

# Experimental Study on Mechanical Characteristics of Graphite and Silicon Carbide Reinforced ZA-27 Metal Matrix Composite

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**ABSTRACT:** Hybrid Metal Matrix Composites (HMMCs) finds its applications in automobile, aviation, robotics and naval equipments due to their superior properties like high strength to weight ratio and wear resistances. The present work is aimed to develop a ZA-27 HMMCs by varying graphite content in the proportion of 2, 4 and 6% along with 6% of silicon carbide for studying its mechanical properties. Tensile properties such as toughness, tensile modulus, strain energy density; ductility and tensile strength for all the three compositions were reduced with addition of graphite. This detrimental effect can be attributed to the presence of possible stress risers, which in turn increases the stress concentration sites with addition of reinforcement particles like silicon carbide and graphite.

**KEYWORDS:** Hybrid Metal Matrix Composites, ZA-27 HMMCs, Tensile properties, Stress risers.

## I. INTRODUCTION

Composite materials offer light weight characteristics and have better durability as compared to conventional materials. Hence they are used extensively in engineering applications such as automobile, aviation, robotics, naval equipments etc. Metal matrix composite comprises of two constituent parts. One of the constituent shall be metal, which forms base material and other may be reinforcement made of different metal. [1]

When MMC is composed of three constituents, then it is termed as hybrid metal matrix composite (HMMC). MMCs are often used due to its higher wear resistance characteristics and better strength to weight ratio which enables them to meet the challenges and to maintain global competitiveness. Examples of reinforcements commonly used for MMC are: Silicon Carbide, Alumina, Graphite etc.

Zinc-aluminium-27 alloy i.e. ZA-27 is used as the matrix material. Zinc aluminum alloys 8, 12, and 27 comprises a new family of zinc casting alloys, they have proven themselves in a wide variety of applications. The alloys designated as 8, 12, and 27 are based on the approximate amount of the aluminum content. Each alloy contains copper and magnesium to attain a combination of properties.

E Delannay et al. [2] have studied about the improvement of mechanical properties of Al, Zn and Cu-based matrix composites, reinforced with continuous fibers of carbon, Sic, Al<sub>2</sub>O<sub>3</sub>. Interface adhesion has been characterized from the distributions of fiber pull-out lengths on fracture surfaces. Bhaskar Raju et al. [3] conducted experimental investigations on SiC particulate filled ZA-27 MMCs. For each cast tube produced, mechanical properties like hardness, tensile strength, compression strength, and ductility were studied. These developed HMMCs possessed improved hardness (from 91 to 209.23 BHN) and Impact strength (from 40 to 62.5 kJ/m<sup>2</sup>). It was also noticed by the authors that, hardness and impact strength increased considerably with the increase in the weight fraction of the filler material. The authors in [4] have applied linear and polynomial equations for finding the mechanical properties, with a simple

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algorithm that links them. This technique is the accurate method available to determine modulus of elasticity and toughness of the anisotropic materials like composites.

It was found that various researchers have evaluated mechanical and wear properties of MMCs and HMMCs by using various reinforcements like silicon carbide [SiC], graphite, Al<sub>2</sub>O<sub>3</sub>, Fly ash and coconut powder. Much work is carried out by varying silicon carbide as reinforcement material in order to enhance the mechanical behavior and wear resistance of aluminum based MMCs. Since ZA-27 finds its applications widely in automotive industry, agricultural machineries, aeronautics, construction, textile machineries and engineering structures. The present work is aimed to develop a ZA-27 HMMCs by varying graphite content in the proportion of 2, 4 and 6% along with 6% of silicon carbide for studying its mechanical properties.

## II. OBJECTIVE OF THE PRESENT WORK

On the basis of the available literature following objectives were selected for this work

1. To develop a ZA-27 MMCs by varying graphite content in the proportion of 2, 4 and 6% along with 6% of silicon carbide using stir casting route.
2. To analyze the effect of varying percentage of graphite on the mechanical behavior of ZA-27 reinforced with 6% silicon carbide HMMCs.

## III. MATERIALS

The materials [matrix and reinforcements] used in this present work listed in the table 1.

**Table 1: Material Selection**

SI No	Material	Matrix/Reinforcement	Important Characteristics
1	Zinc Aluminum [ZA-27]	Matrix	ZA-27 has extremely good wear and corrosion resistance. Density of ZA-27 alloys is reduced significantly with the addition of al. ZA-27 also posses high damping characteristics.
2	Silicon Carbide [SiC]	Reinforcement	It is a commonly used refractory material. It has good wear and corrosion resistance properties. It also has good thermal shock resistance.
3	Graphite	Reinforcement	Self lubricating material, very good wear resistance property. Majorly used in piston rings, thrust bearings, journal bearing and vanes. Shafts and fuel pumps of aircraft jet engines.

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## IV. RESULTS AND DISCUSSIONS

### A. Density Calculation

The theoretical density of the developed HMMCs was computed using equation 1.

$$\rho_c = (\rho_m * v_m) + (\rho_r * v_r)$$

EQ.1

Where,  $v_m$  and  $v_r$  = volume fraction of matrix and reinforcements respectively.  
 $\rho_c$ ,  $\rho_m$ ,  $\rho_r$  = Density of HMMCs, matrix and reinforcement respectively.

The theoretical density of the developed hybrid metal matrix composite specimens namely; ZA-27+6%SiC+2%Gr ZA-27+6%SiC+4%Gr and ZA-27+6%SiC+6%Gr were computed using Eq. 3.1 and the obtained results are in the table 2.

**Table: 2 Density of the HMMCs composites**

SL No.	HMMCs Composition	Density (Kg/m <sup>3</sup> )
1	ZA-27+6%SiC+2%Gr	4727.21
2	ZA-27+6%SiC+4%Gr	4621.27
3	ZA-27+6%SiC+6%Gr	4519.97

From the above table, it is evident that with increase in graphite particles the density of the HMMC specimens decreases appreciably.

### B. Tensile Test

Tensile tests were conducted for all three composition test specimens using UTM as per E8 ASTM standard [5]. Stress-strain diagrams were plotted for evaluating tensile modulus, tensile strength, ductility, strain energy density, toughness and strain at fracture. Three specimens were tested for each composition and average values were considered for determine the above said properties. Figures namely, 1, 2, 3, 4, and 5 indicates the variation of toughness, ductility, tensile strength, strain energy density and tensile modulus for varying percentage of graphite respectively.

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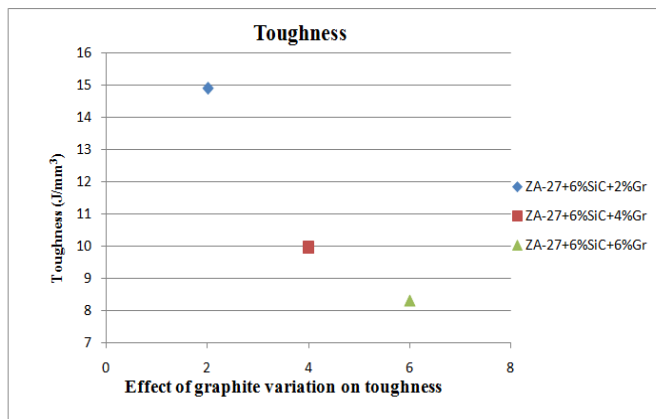


Figure 1: Toughness variation with increasing Gr.

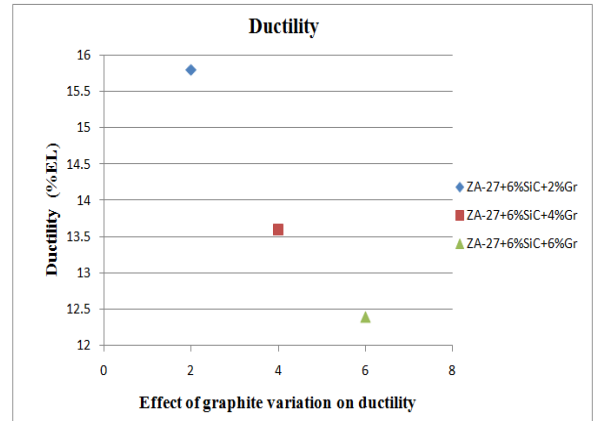


Figure 2: Ductility variation with increasing Gr.

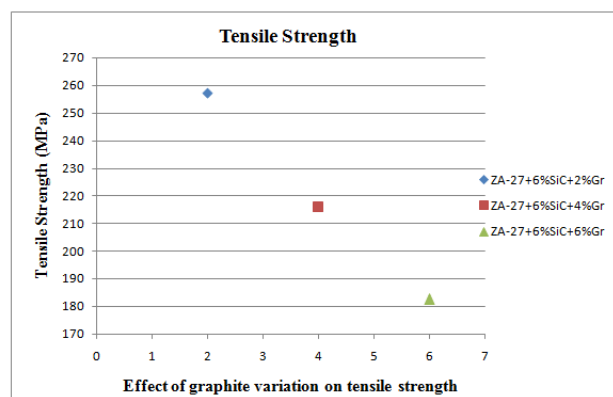


Figure 3: Tensile strength variation with increasing Gr.

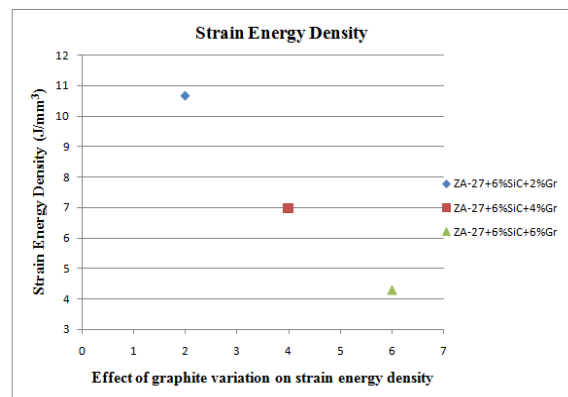


Figure 4: Strain energy density variation with increasing Gr.

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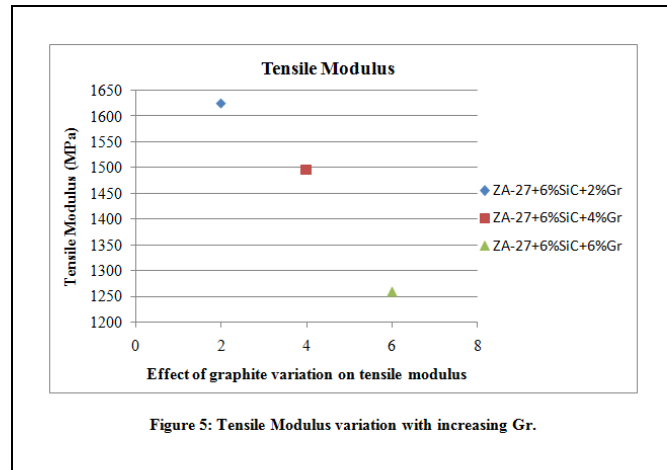


Figure 5: Tensile Modulus variation with increasing Gr.

It is observed that tensile properties such as tensile modulus, toughness, strain energy density and ductility for all the three compositions were reduced with addition of graphite. This effect can be attributed to increase in stress concentration sites with addition of reinforcement particle like silicon carbide and graphite which possibly may act like stress risers under the monotonic loading conditions. From the literature, it was observed that, the presence of reinforcement particle resist the passage of dislocations which intern reduces the above said properties. Increase in reinforcement particles may lead to increase in porosity which intern decreases ductility. The addition of graphite also has a detrimental effect on the toughness, strain energy density and tensile strength.

### C. Vickers Hardness Test

The Vickers hardness tests were carried out for all three set of compositions in accordance with ASTM standard E-92 [6]. Three specimens were tested for each composition and average values were considered for determining diagonal impression. It is found that with the increase in the percentage of graphite particulates, the hardness of the HMMC specimens' increases considerably.

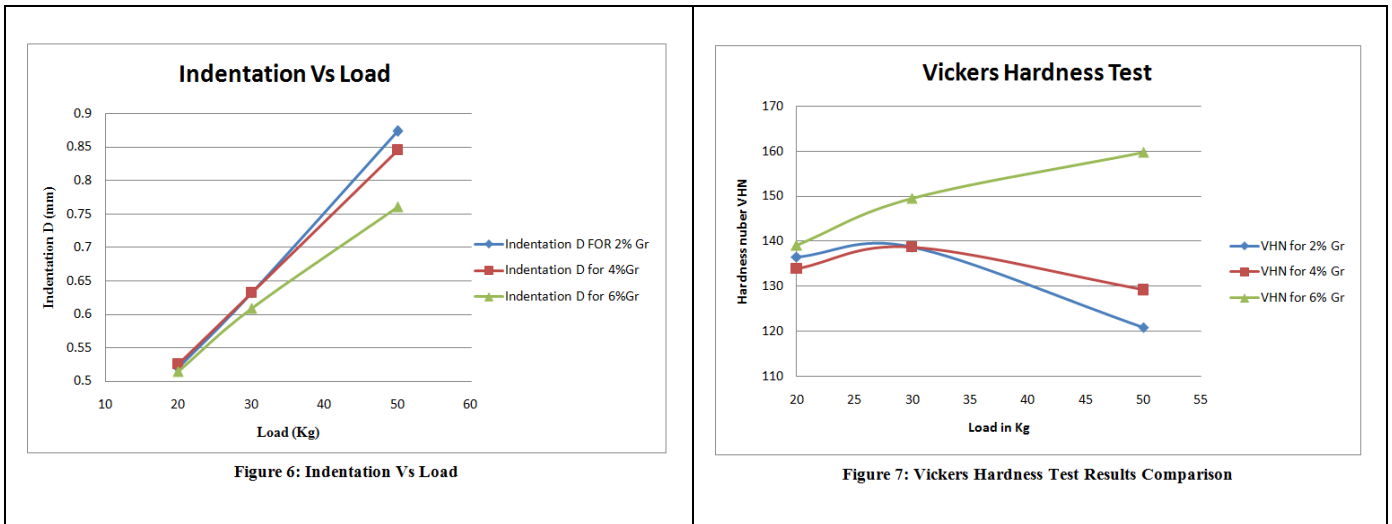
From the figure 6, the result reveals that with raise in the quantity (percentage) of graphite, the amount of indentation in terms of diagonal impression decreases for the same load. This effect is due to the addition of graphite which forms obstacles to the dislocation motion in HMMCs. The Vickers hardness number found for the different compositions of hybrid MMC specimens was in close agreement with the standard values as per ASTM standard E92.

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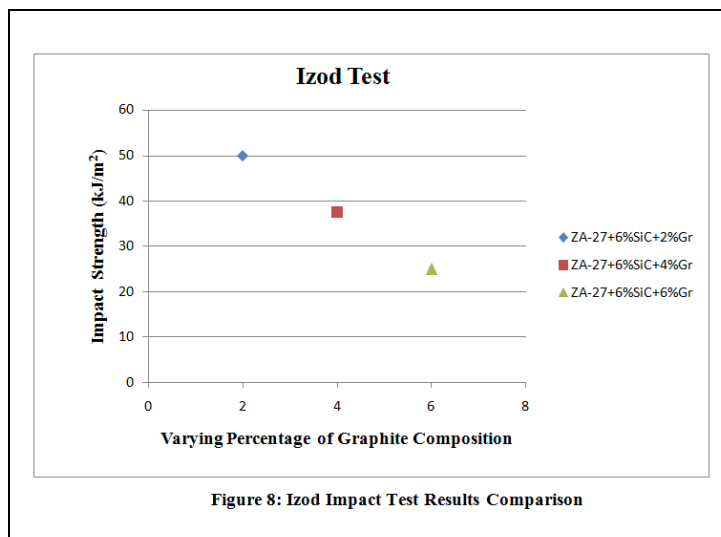
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### D. Izod Impact Test

It is important to understand the impact behavior of composites for efficient and safe design of structure under shock or impact loads. Hence, in this study, Izod impact tests were carried out for evaluating impact strength of HMMC specimens as per ASTM standard E23-07a.



It is observed from the figure that, impact strength of the hybrid composite specimen decreases gradually with increase in graphite content (from 2 to 6%). Maximum energy absorbed was 4J for the developed hybrid composite specimen with 2% graphite.

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## V. CONCLUSIONS

From this work done following conclusions could be drawn

1. HMMCs were successfully fabricated using stir casting for three different compositions namely; ZA-27+6%SiC+2%Gr, ZA-27+6%SiC+4%Gr and ZA-27+6%SiC+6%Gr.
2. The theoretical density of the developed hybrid metal matrix composite specimens decreased appreciably with increase in graphite particles.
3. Tensile properties such as tensile modulus, toughness, strain energy density and ductility for all the three compositions were reduced with addition of graphite.
4. This detrimental effect can be credited to the increase in stress concentration sites with addition of reinforcement particle like silicon carbide and graphite which possibly may act like stress risers under the loading conditions.
5. The addition of graphite also had an unfavorable effect on the tensile strength.
6. With increase in the percentage of graphite particulates, hardness of the HMMC specimens increased notably. These results clearly showed the uniform dispersion of Gr and SiC within the ZA-27 MMCs.
7. The Vickers hardness number found for the different compositions of hybrid MMC specimens was in close agreement with standard values as per ASTM standard E92.
8. Impact strength of the hybrid composite specimen decreased gradually with increases in graphite content from 2 to 6%. Maximum energy was absorbed 4J for the developed hybrid composite specimen with 2% graphite.

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