RESEARCH ARTICLE

RSP Science Hub

International Research Journal on Advanced Science Hub
2582-4376
Vol. 05, Issue 04 April 2023
www.rspsciencehub.com

Check for updates

http://dx.doi.org/10.47392/irjash.2023.029

An Experimental Inquire on Dry Sliding Wear Behaviour of Al-Si-Mg-Cu-SiC Composites Fabricated by Metallurgical Powder Technique

Steve Ales[1], Rajesh Kumar Behera[2], Kamalakanta Muduli[1]

[1]*Department of Mechanical Engineering, Papua New Guinea University of Technology,, Lae, Morobe Province, Papua New Guinea*

[2]*Department of Mechanical Engineering, Krupajal Engineering College, Bhubaneswar, Odisha, India*

Email: kamalakantam@gmail.com

Article History

Received: 16 March 2023
Accepted: 24 April 2023

Keywords:

Powder Metallurgy;
Reinforcements;
sintering;
Wear;
Aluminium Metal Matrix Composite

Abstract

At present, material properties are being continuously improved in line with current technological developments to meet operational and safety standards. Designers and consumers now look for materials that are more energy efficient, stronger, lighter as well as cheaper. A metal-matrix composite (MMCs) will represents a dominant class of material which can be suitably designed to meet the above requirements. With a variety of reinforcing materials and flexibility in their preliminary processing, Aluminum Metal-Matrix Composites (AMMCs) offer great potential for developing composites with desired properties for larger applications. In this research, a novel composite has been fabricated with Silicon, Magnesium, Copper, Silicon Carbide and Aluminium with 0.5, 0.5, 2.5, 15 and 81.5 percent respectively by weight using the metallurgical powder technique. The composite has been studied and investigated its wear behavior in dry sliding mode and found that the wear-rate increases with load applied as well as with sliding-speed and decreases with increase in percent of SiC content in the composites.

1. Introduction

Not only are metal-aluminum matrix composites suitable replacements for structural steels, but they are also suitable replacements for aluminum-based alloys in a range of applications in the automotive and aerospace industries. They offer a great deal of potential for the production of lightweight materials that do not compromise their strength. To accomplish the same goal of reducing the size while maintaining the same level of strength, it is common practice to substitute the existing material with one that has a greater yield strength. Another method for reducing overall weight is to replace certain conventional ferrous-based components with lighter composite materials in particular locations. This can be done selectively. There has been a recent uptick in the use of high-performance and lightweight aluminum metal matrix composites (AMMCs), which are being put to use in an expanding number of consumer-based, aerospace, and automotive applications. This is because it has the capability of establishing a uniform distribution of reinforcements inside a matrix element, which results in the production of composite materials of superior quality (Behera et al.) (Behera, Samal, and Panigrahi). Reinforced aluminum composites with a metal matrix are a class of materials that have useful properties such as high-specific strength and stiffness, low density, a controlled coefficient of thermal expansion, fatigue resistance, and excellent dimensional stability at higher elevated temperatures (B et al.) (Mazahery and Shabani). These properties make reinforced aluminum composites with a metal matrix an attractive choice for a variety of applications. The majority of applications call for the utilization of aluminum composite systems, which are primarily comprised of an aluminum alloy that has been fortified with solid particles of silicon carbide (SiC) (García-Cordovilla, Narciso, and Louis) (Ghosh, Sahoo, and Sutradhar). This material is currently being favored over traditional materials or continuously reinforced composites (Uzkut) (Narayan, Surappa, and Bai) (Park, Crosky, and Hellier) (Prasad) due to the ease with which its properties can be changed to fit the requirements of individual users. As a result of this, a significant amount of research—both experimental and analytical—has been conducted utilizing these composites to investigate their resistance to wear (Salguero et al.) (Zhang, Z Zhang, and Friedrich) (Aruri, K. Adepu, and K. S. Adepu) (Alrobei) (Pradhan, Ghosh, and Barman) (Mittal and Dixit) (Kori and Chandrashekharaia). In the most recent research, an approach was taken to investigate experimentally the wear characteristics of aluminum metal matrix composites having varying percentages of silicon carbide. .

2. Materials and Fabrication

2.1. Materials

Commercially available metal powders were used to produce the Al-Mg-Si-Cu-SiC composites. The chemical constituent of these powders are presented below as in Table 1.

2.2. Fabrication

Metallurgical powdered technique was adopted to produce the novel AMMCs. Metallic aluminum powders were used as main raw materials called, the matrix metal. Other metal powders like Cu, Mg, Si were then added to the aluminum powder for the purpose of strengthening the matrix to fabricate the composite followed by SiC as the reinforcing agent. The percentages by weight of different elements are given during fabrication are: Si-0.5, Mg-0.5, Cu-2.5, SiC-5, 10, 15, Rest-Aluminum.

The powders were first mixed in the ball mill. Then the mixture was compressed into a C 45 steel die using a digital compression tester with a load of 250 KN. The green composite compacted samples were recovered from the steel die and sintered for two hours in a muffle furnace. The temperature during sintering was kept at 620^0 C. All specimens after sintering were annealed for twenty four hours at normal atmosphere. The different metal powders and their mixture and dies used for the compaction process of AMMCs are given in Fig. 1 & 2.

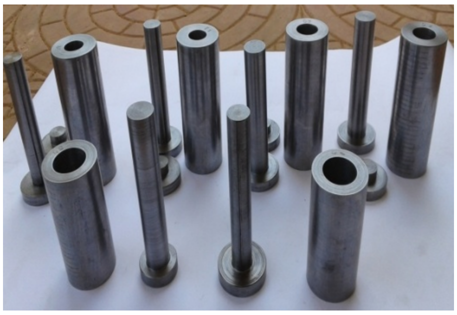


FIGURE 1. **Collection of metal powders**

FIGURE 2. **Die sets prepared by lathe**

2.3. Wear test experimental procedures (by Pin-on-Disc method

The dry sliding wear examination of the matrix composites was executed by Pin on Disc (PoD) tribo-meter (Make: Ducom PoD) shown in Fig. 3. Before start of the test, the pin surface and the disc were sanded with fine emery paper. Samples were clamped and held on the steel disc during the test. All wear examinations were performed under dry-conditions in normal ambient temperature. The different load was applied to the samples through a cantilever mechanism with a tracking radius. The weights of individual test specimen before and after the each test were measured with the help of an

TABLE 1. Chemical Constituents of Individual Metal Powder

Powder element	Atomic number	Density $(gm/cm)^3$	Atomic mass (u)	Melting point (^{0}C)	Purity (%)	Used form	Particle size (mesh)
Al	13	2.70	26.981539	660.3	99.55	powder	325
Mg	12	1.738	24.305	650	99.87	powder	100
Si	14	2.329	28.0885	1414	99.87	powder	325
Cu	29	8.96	63.546	1085	99.77	powder	325
SiC	-	3.21	-	2730	99.92	powder	325

electronic-weighing device of 0.0001gm accuracy. Before each measurement, the surfaces of the specimens were thoroughly cleaned so that the surfaces are free from contaminating impurities.

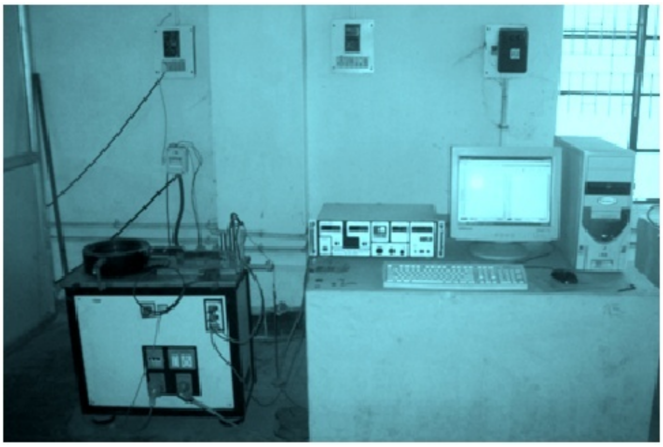


FIGURE 3. Dry-sliding-wear test apparatus

The wear tests were conducted for pins, made of Al - 0.5Si - 0.5Mg - 2.5Cu - 15SiC composites at different loads (50N, 60N, 70N) and at different sliding speeds (3m/s, 5m/s, 7m/s) for a fixed sliding distance of 1000m. The Wear rate (mm^3/m) was measured using the equation (i):

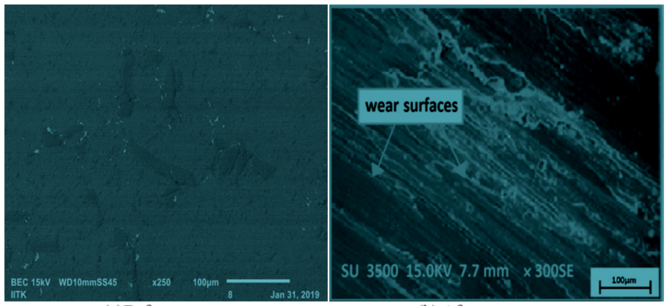
$$Wr = \Delta m/(\rho \times L) \quad \text{(i)}$$

where W_r = Wear Rate (mm^3/m), Δm = Weight loss (gm), ρ = Density (gm/mm^3), L = Sliding distance (m). The results of the wear-test are presented in Table 2 below.

3. Result and Discussions

3.1. The microstructure

The microscopic structural presentations of the composite materials are shown in Fig. 4(a) and (b) respectively, before and after the wear tests. The surface before the tests looks smooth due to the presence of SiC (see, Fig. 4 (a)).The dry sliding wear rate for the AMMCs were determined at a fixed sliding-distance of one thousand meter at various sliding speeds and loads (in Table 2). The worn-surfaces on the test sample clearly show presence of deep permanent grooves along with subtle grooves of soft deformation at the edges as shown in Figure 4 (b). The worn-surfaces have many fine scratches. The wear is by abrasion, as characterized by the formation of grooves. This is possibly due to the cracking of the hard particles, as observed on the surface of the disc as worn hardened debris. The increasing weight percentage of silicon carbide in the composite leads to minimization the rate of wear.



(a)Before wear test (b) After wear test

FIGURE 4. Composite before and after wear test showing worn surfaces

3.2. Wear Analysis

The applied load is the factor that has the greatest influence on the wear rate, followed by the sliding distance, the sliding speed, the weight percentage of reinforcement, and the reinforcement particle size. Figure 5 provides an illustration of this point. It is possible to deduce, by referring to this data, that an increase in load results in an increase in the amount of wear losses. This could be due to the fact that increasing the applied load leads to a reduction in the existing tribolayer, which in turn causes a shift from moderate to severe wear. If there is a lower percentage of SiC by weight, then the composite material will have a lesser resistance to wear caused by dry-sliding conditions. It increases with an increase

TABLE 2. Wear rate with different sliding speed

Load (N)	Sliding speed (m/s)	Wear rate mm^3/m	Sliding speed (m/s)	Wear rate mm^3/m	Sliding speed (m/s)	Wear rate mm^3/m
50	3	1.6317	5	1.7326	7	1.8916
60	3	1.8219	5	1.9722	7	2.2938
70	3	2.0123	5	2.3256	7	2.5416

in the percentage of the reinforcement's weight that it accounts for (see Fig. 6). Moreover, albeit to a lesser extent, the rate of wear is affected by the sliding speed. Wear losses become negligible if the sliding speed reaches a minimum of 3 meters per second. Yet, the losses become more significant as the sliding speed increases. Because of the clogging of the composite material on the surface of the pin, there is also an increase in the total amount of peelable reinforcement.

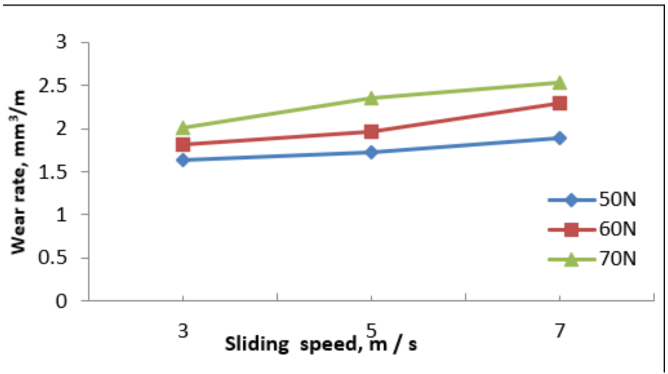


FIGURE 5. Graphical representation of wear-rate vs. Sliding-speed

Fig. 6 shows the wear-rate of the composites made of Aluminum alloy (Al - 0.5Si - 0.5Mg - 2.5Cu) and different weight % of SiC content (5, 10 and 15%) with load 50N, sliding speed 5m / s and sliding-distance of 1000m.

4. Conclusion

AMMC offers a workable replacement for the materials engineer or designer and provides sufficient room for expansion in both the engineering and consumer-based applications of its products. The following is a list of possible inferences regarding the wear behavior of the present composite that can be drawn from the findings of this investigation:

- The amount of force put on composite materials speeds up the rate at which they wear down.
- When the sliding speed goes up, the rate of wear on the AMMCS goes up, too. This could be because

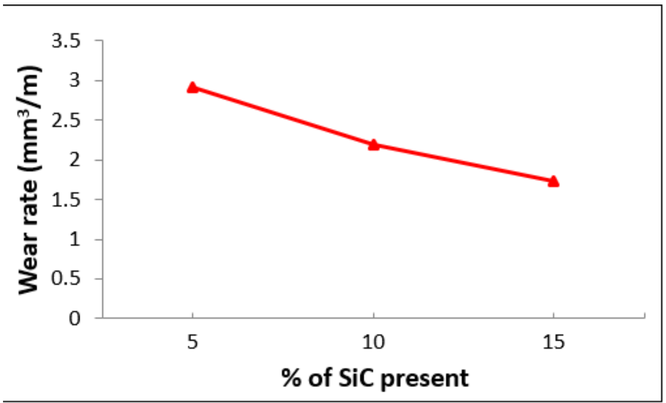


FIGURE 6. Graphical representation of wear rate vs. percentage of SiC present

of the rubbing action that the pin has when it comes into contact with the surface of the specimen, which causes a temperature increase.

- The rate of wear slows down when the proportion of SIC in the material increases from 5% to 15%.

References

Alrobei, H. "Effect of different parameters and aging time on wear resistance and hardness of SiC-B4C reinforced AA6061 alloy". *J. Mech. Sci. Technol* 34.5 (2020): 2027–2034. 10.1007/s12206-020-0446-5..

Aruri, D, K Adepu, and K S Adepu. "Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC + Gr) and (SiC + Al2O3)] fabricated by friction stir processing". *J. Mater. Res. Technol* 2.4 (2013). 10.1016/j.jmrt.2013.08.001..

B, Rajesh Kumar, et al. "Mechanical Properties And Micro-Structural Study Of Sintered Aluminium Metal Matrix Composites By P/M Technique". 3 (2019): 89–97.

Behera, Rajesh Kumar, Birajendu Prasad Samal, and Sarat Chandra Panigrahi. "Manufacture of die and their designing parameters for sintered AMC product". 107 (2019): 605–605.

Behera, Rajesh Kumar, et al. "Microstructural and Mechanical Analysis of Sintered Powdered Aluminium Composites". 2020 (2020): 1–7.

García-Cordovilla, C, J Narciso, and E Louis. "Abrasive wear resistance of aluminium alloy/ceramic particulate composites". *Wear* 192.1-2 (1996): 170–177.

Ghosh, Shouvik, Prasanta Sahoo, and Goutam Sutradhar. "Wear Behaviour of Al-SiCp Metal Matrix Composites and Optimization Using Taguchi Method and Grey Relational Analysis". *Journal of Minerals and Materials Characterization and Engineering* 11.11 (2012): 1085–1094.

Kori, S A and T M Chandrashekharaia. "Studies on the dry sliding wear behaviour of hypoeutectic and eutectic Al-Si alloys". *Wear* 263.1-6 (2007). 10.1016/j.wear.2006.12.025..

Mazahery, Ali and Mohsen Ostad Shabani. "Study on microstructure and abrasive wear behavior of sintered Al matrix composites". *Ceramics International* 38.5 (2012): 4263–4269.

Mittal, P and G Dixit. "Dry Sliding Wear Behavior of 2014 Aluminium Alloy Reinforced with SiC Composite". *Int. J. Eng. Res. Technol* 5.6 (2016): 147–153.

Narayan, Manish, M K Surappa, and B N Pramila Bai. "Dry sliding wear of Al alloy 2024-Al203 particle metal matrix composites". *Wear* 181-183 (1995): 563–570.

Park, B G, A G Crosky, and A K Hellier. "Material characterization and mechanical properties of Al2O3-Al metal matrix composites". *J. Mater. Sci* 36 (2001): 2417–2426. 10 . 1023 / A : 1017946027028.

Pradhan, S, S Ghosh, and T K Barman. "Tribological Behavior of Al-SiC Metal Matrix Composite Under Dry, Aqueous and Alkaline Medium". *Silicon* 9.6 (2017). 10.1007/s12633-016-9456-8..

Prasad, B K. "Investigation into sliding wear performance of zinc-based alloy reinforced with SiC particles in dry and lubricated conditions". *Wear* 262.3-4 (2007). 10.1016/j.wear.2006.06.004..

Salguero, Jorge, et al. "Application of Pin-On-Disc Techniques for the Study of Tribological Interferences in the Dry Machining of A92024-T3 (Al–Cu) Alloys". *Materials* 11.7 (2018): 1236–1236. 10.3390/ma11071236..

Uzkut, M. "Abrasive Wear Behaviour of SiCp-Reinforced 2011 Al-Alloy Composites". *Mater. Sci. Technol* 47 (2013): 635–638. 10 . 1179 / 1743284713Y.0000000268..

Zhang, H, Z Zhang, and K Friedrich. "Effect of fiber length on the wear resistance of short carbon fiber reinforced epoxy composites". *Compos. Sci. Technol* 67.2 (2007). 10.1016/j.compscitech.2006.06.014..

Embargo period: The article has no embargo period.

To cite this Article: Ales, Steve, Rajesh Kumar Behera, and Kamalakanta Muduli. "An Experimental Inquire on Dry Sliding Wear Behaviour of Al-Si-Mg-Cu-SiC Composites Fabricated by Metallurgical Powder Technique." International Research Journal on Advanced Science Hub 05.04 April 2023 (2023): 155–159. http://dx.doi.org/10.47392/irjash.2023.029