Serbian Tribology Society

# SERBIATRIB '25

19th International Conference on Tribology

Faculty of Engineering University of Kragujevac

Kragujevac, Serbia, 14 – 16 May 2025

Research paper DOI:10.24874/ST.25.194

# STUDY ON MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF 7075AL/SIC METAL MATRIX COMPOSITES

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***Abstract:*** *Metal matrix composites (MMCs) have garnered significant attention due to their outstanding engineering characteristics. These materials pose challenges in machining due to the hardness and abrasive nature of reinforcement particles such as silicon carbide. This study aims to produce MMCs of Al7075 with silicon carbide ceramic particles and conduct both mechanical and microstructural analyses. The compositions of the cast specimens include 100 weight percent (wt.%) Al7075, 93 wt.% Al7075 with 7 wt.% SiC, and 86 wt.% Al7075 with 14 wt.% SiC. Hybrid Al7075 composites are successfully manufactured using the stir casting process. The cast specimens will undergo machining for necessary testing in accordance with ASTM standards. Experimental tests will assess mechanical properties such as tensile strength, fatigue, and hardness, while wear properties will be evaluated using the pin-on-disc method. Results will be compared to determine the most effective combination for enhanced performance.*

***Keywords:*** *Metal matrix, composite, properties, microstructure, SEM*

## 1. INTRODUCTION

A composite material comprises two or more constituent materials with notably distinct physical or chemical properties. When combined, these materials create a composite with characteristics distinct from their individual components. Silicon carbide particles (SiCp) reinforced metal-matrix composites (MMCs) have garnered attention as excellent structural materials in various industries such as aeronautics, aerospace transport, and automotive engineering. This is due to their remarkable blend of low density and high thermal conductivity. The enhancement of their properties hinges on the structure, chemistry, and bonding nature of aluminum (Al) - silicon carbide (SiC) interfaces. Conventionally, metal-matrix composites are fabricated using various techniques including power metallurgy, squeeze casting, and stir casting, the latter being a cost-effective method. The 7075-aluminum alloy (AA7075) is primarily alloyed with zinc, offering exceptional mechanical properties such as ductility, high strength, toughness, and resistance to fatigue. However, it is more prone to embrittlement compared to other aluminium alloys due to micro segregation. Nonetheless, it boasts superior corrosion resistance compared to alloys in the 2000 series. It stands as one of the most widely utilized aluminium alloys for highly stressed structural applications. The composition of the 7075-aluminum alloy typically includes approximately 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than half a percent of silicon, iron, manganese, titanium, chromium, and other trace metals. It is available in various tempers, including 7075-0, 7075-T6, and 7075-T651. Silicon, a fundamental element in the periodic table with atomic number 14 and symbol Si, occupies a central role in modern technology and industry. Renowned for its versatility and abundance, silicon is a semiconductor that plays a pivotal role in electronics, solar energy generation, and countless other applications. At the atomic level, silicon exhibits a crystalline structure, characterized by a lattice arrangement of silicon atoms bonded covalently. This structure imparts unique properties to silicon, including excellent thermal conductivity, stability at high temperatures, and a moderate bandgap crucial for its semiconductor behavior. One of the most significant aspects of silicon is its prevalence in the Earth's crust, where it ranks as the second most abundant element after oxygen. Silicon dioxide, commonly known as silica, constitutes the primary compound of silicon found in nature, present in various forms such as quartz, sand, and silicates. This abundance ensures a stable and cost-effective supply for industrial processes. Silicon's importance in electronics stems from its semiconductor properties, which allow for precise control of electrical conductivity. By doping silicon with specific impurities, such as phosphorus or boron, engineers can create n-type or p-type semiconductors, enabling the fabrication of diodes, transistors, and integrated circuits—the building blocks of modern electronics. Moreover, silicon's optical properties make it indispensable in photovoltaic technology for solar energy conversion. Silicon solar cells, utilizing the photovoltaic effect, harness sunlight to generate electricity efficiently and sustainably, driving the global transition towards renewable energy sources. Beyond electronics and solar energy, silicon finds applications in diverse fields such as metallurgy, construction, and biotechnology. In metallurgy, silicon serves as a deoxidizing agent and alloying element, enhancing the mechanical properties of steel and aluminium alloys. In construction, silicones, derived from silicon-oxygen polymers, offer exceptional durability and flexibility as sealants and adhesives. Furthermore, silicon's biocompatibility and chemical stability make it valuable in medical implants, drug delivery systems, and biosensors, revolutionizing healthcare and diagnostics.

The application of particulate reinforced composites is gaining importance due to their enhanced strength, high hardness, reduced weight, and improved ductility. The physical, mechanical, and tribological properties of aluminium matrix composites reinforced with micro-sized silicon carbide particles (at varying quantities of 0, 3, 6, and 9 wt.%) prepared using the stir casting fabrication process. As the weight percentage of SiC reinforcement increases, the composite's density rises from 2.76 gm/cc to 2.83 gm/cc, and its porosity decreases from 1.78% to 0.56%. Both ultimate tensile strength (UTS) and hardness of the SiC particle increase accordingly [1]. Al7075-SiC composites with 5%, 10%, and 15% weight percentages of SiC have been fabricated using powder metallurgy. The mechanical and tribological properties of these composites were investigated under dry sliding conditions. Microstructural characterization confirmed the even dispersion of SiC particles and strong interfacial bonding between the reinforcement and the matrix [2]. In this research work, Aluminium 7075 reinforced with 7% and 14 % by weight SiC is analysed for its microstructural and mechanical properties. The effect of reinforcement on the mechanical as well as microstructural properties of the matrix is analysed.

## 2. EXPERIMENTAL METHODOLOGY

The 7075 Al/SiC MMCs of different composition 0%, 7% and 14% SiC were stir casted. Stir casting is an economical method for preparing the matrix of Al 7075-SiC. The Al7075 alloy is added to the crucible and heated to the molten temperature and then allowed to cool in the crucible to obtain cylindrical rod samples of matrix. The same procedure is repeated in casting the matrix with 7% and 14% SiC reinforcement, where the matrix is allowed to heat to the molten state and SiC particles are poured and stirred to obtain the mixture. The mixture is allowed to cool and cylindrical pieces of the MMC are obtained. EDAX is performed on the Al7075 matrix using Carls Zeiss SEM setup to ascertain the chemical composition of the alloy. The specimens from all the three compositions are then cut using a diamond cutter and machined as per G-99a for Adhesive wear. The wear test is carried out on DUCOM apparatus for a load of 5Kg and 6Kg keeping the sliding speed and wear track diameter constant. The disc specimens from the three compositions are machined for compression test as per ASTM D695. The specimens from the compositions are tested for compression on the UTM for fracture. The effect of SiC reinforcement was analysed by conducting the Brinell hardness test on the specimens. The samples were loaded on the Brinell hardness tester applying a load of 25kgf and the corresponding values of Brinell hardness was studied. The mechanical property of the samples was further analysed by performing Fatigue test. The specimens from the three compositions were analysed on Walter & Bai fatigue testing machine for fatigue life and examine the effect of the reinforcement on the matrix for its fatigue life. The fractured surfaces of the specimens from the fatigue test were analysed using Carls Zeiss SEM set-up to ascertain the nature of the fracture.

## 3. RESULTS AND DISCUSSION

The compression test results for the three compositions are presented graphically in Figure 1.

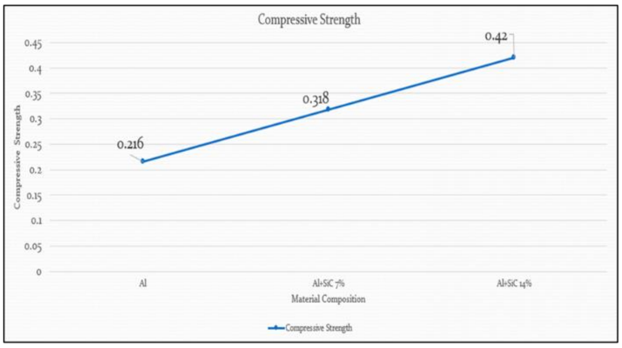


**Figure 1.** Compressive test results

It is observed from Figure 1 that the compressive strength increases linearly as per the addition of the SiC reinforcement in the matrix. The cause of an increase in the compressive strength could be an increase in the material density of the composite material upon an increase in the reinforcement. However, the hardness variation of the material could also attribute to an increase in the compression strength.

The results of the adhesive wear test are presented graphically in Figures 2 a-c.

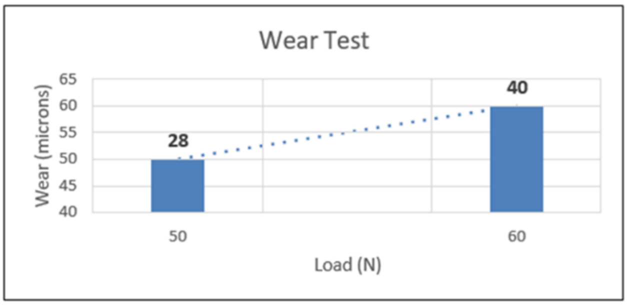


**Figure 2a** Wear test result of Al7075-0%SiC

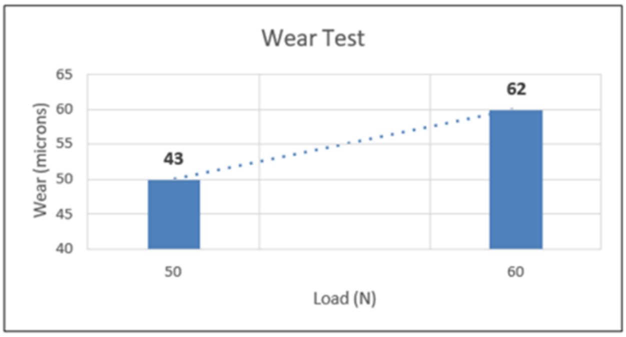


**Figure 2b** Wear test result of Al7075-7%SiC

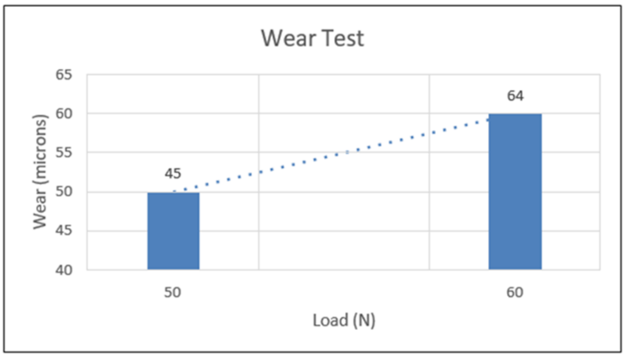


**Figure 2c** Wear test result of Al7075-14%SiC

It is observed from Figures 2a-c that the wear increases with an increase in the load from 5Kg to 6Kg. This indicates that the material tends to wear out evenly upon an increase in the loading. Further, there is a significant reduction in the wear resistance of the material upon an increase in the percentage of SiC reinforcement. Compared to 2-a, the wear is seen to increase exponentially in 2-b where the reinforcement has been increased to 7% and furthermore the wear seems to increase in 2-c marginally upon an increase in the reinforcement to 14% SiC. This increase in the wear of the material could attribute to the softening of the matrix upon an increase in the reinforcement percentage. The particulate reinforcement could be occupying various vacant sites in the matrix thereby causing an increase in the ductility of the matrix thereby causing an increase in the wear.

The results of the Brinell hardness of the three compositions is shown in Figure 3.

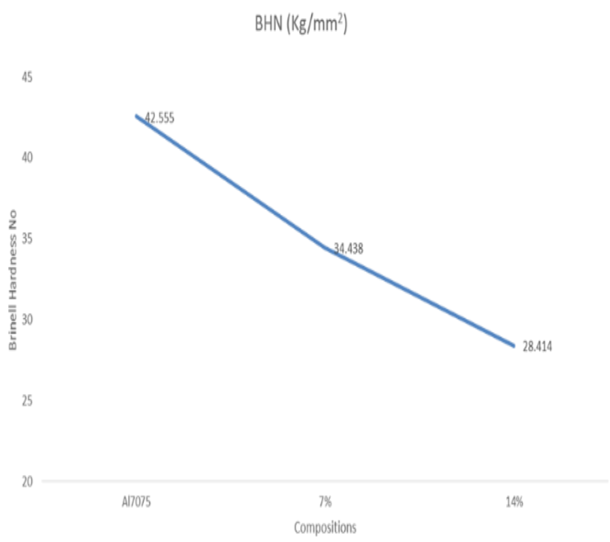


**Figure 3** Brinell hardness test results

It is observed from Figure 3 that there is a significant decrease in the Hardness of the material. The hardness appears to be at the highest at 42.55 Kg/mm$^2$ for the first composition without any reinforcement. However, upon an increase of the reinforcement percentages for the second and third compositions, the hardness seems to dip linearly upon an increase of the reinforcement percentages.

The fatigue test results for the three compositions are shown in Figures 4a-c.

As the fatigue property is an unpredictable phenomenon, it is seen from Figures 4 a-c that the specimen without any reinforcement is seen to fail at only 5 cycles of tension and compression. In Figure 4-b, the specimen undergoes a whopping 8900 cycles of tension and compression and then fails on account of fatigue. Whereas, in Figure 4-c, the specimen is observed to fail at 4559 cycles of alternating tension and compression. To ascertain the fatigue life of the material, it is seen that an increase in the reinforcement percentage to 7% increase the fatigue life marginally. Further increase in the reinforcement percentage to 14% is seen to make the specimen fail at an earlier stage. This shows that the prediction of the fatigue life of the material is not a very simple phenomenon as we would need several samples to get the Stress vs number of cycles curve of the material.

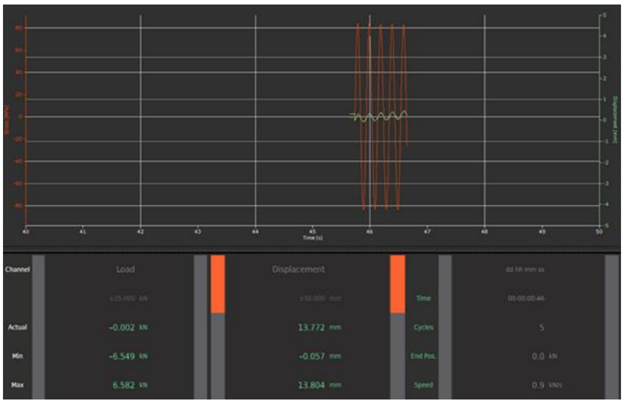

**Figure 4a** Fatigue result of Al-7075-0% SiC specimen

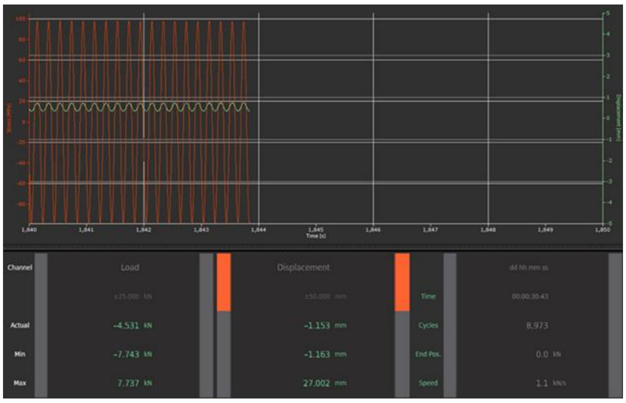

**Figure 4b** Fatigue result of Al-7075-7% SiC specimen

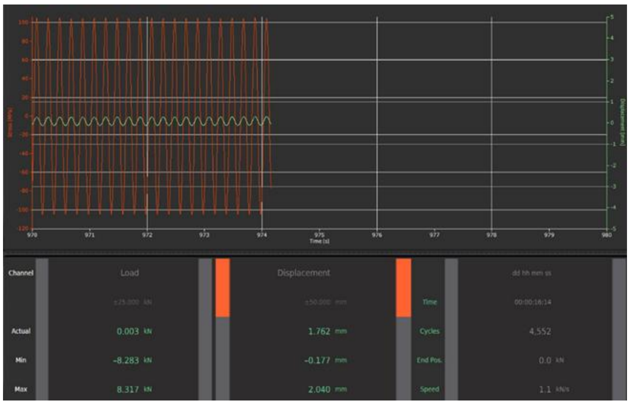

**Figure 4c** Fatigue result of Al-7075-14% SiC specimen

The SEM images of the fractured samples through fatigue is presented in Figures 5 a-c.

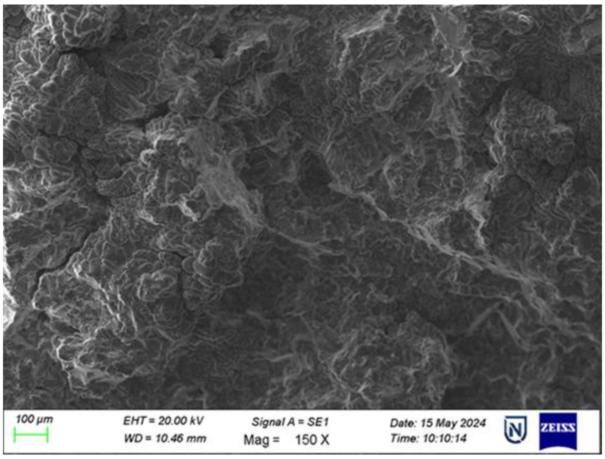


**Figure 5-a** Fractured surface of Al7075-0% SiC specimen

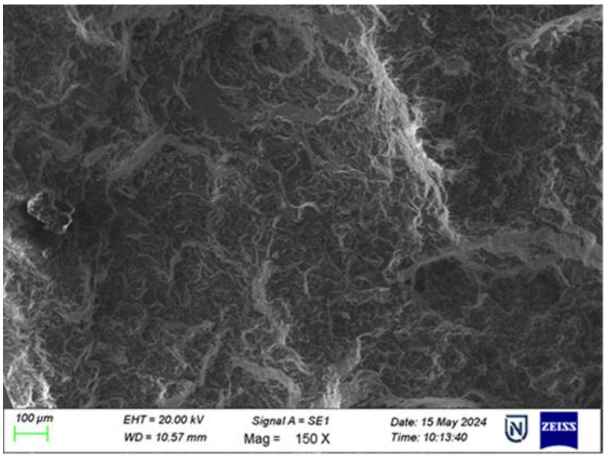


**Figure 5-b** Fractured surface of Al7075-7% SiC specimen

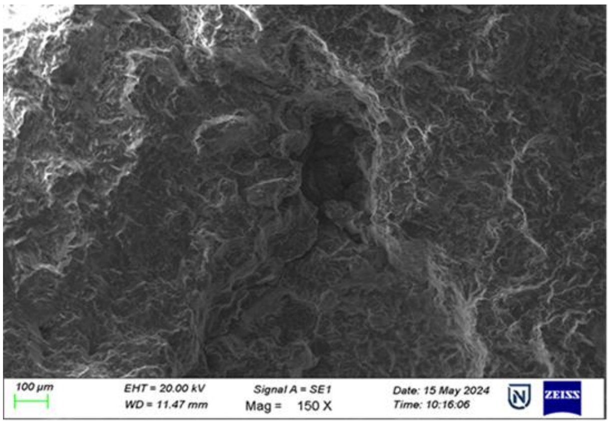


**Figure 5-c** Fractured surface of Al7075-14% SiC specimen

It is seen from Figure 5-a that the fracture is transgrannular in nature. The craters formed in the image clearly specifies that the fracture is ductile in nature [3]. The grains seem to be distributed evenly in the microstructure. Figure 5-b shows that the grains are much more widespread in the case of reinforcement of 7% SiC in the matrix. A lot of variations are seen in the microstructure of the fractured specimen that shows that the fracture is ductile in nature [4]. The grains are much more spaced apart as compared to Figure 5-a that could be attributing to the fractured surface showing the distribution of the reinforcement. Figure 5-c shows a much-enlarged SEM structure of the fractured surface. A crater is seen in the centre of the structure followed by a much more widely spaced grain. The structure is transgrannular showing a ductile fracture. The grains being furthermore spaced could indicate the presence of SiC particulates making the material more ductile compared to Figure 5-b.

## 4. CONCLUSIONS

1. The compression strength of the composite material is seen to go up marginally with an increase in the percentage of SiC in the matrix.
2. The wear of the specimens is seen to increase with an increase in the loading. Further, with an increase in SiC, the wear rate is seen to increase. This could attribute to softening of the composite with increase in SiC reinforcement.
3. The Brinell hardness is seen to reduce upon an increase in the reinforcement percentage.
4. The fatigue behaviour however doesn't seem to be altered much with the change in the composition. However, it is seen to vary marginally up and down with change in the reinforcement.
5. The SEM micrographs of the fatigue samples show that the fracture looks to be transgrannular in nature with cracks seen in the micrograph.

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## REFERENCES

[1] T.S Srivatsan, Meslet Al-Hajri, M Petraroli, B Hotton, P.C Lam, "Influence of silicon carbide particulate reinforcement on quasi static and

cyclic fatigue fracture behaviour of 6061 aluminium alloy composites “, Material Science and Engineering, Vol. 28, Issue 2, 2002.

[2] Mulugundam Siva Surya, S.K Gugulothu, “Fabrication, Mechanical and Wear characterization of Silicon Carbide Reinforced Aluminium 7075 Metal matrix composite”, Vol. 11, Issue 2, 2021.

[3] Atla Sridhar, K. Prasanna Lakshmi, CH.V. Satyanarayana Raju, “Microstructure, Mechanical and Tribological Properties of Al7075/SiC/Graphite Hybrid Metal Matrix Composites”, Issue 1, July 2022.

[4] N. Vinoth Babu, T.V. Moorthy, “Synthesis and Characterization of Al7075/SiC Composite by Stir casting”, Applied Mechanics and Materials, July 2014.