%, and 12% SiC composite increased with SiC order. From the findings, it can be deduced that the composite material with silicon carbide content of 12 percent exhibits stronger wear resistance than the other two composite materials with silicon carbide contents of 4 percent and 8 percent. In order to improve the qualities of aluminum-based metal matrix composites that can be employed in various automobile applications, silicon carbide particles may be added as a reinforcing material.

References

[1] R.K.Behera,B.P.Samal et al. Erosion Wear Characteristics of Novel AMMC Produced Using Powder Metallurgy, Arch. Metall. Mater. 67 (2022), 3,PP 1027-1032
[2] P.K Rohatgi, Metal-matrix Composites, Defence Science Journal, Vol.43, No 4, October 1993, pp323-349.
[3] M. K. Surappa. Aluminum matrix composites: Challenges and opportunities. Sadhana February/April 2003;28(1 &2):319–334p.
[4] A.K.Dhingra, “metal replacement by composite”, *JOM* 1986, Vol 38 (03), p. 17.
[5] K.Upadhya, “composite materials for aerospace applications, developments in ceramic and metal matrix compositesTMS publications, 1992, pp. 3-24.
[6] Greg Fisher, “Composite: Engineering the ultimate material”, Am. Ceram. Soc, Bull. Vol. 63 (2), pp. 360-364.
[7] T.G.Nieh, K.R. Forbes, T.C. Chou and J. Wadsworth, TMS-New Jersey, 1990, pp 85-96.
[8] T. W. Clyne, An Introductory Overview of MMC System, Types and Developments, in Comprehensive Composite Materials, Vol-3; Metal Matrix Composites, , 2000, pp.1-26.
[9] P.C. Maity, P.N. Chakrabarty, S.C. Panigrahi: *Journal of Material Science*, 1996, 31, 6377 – 6382
[10] P.K. Rohatgi, R.Asthana and S. Das Int. Met Rev.,Vol.31 No. (1986) P-115-139.
[11] R.K.Behera,B.P.Samal,S.C.Panigrahi, K.K. Muduli, *Hindawi Advances in MaterialsScienceandEngineering.*2020,*2020*,1,1893475.
[12] S. Basavarajappa, G. Chandramohan, R. Sub-ramanian,A.Chandrasekar,*MaterialsSci-ence-Poland.*2006,*24*,358.
[13] S.Das,S.V.Prasad,T.R.Ramachandran, *Wear.*1998,*133*,173.
[14] G.Ferhat,A.Mehmet,*Comp.Sci.Technol.* 2004,*64*,959.
[15] J. Hashim, L. Looney, M.S.J. Hashmi, *Mater.Proc.Technol.*2002,*123*,251.
[16] S.A. Kori, T.M. Chandrashekharaia, Wear. 2007, 263, 745.
[17] H. Alrobei, J. of Mechanical Science and Technology. 2020, 34, 1.
[18] R.K Behera, B.P. Samal, S.C. Panigrahi, Ma- tériaux & Techniques. 2019, 107, 605; Tech-niques. 2019, 107, 605.
[19] R.L. Deuis, C. Subramanian, J.M. Yellup, Wear. 1996, 201, 132.
[20] B. Stojanovic, J. Blagojevic, M. Babic, S. Ve- lickovic, S. Miladinovic, Industrial Lu- brication and Tribology. 2017, 69, 1005.
[21] T. Satish, S. Karthick, Jounal of Materials Re- search and Technology. 2020, 1340 1–7.