# Microstructure and Mechanical Properties of SiC and Graphite Reinforced ZA-12 Metal Matrix Composite

**Sachin K[1], Shreyas H.S[1], Theertha B.S[1], Gopi K.R[2]*

[1]*Student, Department of Mechanical Engineering, Rajeev Institute of Technology, Hassan, Karnataka, India 573201*

[2]*Associate Professor, Department of Mechanical Engineering, Rajeev Institute of Technology, Hassan, Karnataka, India 573201*

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**Abstract** –*ZA-12 metal matrix composite (MMC) was produced using stir casting processby adding silicon carbide (SiC) and graphite reinforcements with varying percentages. Fabricated composite was subjected to microstructural studies and mechanical testing.Microstructure showed uniform distribution of reinforcements within the matrix as observed in scanning electron microscope (SEM). Mechanical properties of the produced composite increased with increment in percentage of reinforcements. Fabricated MMC exhibit higher strengthand wear properties as compared to as-cast alloy.*

***Key Words***:ZA-12 alloy, Stir Casting, Mechanical Properties.

## 1. INTRODUCTION

The metal matrix composites (MMC) possess several advantages in comparison to the base alloys due to their useful structural applications. The composites are advantageous with their properties like improved strength, high modulus and better strength to weight ratio. Among metal matrix composites, the particulate reinforced composites attracted morein the area of industrial segment and also academics. More requirements towards the information regarding different material processing techniques for metal matrix composite (MMC) has become refined and commercialized. Zinc-Aluminum (ZA) alloys have attained more importance commercially due to their properties like highload bearing and moderate speed applications. The ZA series materials are available at low cost and they can be used as alternative for cast iron, aluminium and brass alloys. They possess similar properties in comparison to aluminium alloys [1,2].

Many researchers worked on ZA alloy series with different reinforcements. Bobic et al. [3]observed that, addition of smaller $Al_2O_3$enhanced the strength than the as-cast alloy. Zircon reinforcements were added with ZA-27 alloy bySharma et al. [4]and exhibited an increase in tensile strength and yield strength with reduction in ductility including impact strength by increment in percentage of reinforcement. With the above literature, it was witnessed that, limited work conducted on the production of zinc-aluminium (ZA)MMC. ZA-12 alloy can be used in different industrial applications. Silicon carbide possesses good hardness property and graphite has lubrication property. With these reinforcements, overall the composite property can be improved. Further research is required with these reinforcements to increase the applications of these materials in different industrial sectors.

In the present work, ZA-12 hybrid composite is produced by adding silicon carbide (SiC) and graphite as reinforcements. The fabricated MMC is tested for microstructural studies to witness the distribution of reinforcements and their mechanical properties with wear behavior in comparison to as-cast alloy.

## 2. METHODOLOGY AND EXPERIMENTAL PROCEDURE

The flow chart shows the different stages involved for material processing and various tests conducted on as-cast and produced composite material as shown in Fig. 1.The composition of ZA-12 alloy used in casting process is shown in table 1. ZA-12 alloy was reinforced with silicon carbide (SiC) and graphite reinforcements with varying percentages as shown in table 2 with composition codes.MMC was produced using stir casting technique by electric arc furnace as shown in Fig. 2. ZA-12 alloy ingots were allowed to melt in the crucible placed inside furnace with a temperature of 750 °C. The temperature is monitored by temperature controller by the thermocouple connected to the furnace. By the time the temperature as reached 750 °C, the alloy is fully liquefied and reached the molten state. Degassing (hexchloroethene) tablets are added to the molten metal to remove the entrapped gasses. Coverall is added into the melt to form a protective layer against oxidation. Magnesium chips are added to molten metal to increase the wettability property. Mild steel die machined with cylindrical channels of diameter 25 mm and length 130 mm was pre-heated at a temperature of 400 °C. Die was pre-heated to avoid the distortion, when the molten metal is poured into it. Prior

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to adding of reinforcement to the molten metal, it is to be pre-heated to remove moisturecontent present in reinforcement and to improve the property of wettability [5, 6].Reinforcement is allowed to flow into the molten metal at slower rate with stirring speed of 200 RPM and stirring in continued for 5 min after adding reinforcement. The molten metal is allowed to heat further at same temperature before pouring to the die.The cast specimens were turned to the required sizes as per ASTM standards. Tensile specimens were prepared in dog bone shape as per ASTM E8M standards and test was conducted using computerized universal testing machine (UTM) of 100 kN capacity. Hardness test samples were machined as per ASTM E10 and test was conducted using brinell hardness tester. Wear test was carried out using pin-on-disc wear testingequipment with sample preparation using ASTMG99 standards. Microstructural studies were conducted using scanning electron microscope (SEM) to witness the dispersal of reinforcements.

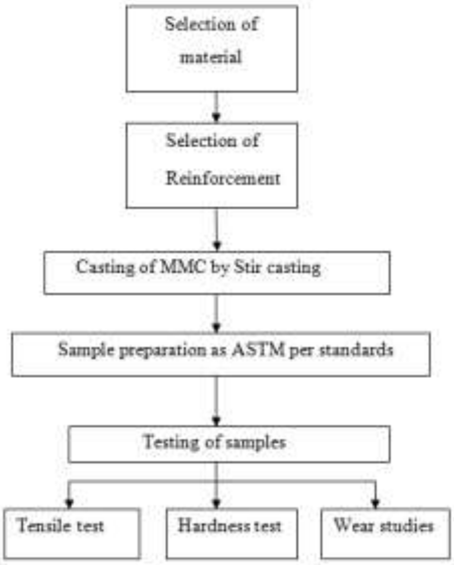


**Fig -1**: Flow chart of the process

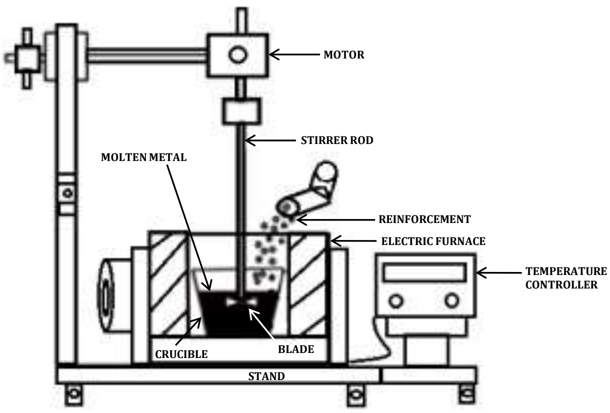


**Fig -2**: Stir casting set-up

**Table -1:** Composition of ZA-12 alloy in weight percentage (wt%)

| Elements | Al | Cu | Fe | Mg | Pb | Cd | Sn | Zn |
|---|---|---|---|---|---|---|---|---|
| wt% | 11.5 | 1.2 | 0.075 | 0.03 | 0.006 | 0.006 | 0.003 | Balance |

**Table -2:** Composition codes of ZA-12 alloy

| Code | Composition |
|---|---|
| C1 | ZA-12 |
| C2 | ZA-12+ 2% SiC+2% Graphite |
| C3 | ZA-12+ 4% SiC+2% Graphite |
| C4 | ZA-12+ 6% SiC+2% Graphite |

## 3. RESULTS AND DISCUSSION

Microstructures of as-cast and produced MMC samples are shown in Fig. 3.Microstructural analysis gives the information regarding the distribution of reinforcements with in the matrix. The reinforcement distribution directly influences the properties of the produced composite. Microstructure shows clear distribution of reinforcements which are visible and distributed fairly throughout the matrix.

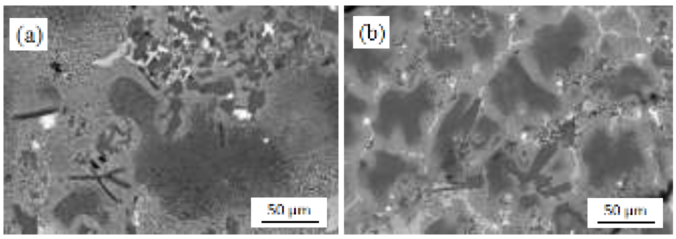


**Fig -3**: Microstructures of C1 and C4 samples

Figure 4 and table 3 shows the deviation of ultimate tensile strength (UTS) with reverence to varying percentage of SiCand graphite reinforcement particles.The UTS of C4 composite is higher in comparison to C3 and C2 composites and as-cast zinc alloy.

From the graph, it is observed that the UTS has increased with increment in percentage of reinforcements. This happened because of interfacial bonding with the matrix and reinforcement. The produced composite possess high dislocations and caused strengthening of the composite [7]. The generation of dislocations is because of SiC particles because of variation in thermal expansion coefficient [8]. Similar resultswere obtained by many researchers [9, 10].

**Table -3:** Tensile test of ZA-12 alloy

| Sample | Samples | UTS (MPa) |
|---|---|---|
| C1 | ZA-12 | 163.77 |
| C2 | ZA-12+ 2% SiC+2% Graphite | 181.87 |
| C3 | ZA-12+ 4% SiC+2% Graphite | 183.01 |
| C4 | ZA-12+ 6% SiC+2% Graphite | 208.63 |

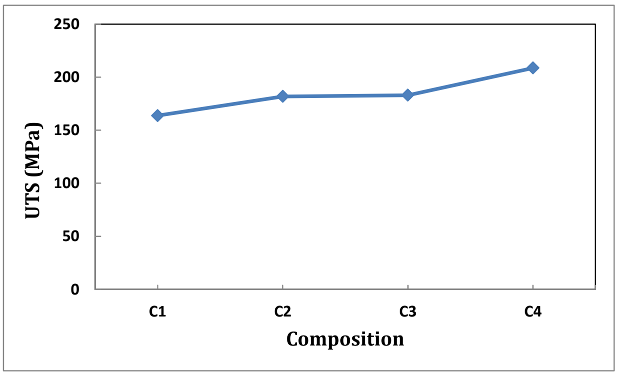


**Fig -4**: UTS of C1, C2, C3 and C4 samples

Hardness test was conducted on different sample composition as shown in table 4. Figure 5 shows the variation in hardness values obtained for increase in percentage of reinforcements. Maximum hardness value obtained is 118 BHN with the addition of 6% SiC and 2% graphite for C4 sample in comparison to 88 BHN obtained for as-cast condition. This shows that, hardness improved with rise in percentage of reinforcement. The presence of harder particles of SiC increased the hardness of composite hindering the dislocation movements in the matrix. Wear test was conducted for a sliding speed of 300 RPM and 600 RPM with constant load of 20N for a distance of 1000 m.

**Table -4:** Hardness test of ZA-12 alloy

| Sample | Samples | BHN |
|---|---|---|
| C1 | ZA-12 | 88 |
| C2 | ZA-12+ 2% SiC+2% Graphite | 96 |
| C3 | ZA-12+ 4% SiC+2% Graphite | 107 |
| C4 | ZA-12+ 6% SiC+2% Graphite | 118 |

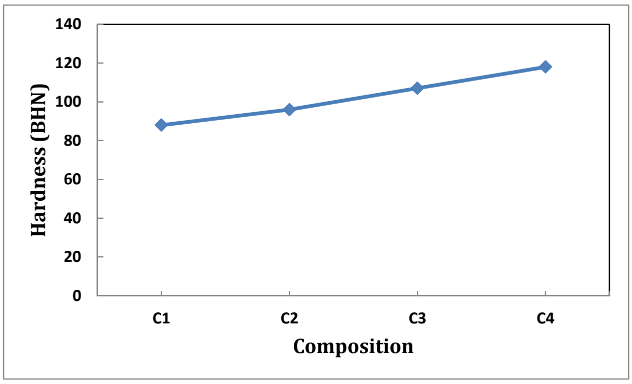


**Fig -5**: Hardness of C1, C2, C3 and C4 samples

Table 5 and table 6 shows different sample compositions tested for different sliding speed. Before wear test was conducted, the disc was prepared using emery paper to eliminate any debris present on the sliding surface. Later the disc surface was washed with acetone. From Fig. 6 and Fig. 7, it is observed that the wear resistance increases for the samples with rise in percentage addition of reinforcements. Addition of SiC and graphite reinforcements restricted the material loss from the sample surface. This is due to the hardness of SiC particles and lubrication property of graphite which avoided the formation of debris and delamination.

**Table -5:** Wear mass lossof ZA-12 alloy for 300 RPM

| Sample | Composition | Material Loss in mg |
|---|---|---|
| C1 | ZA-12 | 10.3 |
| C2 | ZA-12+ 2% SiC+2% Graphite | 9.5 |
| C3 | ZA-12+ 4% SiC+2% Graphite | 8.9 |
| C4 | ZA-12+ 6% SiC+2% Graphite | 8.2 |

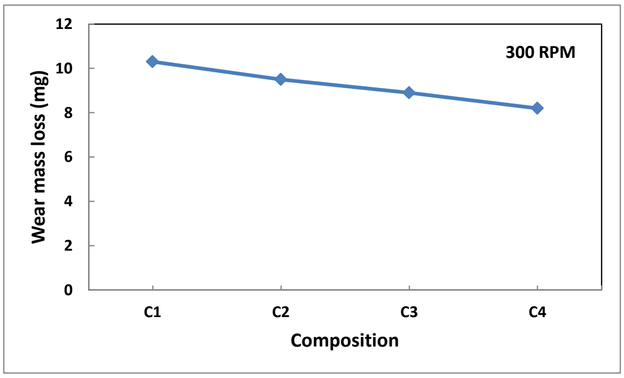


**Fig -6**: Wear mass loss of C1, C2, C3 and C4 samples at 300 RPM

With increment in sliding speed, the wear mass loss increases as observed from table 5 and table 6. But increase in percentage of reinforcements reduced the wear mass loss for both the sliding speeds (300 and 600 RPM).

**Table -6:** Wear mass loss of ZA-12 alloy for 600 RPM

| Sample | Composition | Material Loss in mg |
|---|---|---|
| C1 | ZA-12 | 13.5 |
| C2 | ZA-12+ 2% SiC+2% Graphite | 11.5 |
| C3 | ZA-12+ 4% SiC+2% Graphite | 10.3 |
| C4 | ZA-12+ 6% SiC+2% Graphite | 9.6 |

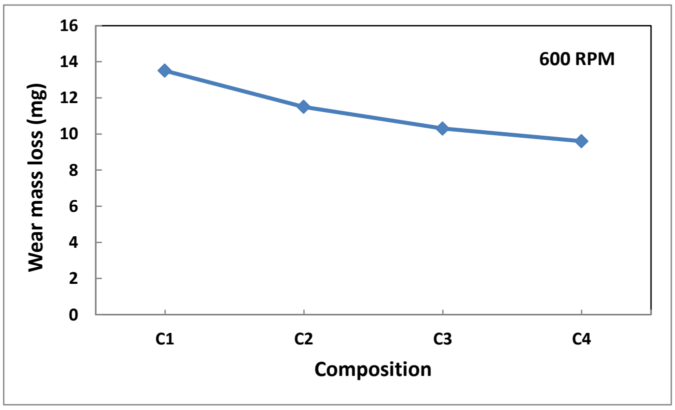


**Fig -7**: Wear mass loss of C1, C2, C3 and C4 samples at 600 RPM

## 4. CONCLUSIONS

ZA-12MMC was producedby stir casting process with varying percentage of reinforcements. Microstructural behavior and mechanical performance of producedsamples were studied. With the obtained experimental results, the succeeding conclusions are drawn as below:

• Implementation of stir casting process for fabricatingZA-12 MMC was successful with the addition of SiC and graphite reinforcements.

• Moderate distribution of SiC and graphite particles were observed in zinc matrix, which helped in improving the properties of produced MMC.

• UTSof C4 composite considerablyenhancedwith the addition of 6% SiC particles up to 208.63 MPa.

• Hardness of produced composite increased with increment in percentage of reinforcement and it was 118 BHNfor C4 condition compared to as-cast condition of 88 BHN.

•Wear resistance improved with increment in percentage of reinforcement addition, thereby restricting the formation of debris and causing of delaminationon composite surface.

## REFERENCES

[1] Ahmet Turk, Can Kurnaz and HuseyinSevik,"Comparison of the wear properties of modified ZA-8 alloys and conventional bearing bronze," Material Design,vol. 28, Jan. 2007, pp. 1889-1897.

[2] B.K. Prasad, A.K. Patwardhan, and A.H. Yegneswaran,"Characterization of the wear response of a modified zinc-based alloy, conventional zinc-based alloy and a bearing bronze at a high sliding speed," Metallurgical and Materials Transactions A., vol. 27, Nov. 1996, pp. 3513-3523.

[3] I. Bobic,M.T. Jovanovic and N. Ilic, "Microstructure and strength of ZA-27-based composites reinforced with Al2O3 particles," MaterialsLetters, vol. 57, Mar. 2003, pp. 1683-1688.

[4] S.C. Sharma, B.M. Girish, D.R. Somashekar, R. Kamath, and B.M. Satish, "Mechanical properties and fractography of zircon-particle-reinfored ZA-27 alloy composite material," Composite Science and Technology, vol. 59, Sept. 1999, pp. 1805-1812.

[5] S.A. Sajjadi, H.R. Ezatpour and H. Beygi, "Microstructure and mechanical properties of Al–Al2O3 micro and nano composites fabricated by stir casting," Materials Science and Engineering: A,vol. 528,Nov. 2011, pp. 8765–8771.

[6] S.A. Sajjadi, M.T. Parizi, H.R. Ezatpour and A. Sedghi, "Fabrication of A356 composite reinforced with micro and nano Al2O3 particles by a developed compocasting method and study of its properties," Journal of Alloys and Compounds, Jan 2012, vol 511, pp. 226-231.

[7] V.B. Manoji, V.R. Biradar, N. Venkatesh and L. I. Haragapure, "Characterization of silicon carbide reinforced aluminum matrix composites by using stir casting," International Journal of Mechanical and Production Engineering, pp. 85-89.

[8] Vogelsang Mary, R. J. Arsenault, R. M. Fisher, "An in situ HVEM study of dislocation generation at Al/SiC interfaces in metal matrix composites," Metallurgical Transactions A, vol. 17, Mar. 1986, pp. 379-389.

[9] P. Ajagol, B.N. Anjan, R.N. Marigoudar and G.P. Kumar,"Effect of SiC reinforcement on microstructure and mechanical properties of aluminum metal matrix composite,"IOP Publishing,Vol. 376, Jun. 2018, pp. 012057.

[10] R. Sri Priya, R. Yogeshwaran, K. Syed Mohammed, S. Bharathvaj and M. Shanmugaraja,"Investigation on mechanical properties of aluminium 6061 reinforced with SiC and $Al_2O_3$," ISSN: 2349-2362.