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# Dry Sliding Wear Behavior of Aluminum Metal Matrix Composite Produced By Powder Metallurgy Method

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## ABSTRACT

The new age structural material is considered as aluminum metal matrix composite (AMMC) for its light weight, high strength and good wear properties. In the present research work three composite specimens are produced with composition Al-0.5Si-0.5Mg-2.5Cu-5, 10, 15SiC by weight. The microstructure reveals the fair distribution of silicon carbide particles uniformly so that the material properties are isotropic. The wear test conducted in pin-on-disc method without lubrication where pin is made up off the AMMC whereas the disc is of EN-31 steel. Two different loads such as 30N and 50N wear taken during the wear test. The sliding distance was taken as 500m, 1000m, 1500m, and 2000m with sliding speed of 2m /s. The result shows that the wear rate and specific wear rate as well as the volume loss is much less with increase in percentage of SiC and increase in sliding distance. Further as the load increases the dry sliding wear rate increases. Due to its good wear resistance in dry sliding condition, the material can be significantly used in automobile sector such as brake shoe, brake disc etc.

***Keywords:*** AMMC, Powder Metallurgy, Dry Sliding Wear, Sliding Distance, microstructure, hardness, Percentage SiC,

# INTRODUCTION

Generally there is need of light weight with good mechanical property are always need of Industrial applications which is mostly used in automotive & aerospace industries. Composites are one such kind of material which can replace the convectional materials because of its high performance. There are many methods known to produce composites but powder metallurgy route is most convenient and economical method for production of composites. Aluminum metal matrix composite (AMMC) is considered as the new structural material to be utilized in mechanical infrastructure [1-7]. There are several methods for manufacturing AMMC but powder metrology (PM) method is most suitable for composite preparation in solid route. Because it causes smooth distribution of reinforcement in the desired alloys and it affect the qualities as well as properties of the composites. The manufactured composites show excellent mechanical strength, stiffness, thermal properties and high fatigue strength. In the present study Al-0.5Si-0.5Mg-2.5Cu-5, 10, 15SiC composites are produced through PM method and it was tested for sliding wear without lubrication at different load [8-14].

The testing was conducted at normal atmosphere to justify the use of AMMC used at mechanical infrastructure. The hard SiC particles incorporated in the alloys improves the wear behavior of the composites. To observe the wear behavior of the manufactured composites with different wear inputs such as load, sliding distance, test was conducted with DUCOME wear apparatus. All the particles of the AMMC are of different mesh size. In the present study a new approach has been made to produce a novel AMMC which can be utilizes in automotive and structural applications [15-20]. The micro structural and wear properties of the composites depend on the manufacturing route [21-27]. The reinforced particle of SiC increases the specific strength and wear properties of the base alloys. Here the magnesium is added to increase the wetting property of aluminum, copper increases the corrosion property, silicon increases the strength and SiC particles are reinforced in to the Al-Mg-Cu-Si alloy. Above all the mechanical properties of the AMMC is improved so that it can be used in many applications [4, 7-11]. Wear is the process of material removal due to sliding of two bodies and it is the major removal at the surface of contact. The reinforced SiC particles in preparation of AMMC increases surface hardness. So, wear rate decreases as compare to pure Aluminum metal. To test the wear behavior of the AMMC produced, Pin-On-Disc methods were used where pin is the AMMC and disc is the conventional EN-31 steel. The test was conducted taking two loads 30N & 50N with different sliding distance such as 500m, 1000m, 1500m, 2000 and with sliding speed of 2m/s. The results of the wear behavior in dry condition show encouraging results.

## EXPERIMENTAL PROCEDURE

Proper die punch system is essential for production of metal matrix composites through powder route. High load compaction is required to decrease the porosity in the product. The sintering temperature is an important parameter for manufacturing composites. Accordingly the die punch system is design and proper sintering temperature is selected. The die punch system used for compaction of the powder of Al-Si-Mg-Cu-SiC particles with required weight percent was done in the apparatus shown below.

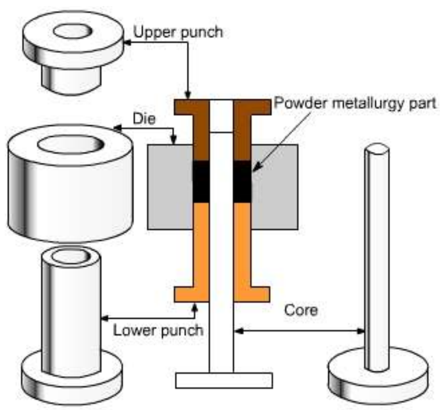


**Figure 1: Parts of Die**

The die punch is made of C-45 steel which is used to manufacture the composites and its compositions are given in the following tables.

| Density gm/cm$^3$ | C | Mn | Cr | Ni | Si | Mo | P | S | Iron(Fe) |
|---|---|---|---|---|---|---|---|---|---|
| 7.87 | 0.45 | 0.65 | 0.4 | 0.4 | 0.27 | 0.1 | 0.045 | 0.045 | Rest |

Table 1: Chemical Composition of C45 Steel in %

The mechanical properties of the C-45 steel are mentioned in the table below

| Diameter (D) in mm | Hardness (BHN) | Tensile strength in (MPa) | Yield strength in (MPa) | Young's modulus in (MPa) | Poisson's ratio | Density (ρ) in gm/cm$^3$ | % of Elongation |
|---|---|---|---|---|---|---|---|
| 41-100 | 170-210 | 600-800 | 340-485 | 210000 | 0.29 | 7.87 | 16 |

Table 2: Mechanical properties of C45 Steel

The commercially available C45 steel is purchased with external diameter 50 mm and internal diameter 20 mm, height 130 mm.

1. The upper punch height is 100 mm and the diameter is 18 mm.
2. The lower punch height is 10 mm and the diameter is 18 mm.
3. The working load is 150 KN.
4. Stress=$\frac{load}{area}$= 477.28 MPa

**Figure 2: Die and punch system made of C45 steel.**

# MATERIALS

## Materials required

Metal powders were selected and purchased from the commercial sources for conducting the experiment to produce Al-Mg-Si-Cu-SiC composite. The powder particles that were used to make the composite had the following chemical analysis.

| Elements (Powder) | Atomic number | Density $(gm/cm)^3$ | Atomic mass (u) | Melting point ($^0C$) | 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 |

Table 3: Chemical analysis of metal powders.

# MANUFACTURING OF THE COMPOSITES

The samples of composite were manufactured by powder metallurgy route and it is the most economical method for composite manufacturing. Here the major constituent is Aluminum powder and was added with Mg, Si, Cu along with SiC particles. The powder size for composite preparation is shown in the table. In the present study, the powder metallurgy technique was adopted to produce the AMMCs metallic aluminum powders were used as the main raw materials for the matrix. Other metal powders like Cu, Mg, Si powders were then added to the

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aluminum powder for the purpose of strengthening the matrix. SiC was the reinforcing agent. The percentage by weight of different elements was as given below:

Magnesium 0.5% - Silicon 0.5% - Cupper 2.5% - Silicon-Carbide 10% - Rest Aluminum

All the above powders were blended (mixed) in the Ball mill and these mixtures were compacted with C45 die with the load of 250 KN. The prepared composite samples were then sintered in the resistance furnace for three hours with the furnace temperature of 550°C and those samples were then annealed for twenty-four hours. The prepared samples were collected for dry-sliding wear test.


**Figure 3: Samples of AMMC produced with 5%, 10% and 15% SiC**

## Density of AMMC

The density of the composite sample prepared by powdered metallurgy method containing 5%, 10% and 15% SiC were measured by immersion method and the results are given below.

$\rho_5$ – 2.598 gm/cm$^3$

$\rho_{10}$ – 2.651 gm/cm$^3$

$\rho_{15}$ – 2.695 gm/cm$^3$

## Wear test:

The composite samples are taken for dry sliding wear test using Dry sliding wear was conducted using Pin-On–Disk method by the wear testing machine made by DUCOM. Here composites are taken as the pin and EN-31 steel as taken as the disk. These sliding wear tests were conducted in atmospheric conditions to find out the weight loss, volume loss, wear rate and specific wear rate.

**Figure 4: Pin-on-disk apparatus for wear test**

Cylindrical sample PIN was fabricated for the size 10mm diameter and 20mm length. The testing was conducted for different axial load of 30N, 50N. Wear test parameters were tabulated.

## Mathematical calculations

The wear parameters in the present study were calculated and The different wear parameters are calculated up to three decimal points using the following formula:

Cumulative weight loss ($C_w$) = initial weight – final weight (mg)

Cumulative volume loss ($C_v$) = $\frac{initial\ weight - final\ weight\ (mg)}{density\ (\frac{mg}{mm^3})}$, ($mm^3$)

Wear Rate ($W_{rate}$) = $\frac{Cumulative\ volume\ loss}{Sliding\ distance}$ , ($mm^3/m$)

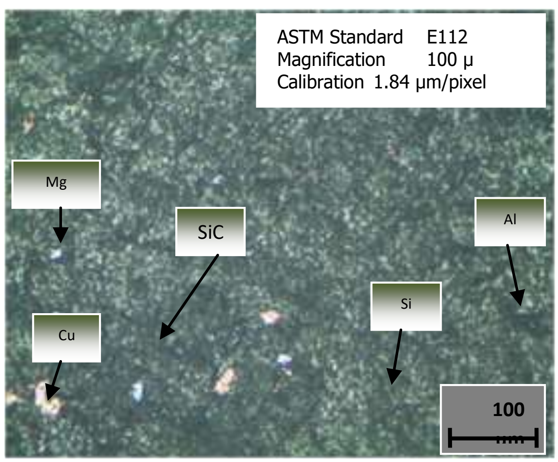
Specific wear rate ($SW_{rate}$) = $\frac{Wear\ rate}{Load}$ ($mm^3/ Nm$).

## Microstructure Test

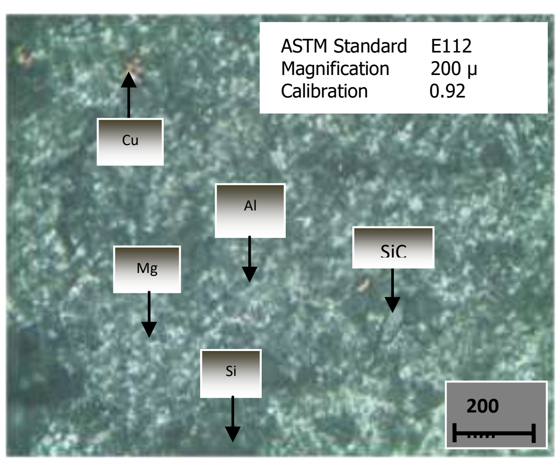
The microstructure of three composites containing 5%, 10% and 15% silicon carbide were taken to observe the reinforcement using optical inverted microscope as shown in figure-5.

**Figure 5: Optical inverted microscope**

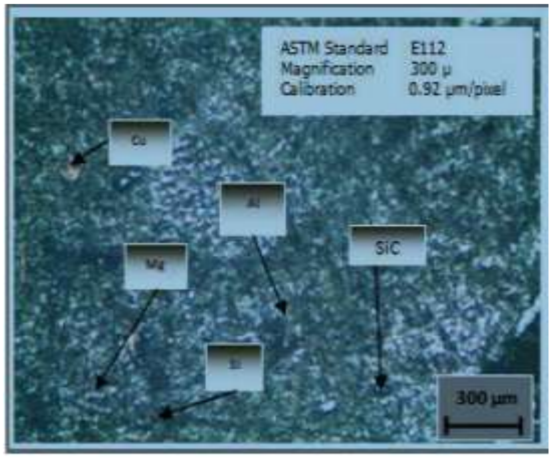
All the particles are distributed uniformly are shown in microstructure (Figure-6), so the composites are considered as isotropic material.




**AMMC containing 5% SiC**



**AMMC containing 10% SiC**




**AMMC containing 15% SiC**

**Figure 6: composite microstructure containing 5%, 10% and 15% SiC along with Mg, Cu, Si in aluminum matrix.**

The above microstructures show that the uniform distribution of SiC particles inside the Al-Mg-Cu-Si alloys leads to enhance the wear properties.

## Rockwell Hardness Test

Hardness of the prepared composites is tested with Rockwell hardness tester made by Fuel instruments and engineers pvt. Ltd. (Shown in figure-7). The measurement of MMC hardness was done using steel ball indenter with Rockwell scale B.

**Figure 7: Rockwell hardness tester**

| composite | 5% SiC | 10% SiC | 15% SiC |
|---|---|---|---|
| Hardness(HRB) | 47.2 | 52.5 | 57.8 |

Table 4: Hardness table for different composition of SiC in the composite

The incorporation of hard SiC particles increases the hardness as the reinforcement increases. From the table-4, it can be observed that there is increase in hardness of 11.22% with inclusion of 10% Sic and 22.45% with the inclusion of 15% SiC.

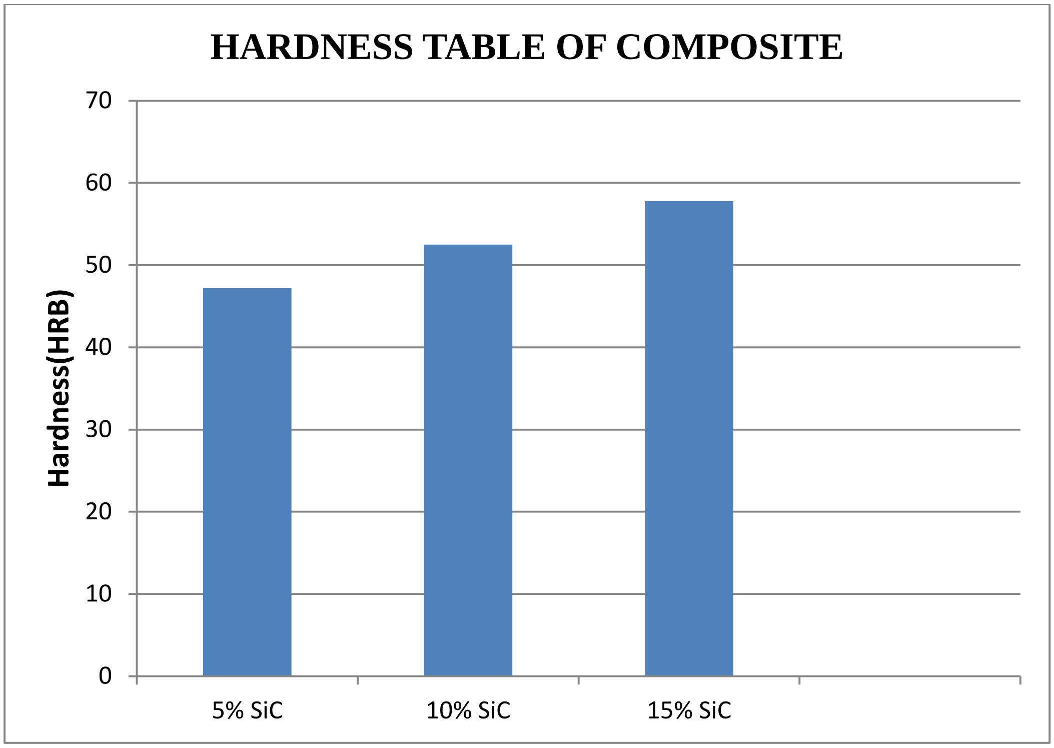



**Figure 8: Hardness of AMMC produced**

Table-4 and Figure-8 describes that hardness of the AMMC produced increases with increase in percentage of SiC.

**Dry sliding wear test of composites at 30N:**

The dry sliding wear test was conducted on pin-on-disk method where pin is the samples of composite and disc is the EN-32 steel. The load taken is 30 N and the test was conducted in normal atmospheric condition.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 4.588 | 1.766 | 3.532 | 0.117 |
| 2 | 10 | 3.245 | 1.224 | 2.448 | 0.081 |
| 3 | 15 | 2.353 | 0.873 | 1.746 | 0.058 |

Table 5: For sliding distance 500m, load 30N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 4.970 | 1.913 | 1.913 | 0.063 |
| 2 | 10 | 4.045 | 1.526 | 1.526 | 0.050 |
| 3 | 15 | 3.358 | 1.246 | 1.246 | 0.041 |

Table 6: For sliding distance 1000m, load 30N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 5.518 | 2.124 | 1.416 | 0.047 |
| 2 | 10 | 4.764 | 1.797 | 1.198 | 0.039 |
| 3 | 15 | 4.210 | 1.562 | 1.041 | 0.034 |

Table 7: For sliding distance 1500m, load 30N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 6.004 | 2.311 | 1.155 | 0.038 |
| 2 | 10 | 5.331 | 2.011 | 1.005 | 0.033 |
| 3 | 15 | 4.819 | 1.788 | 0.894 | 0.029 |

Table 8: For sliding distance 2000m, load 30N and sliding speed 2 m/s.

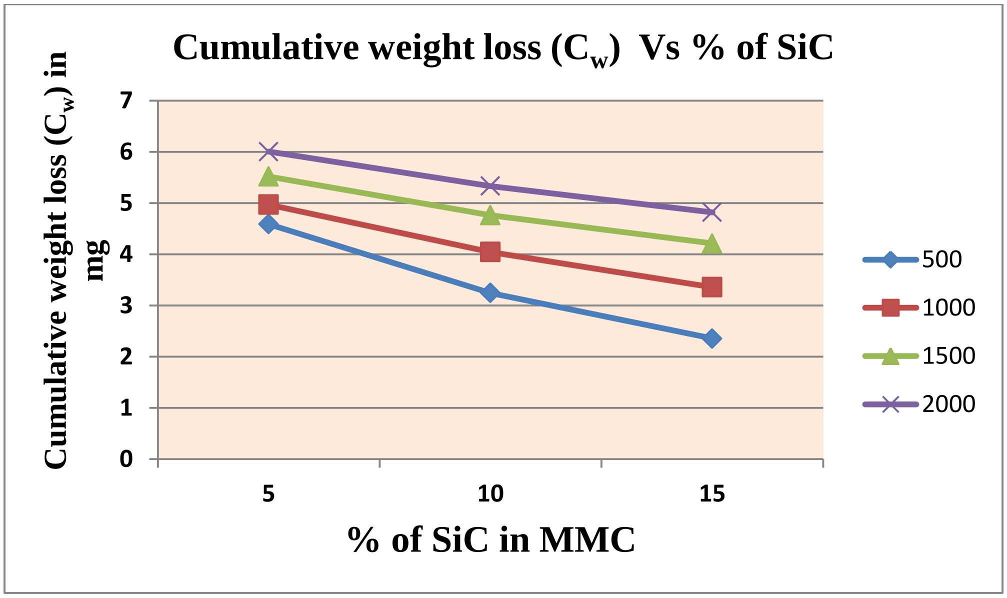



**Figure 9: Graph of variation of cumulative weight loss ($C_w$) vs. % of SiC**

The *cumulative weight loss* ($C_w$) of the wear sample was calculated by the formula

$$C_w = (\text{Initial weight of the sample} - \text{Final weight of the sample})$$

Table-5 to Table-8 and figure-9 describe variation of the cumulative weight loss VS % of SiC in MMC with different sliding distance and it shows that $C_w$ decreases with increase in % of SiC as well as with increase in sliding distance.

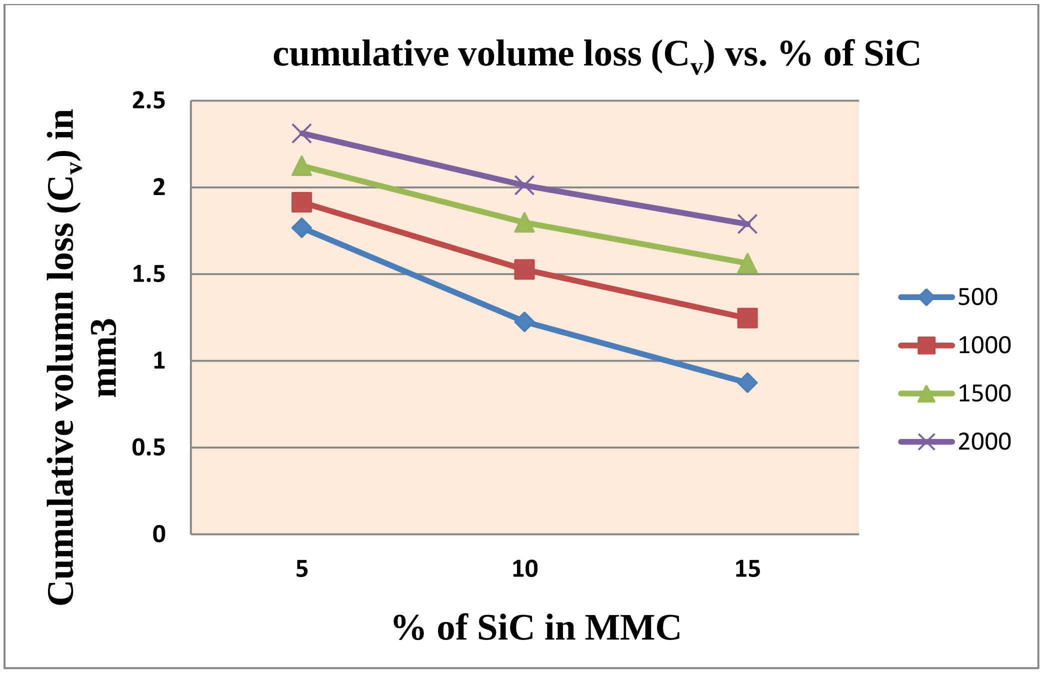



**Figure 10: Graph of variation of cumulative volume loss ($C_v$) vs. % of SiC**

The *cumulative volume loss* ($C_v$) of the wear sample was calculated by the formula

$$C_v = \frac{Cw}{\text{Density of MMC}}$$

Table-5 to Table-8 and figure-10 describe variation of the cumulative volume loss ($C_v$) VS % of SiC in MMC with different sliding distance and it shows that $C_v$ decreases with increase in % of SiC as well as with increase in sliding distance.

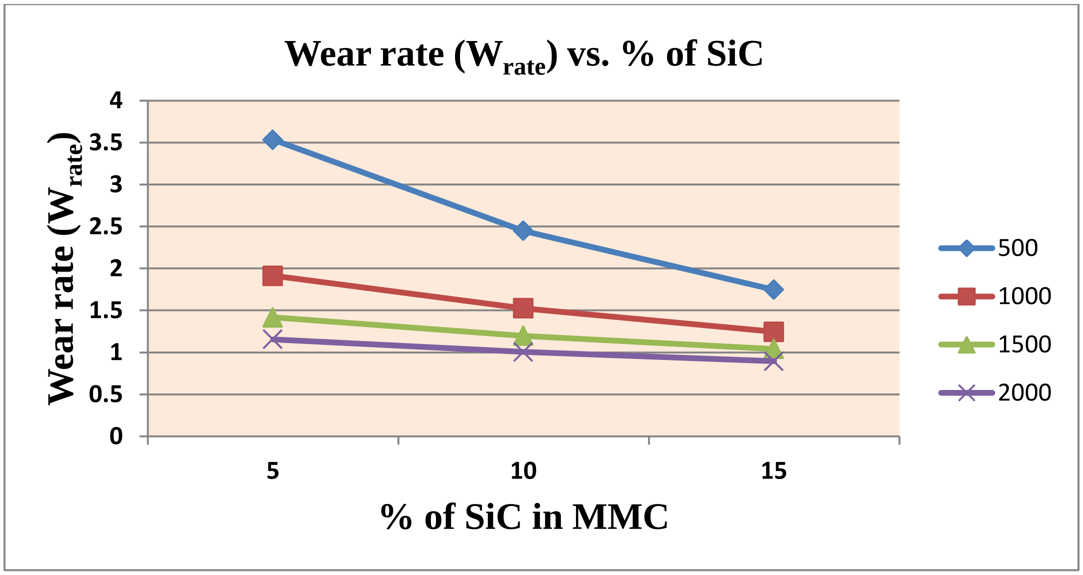



**Figure 11: Graph of variation of Wear rate ($W_{rate}$) vs. % of SiC**

The *Wear rate* ($W_{rate}$) of the wear sample was calculated by the formula

$$W_{rate} = \frac{Cv}{\text{Sliding distance}}$$

Table-5 to Table-8 and figure-11 describe variation of the Wear rate ($W_{rate}$) VS % of SiC in MMC with different sliding distance and it shows that $W_{rate}$ decreases with increase in % of SiC as well as with increase in sliding distance.

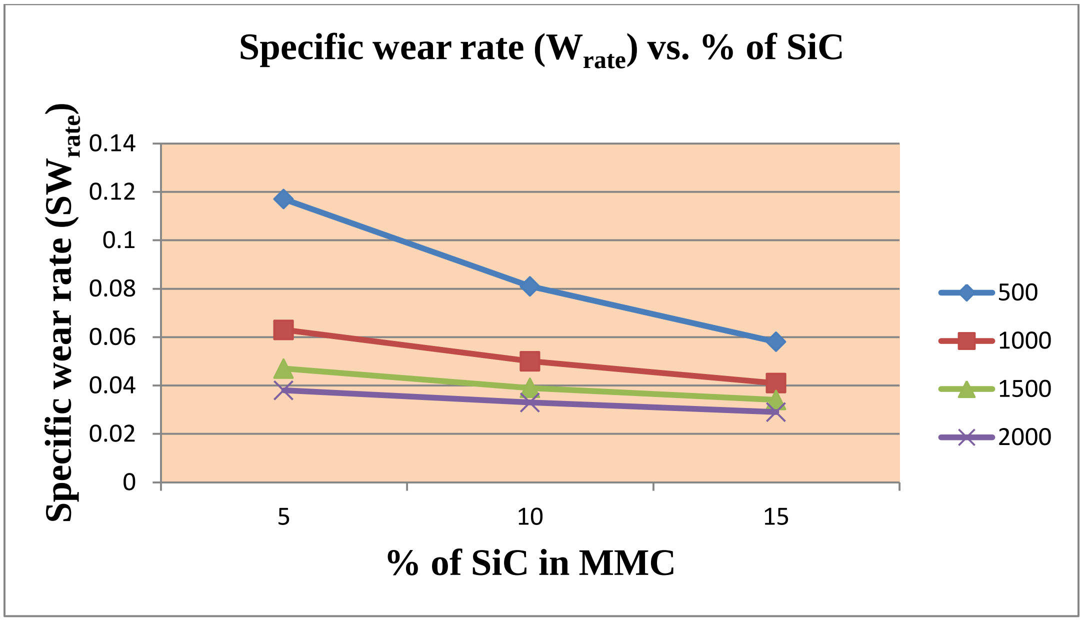



**Figure 12: Graph of variation of Specific Wear rate ($SW_{rate}$) vs. % of SiC**

The *Specific wear rate* ($SW_{rate}$) of the wear sample was calculated by the formula

$$SW_{rate} = W_{rate} / \text{Load}$$

Table-5 to Table-8 and figure-12 describe variation of the Specific wear rate ($SW_{rate}$) VS % of SiC in MMC with different sliding distance and it shows that $SW_{rate}$ decreases with increase in % of SiC as well as with increase in sliding distance.

**Dry sliding wear test of composites at 50N:**

The dry sliding wear test was conducted on pin-on-disk method where pin is the samples of composite and disc is the EN-32 steel. The load taken is 50 N and Sliding speed 2m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 8.342 | 3.211 | 6.422 | 0.128 |
| 2 | 10 | 6.635 | 2.503 | 5.006 | 0.100 |
| 3 | 15 | 5.730 | 2.126 | 4.252 | 0.085 |

Table 9: for sliding distance 500m, load 50N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 11.291 | 4.346 | 4.346 | 0.086 |
| 2 | 10 | 8.250 | 3.112 | 3.112 | 0.062 |
| 3 | 15 | 6.640 | 2.464 | 2.464 | 0.049 |

Table 10: for sliding distance 1000m, load 50N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 14.372 | 5.532 | 3.688 | 0.073 |
| 2 | 10 | 10.938 | 4.126 | 2.750 | 0.055 |
| 3 | 15 | 8.384 | 3.111 | 2.074 | 0.041 |

Table 11: for sliding distance 1500m, load 50N and sliding speed 2 m/s.

| Sl. No. | % of SiC In MMC | $C_w$(mg) | $C_v$ (mm3) | $W_{rate}$ ($mm^3/m \times 10^{-3}$) | $SW_{rate}$ ($mm^3/Nm$) |
|---|---|---|---|---|---|
| 1 | 5 | 16.138 | 6.212 | 3.106 | 0.062 |
| 2 | 10 | 12.642 | 4.769 | 2.384 | 0.047 |
| 3 | 15 | 9.947 | 3.691 | 1.845 | 0.036 |

Table 12: for sliding distance 2000m, load 50N and sliding speed 2 m/s.

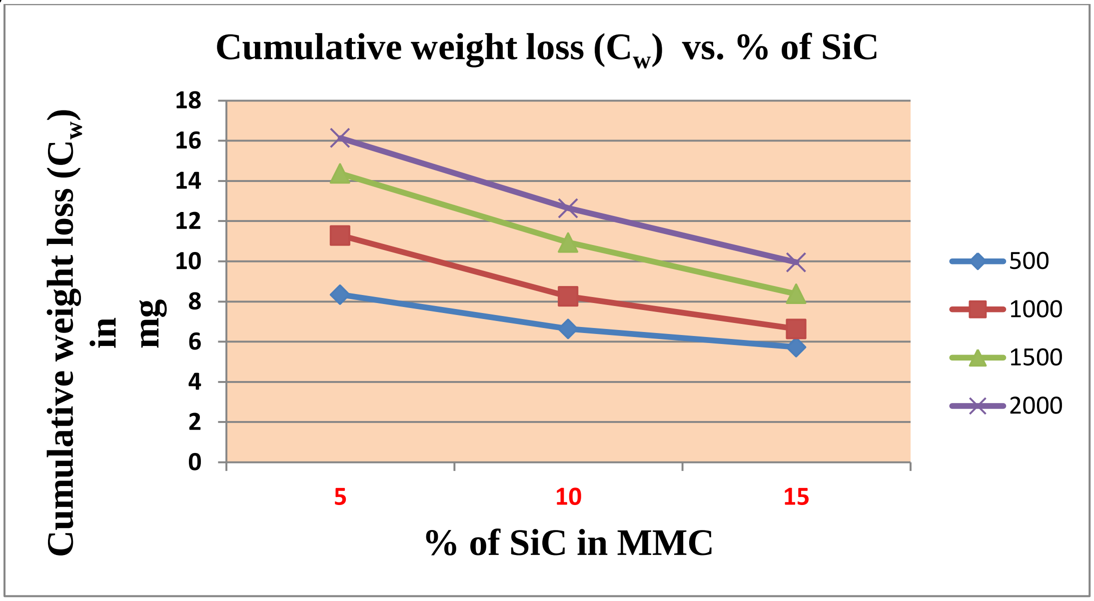



**Figure 13: Graph of variation of Cumulative weight loss ($C_w$) vs. % of SiC**

The cumulative weight loss ($C_w$) of the wear sample was calculated with another wear load (50N) and it shows that with increase in load the $C_w$ increases.

Table-9 to Table-12 and figure -13 also show that $C_w$ decreases with increase in % of SiC as well as with increase in sliding distance.

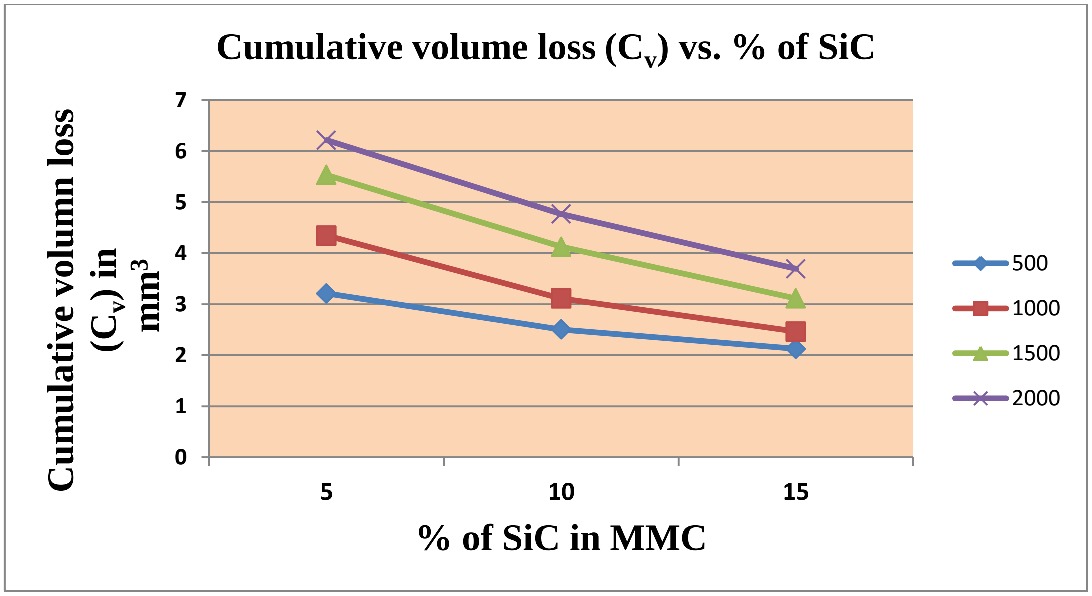



**Figure 14:** Graph of variation of Cumulative volume loss ($C_v$) vs. % of SiC

The cumulative volume loss ($C_v$) of the wear sample was calculated with another wear load (50N) and it shows that with increase in load the $C_v$ increases.

Table-9 to Table-12 and figure -12 also show that $C_v$ decreases with increase in % of SiC as well as with increase in sliding distance.

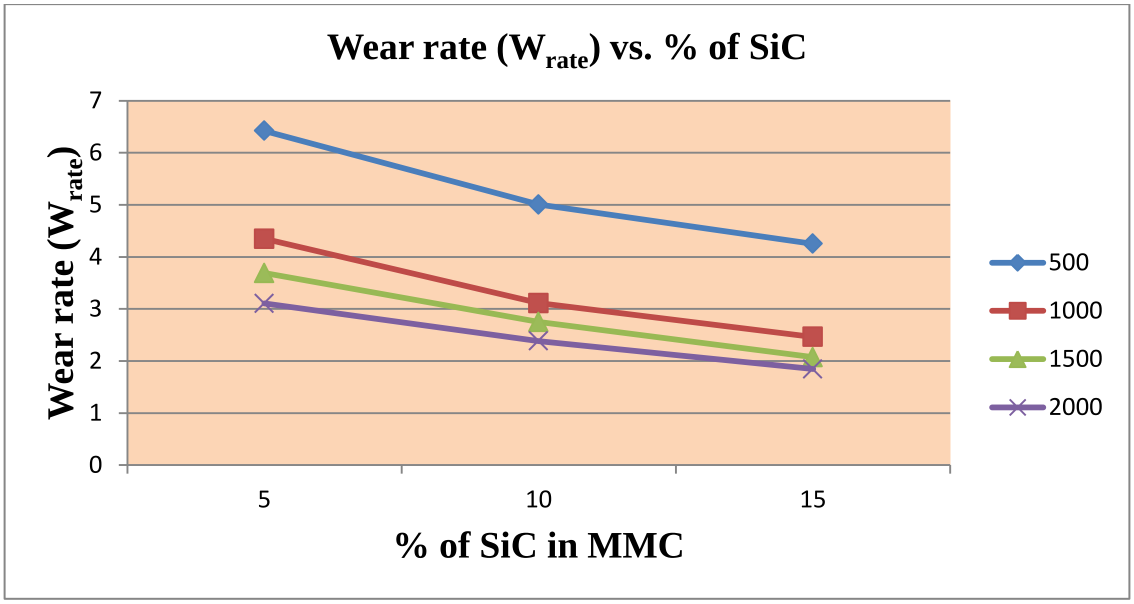



**Figure 15: Graph of variation of Wear rate ($SW_{rate}$) vs. % of SiC**

The Wear rate ($W_{rate}$) of the wear sample was calculated with another wear load (50N) and it shows that with increase in load the $W_{rate}$ increases.

Table-9 to Table-12 and figure -13 also show that $W_{rate}$ decreases with increase in % of SiC as well as with increase in sliding distance.

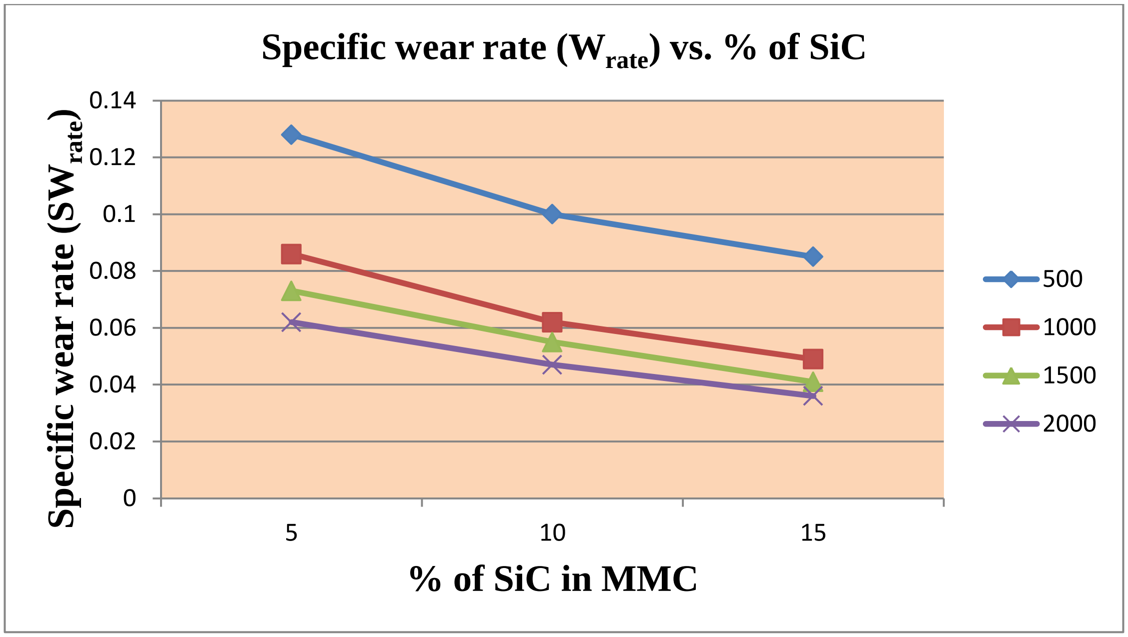



**Figure 16: Graph of variation of Specific Wear rate ($SW_{rate}$) vs. % of SiC**

The Specific wear rate ($SW_{rate}$) of the wear sample was calculated with another wear load (50N) and it shows that with increase in load the $SW_{rate}$ increases.

Table-9 to Table-12 and figure -14 also show that $SW_{rate}$ decreases with increase in % of SiC as well as with increase in sliding distance.

## Discussions

As per the result given in Table 5 to Table 12 also the figures shown in Figure 7 to Figure 14, the variation of the volume loss decreases with increase in sliding distance. The wear rate and the specific wear rate also decreases with increase in sliding distance. The hard particles of Silicon-Carbide (SiC) incorporated in the Al-Mg-Cu-Si alloy improve the wear behavior, so increasing the % of SiC improves the wear properties. It is evident from the figures mentioned above, as the SiC percentage increases in the composite the volume loss in the sample decreases along with wear rate ($W_{rate}$) and specific wear rate ($SW_{rate}$). Initially the wear rate is higher because of the surface roughness of the sample. As the sliding distance increases the surface roughness decreases due to burnishing action. Therefore the volume rate and the wear rate decreases.

## Conclusions

Al-Mg-Si-Cu-SiC metal-matrix composite (MMC) are successfully fabricated using powder metallurgy method. The reinforcement with SiC particles improves the mechanical properties and the microstructure shows that uniformity distribution of SiC particles in MMC. Hardness of the composite increases with increase in SiC particles. The dry sliding wear rate and specific wear rate decreases with increase in sliding distance. The loss of wear volume decreases as the percentage of hard SiC particles incorporation in the composite increases. The wear test result shows that as load increases dry sliding wear rate increases. As the mechanical properties and wear properties improve with increase in percentage of SiC particles, these can be used for industrial applications.

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## REFERENCE

1. A.B. Strong, “Fundamentals of Materials, Methods, and Applications,” *Society of Manufacturing Engineers*, USA, 2008.

2. K.K. Chawla, “Composite Materials - Science and Engineering,” *Springer*, New York, 2012.

3. S. Deutsch, “Automotive applications for advanced composite materials,” *Proceedings of the 23rd National SAMPE Symposium*, p.34, 1978

4. D. Puhan, S. S. Mahapatra, J. Sahu, L Das,” A hybrid approach for multi-response optimization of non-conventional machining on AlSiCp MMC,” Measurement vol.46, pp. 3581‑3592, 2013.

5. R.K. Behera, B.P. Samal, TIG Welding Feasibility of Powder Metallurgy Aluminium Composite Product, National Seminar on Recent Manufacturing Processes & Welding on Internet (RMPWI -2018), 2018, 07-09.

6. R.K. Behera, B.P. Samal, S.C. Panigrahi, Aluminium Alloys for Al-Mg-Si-Cu-SiC Composites, National Seminar on Recent Trends in Mechanical Engineering (RTME 2018), 2018, 05-09.

7. R.K. Behera, B.P. Samal, S.C. Panigrahi, Modified Stir Casting Method used for Production of Al-Mg Alloys and Particle Reinforced MMC, National Seminar on Recent Trends in Mechanical Engineering (RTME 2018), 2018, 01-04.

8. R.K. Behera, B.P. Samal, S.C. Panigrahi, et al. Compaction Die Design and Preparation of Aluminium Matrix Composite Products by Powder Metallurgy Technique, Diamond Jubilee Convention of IIIE & International Conference on Role of Industrial Engineering in Industry 4.0 Paradigm (ICIEIND 2018), 2018, 22.

9. R.K. Behera, B.P. Samal, S.C. Panigrahi, A Novel Method for Preparation of Al-Mg Alloy and Evaluation of Magnesium Recovery to Produce Metal Matrix Composites, National Seminar on Recent Developments in Engineering Materials & Processes (RDEMP 2019), 2019, 58-61.

10. R.K. Behera, B.P. Samal, S.C. Panigrahi, A Novel Method for Preparation of Al-Mg Alloy Used in Refrigeration and Air-Conditioning Pipe Parts, International Conference on Recent Advancement in Air-Conditioning & Refrigeration (RAAR-2019), 2019, 64.

11. R.K. Behera, B.P. Samal, S.C. Panigrahi, Production and Characterization of A Novel Aluminium metal matrix Composite by the process of Powder Metallurgy, Technical Annual, 62$^{nd}$ Session 2021 at The Institution of Engineers (India), Odisha State Centre, Bhubaneswar, 2021, 288-294.

12. R.K. Behera, B.P. Samal, S.C. Panigrahi, et al. Erosion Wear Characteristics of Novel AMMC Produced By Metallurgical Powdered Method, 1$^{st}$International Conferenceon Material Processing and Technology 2021 (ICMProTech 2021), 2021, 61.

13. G. Arslan and A. Kalemtas, “Processing of silicon carbide–boron carbide–aluminium composites,” *Journal of the European Ceramic Society*, vol. 29, no. 3, pp. 473-480, 2009.

14. J.R. Davis, “Corrosion of Aluminum and Aluminum Alloys,” *ASM International*, USA, 1999.

15. J.M. Monaghan and O. Reilly, “Machinability of aluminium alloy: Silicon carbide metal matrix composite,” *Proceedings of Advanced Materials*, vol. 2, pp. 37-46, 1992.
16. F. Akhlaghi, A. Lajevardi and H.M. Maghanaki, “Effects of casting temperature on the microstructure and wear resistance of compocast A356/SiCp composites: a comparison between SS and SL routes,” *Journal of Materials Processing Technology*, vol. 155-156, pp. 1874- 1880, 2004.

17. R. Ipek, "Adhesive wear behaviour of $B_4C$ and SiC reinforced 4147 Al matrix composites (Al/B4C–Al/SiC)," *Journal of Materials Processing Technology*, vol. 162-163, pp. 71-75, 2005.

18. R.L. Deuis, C. Subramanian and J.M. Yellup, "Abrasive wear of aluminium composites-a review," *Wear*, vol. 201, no. 1-2, pp.132-144, 1996.

19. B. Stojanovic, J. Blagojevic, M. Babic, S. Velickovic and S. Miladinovic, "Optimization of hybrid aluminum composites wear using Taguchi method and artificial neural network," *Industrial Lubrication and Tribology.*, vol. 69, no- 6, pp.1005–1015, 2017.

20. S.S. Karthick, *Journal of Materials Research and Technology.*, 2020, 1340 1-7.

21. A.R. Riahi and A.T. Alpas, "The role of tribo-layers on the sliding wear behavior of graphitic aluminum matrix composites," *Wear*, vol. 251, no. 1-12, pp.1396-1407, 2001.

22. K.R. Padmavati and R. Ramkrishnan, "Tribological Behaviour of Aluminium Hybrid Metal Matrix Composite," *Procedia Engineering*, vol.97, pp.660-667, 2014.

23. A. Mazahery and M.O. Shabani, "Study on microstructure and abrasive wear behavior of sintered Al matrix composites," *Ceramics International*, vol.38, no.5, pp.4263–4269, 2012.

24. M. Uzkut, "Abrasive Wear Behaviour of SiCp-Reinforced 2011 Al-Alloy Composites," *Materials and Technology*, vol. 47, pp.635–638, 2013.

25. R. Yousefi, M.A. Kouchakzadeh, J. Rahiminasab *et al.*, "The Influence of SiC Particles on Tool Wear in Machining of Al/SiC Metal Matrix Composites Produced by Powder Extrusion," *Advanced Materials Research*, vol. 325, pp.393–399, 2011.

26. B. Stojanović, A. Vencl, I. Bobić, S. Miladinović and J. Skerlić, "Experimental optimisation of the tribological behaviour of Al/SiC/Gr hybrid composites based on Taguchi's method and artificial neural network," *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, vol. 40, no. 311, pp.1-14, 2018.

27. N. Radhika, A. Vaishnavi and G.K. Chandran, "Optimisation of Dry Sliding Wear Process Parameters for Aluminium Hybrid Metal Matrix Composite," *Tribology in Industry*, vol. 36, pp.188-194, 2014.