EFFECT OF SILICON CARBIDE IN MECHANICAL PROPERTIES OF ALUMINIUM ALLOY BASED METAL MATRIX COMPOSITES

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Abstract. Metal Matrix Composites are a class of composites with evaluated properties that get another perspective of material structure and are generally utilized in the aviation and automobile industry. These materials have the properties of both the base matrix material as well as the reinforced materials. These metal matrix composites have low residual stress and thermal residual stresses. Due to this concept, the materials posses enhanced adhesive bonding between the matrix and reinforcements. Aluminium alloy with silicon carbide is applicable where hardness and toughness are the requirements. Metal Matrix Composites are designed in order to have the combined properties of both metals and ceramics. The specimens are fabricated for various proportions of the materials. In the fabrication, it begins with Aluminium alloy and Silicon carbide. The specimen is evaluated for diverse mechanical tests, and the experimental result is the pure aluminium undergoes more wear when compared to the reinforced specimen.

1. Introduction
The word composite generally refers to a material system which constitutes two materials that is a metal and a ceramic distributed evenly throughout the cross section. On the basis of physical and chemical nature of the matrix material, Composite materials are classified as metal matrix composites, ceramic matrix composites and polymer matrix composites. In composite material, the individual components retain their individual characteristics and to reveal only their positive outcomes and not their drawbacks, in order to acquire an improved material.

Metal Matrix Composite (MMC) is composed of a metallic metals mostly magnesium, aluminium, Titanium, cobalt and copper and Ceramics (Carbides and Oxides) or metallic (Tungsten, Molybdenum) phase. When three materials are identified in a composite, it is known as hybrid metal matrix composite.
Metal Matrix Composites were made of dispersed reinforcement material into base metal matrix. The reinforcement material is coated in order to stay away from chemical reaction with the matrix material. The matrix is the single block of material into which the reinforcement is dispersed and is continuous throughout the surface. The matrix material is usually a lighter metallic material like Aluminium or Titanium or Magnesium to provide complete support to the reinforcement.

The reinforcement materials were surrounded with the matrix, which is used to alter the mechanical and electrical properties. The reinforcement material is dispersed neither continuous nor discontinuous. Aluminium alloy metal matrix composite (AMMC) offers designers with many included advantages, as they are especially appropriate for applications requiring improved strength, good structural stiffness, and dimensional constancy and lightweight. MMCs provide enhanced properties over monolithic alloy. In Aluminum alloy metal matrix composite (AMMC) the major constituent is aluminum or aluminum alloy, which form porous surface and is termed as matrix layer. The other constituents embedded in this aluminum/aluminum alloy porous matrix layer and serve as reinforcement, which is usually a nonmetallic and commonly ceramics such as Silicon Carbide or Aluminium Oxide. Properties of AMMCs can be varied by varying the composition of constituents and their volume fractions.

2. Literature Review
The effect of the addition of Silicon Carbide reinforcement to aluminium on microstructure and wear properties of Al 5083-SiC by adding the SiC 2%, 3% and 5wt.% through stir casting is experimented by [1]. By adding 5% wt. of Silicon Carbide particles to aluminium alloy the maximum hardness value, maximum ultimate tensile strength and tribological properties were improved due to a fair distribution of Silicon Carbide particles in aluminium matrix. Hybrid metal matrix composite was fabricated by [2] by reinforcing the Silicon carbide and Titanium diboride on aluminium and the results shows that addition of reinforcement up to 15% wt reveals the reduction of the hardness value and its tensile test results in reduction of strength to 50-60% is by TiB$_2$ but the addition of Titanium diboride increases the wear resistance of the material, maximum addition of TiB$_2$ is limited to 2.5% because 5% lead to porosity and affect the hardness value. [3] fabricated a MMC by stir casting method and investigated the mechanical properties by hybrid reinforcing Aluminium 8011 matrix with boron carbide (B$_4$C) and alumina particles and summed up that with increase in weight percentage of reinforcement particles increases the mechanical strength while the composite with 90% Al + 5%B$_4$C+5% Al$_2$O$_3$ have greater mechanical properties than the other samples prepared. Long-term naturally aging die cast of Aluminium-Silicon-Copper alloys is studied by [4] in the presence of corrosive environment, the material increases over 10 year period and variation in microstructure affecting the physical properties. The cause for modification in microstructure is mainly of higher casting pressure and quick cooling process. But in Al alloy heavy walls, the change in microstructure not occur even after natural aging. [5] Proposed an investigation on the effect of the addition of Silicon Carbide (SiC) to the Aluminium alloy upto 60% SiC on the composites. The porosity of the composites is reduced and microscopically it's found to be homogeneous in distribution. [6] evaluate the mechanical properties of hybrid reinforced Al alloy 7075 reinforced with SiC and Al$_2$O$_3$ metal matrix composites in the proportions of 3%, 5%, 7% and 9% weight of Al$_2$O$_3$ and 2% weight of SiC by stir casting method and concludes that ductility alone decreases while hardness and tensile increases with their addition and the sample containing the highest percentage of Al$_2$O$_3$ exhibit high tensile strength and hardness with a minimum % of elongation.
The investigation conducted by [7] on the mechanical properties of particulate reinforced aluminium and Silicon Carbide MMC’s by stir casting route and stirring the MMC slurry in partial molten state helps to disperse ceramic particles into matrix material properly while holding temperature, stirring speed and the size and position of impeller are the important factors to be considered while casting of these composites since they have an crash on the mechanical properties and the wear rate tends to decrease with the increase in weight percentage of SiC and these materials can be used in high elevated temperatures, for better wear resistance and corrosion resistance. [8] fabricated Aluminium-Silicon Carbide composites with weight percentage varying from 5% to 30% weight of SiC using powder metallurgy process and its various tests results were measured. Alloying of composites for 16 hours of milling resulted in uniform powder structure and the quality of the final product depends upon the initial compact. It resulted in the increased hardness, compressive strength, density by the reinforcement of contents from 5% to 30% weight of SiC. [9] Investigated the aluminium alloy metal matrix composite by stir casting method for various proportions of boron carbide(B₄C) and silicon carbide (SiC), and concluded that 96% Al, 2% SiC and 2%B₄C has a higher strength due to higher quantity of carbides in composite and for different casting method its mechanical properties can be found. An overview of Aluminium matrix composite of the effect on addition of reinforcements in aluminium alloy with different mechanical properties like a tensile test, strain, hardness and wear are discussed by [10]. It concludes that SiC reinforced have high wear resistance and compressive strength compared to other reinforcements like Al₂O₃ and B₄C in MMC.

### 3. Materials and Sample Preparation

Aluminum and its combinations have outstanding properties like density, good plasticity, great versatility and flexibility and great wear resistance. They find broad applications in aircrafts, astronautics, automobiles and train fields. Nonetheless, low hardness and poor shock resistance bring about their restricted application in heavy duty conditions. Similar to all composites, aluminium based composites were not a solitary material, but rather a group of materials whose strength, flexural, density, stiffness, electrical and heat carrying properties can be customised. The proportions of matrix material, reinforced material, shape and size, the method of reinforcement and the method of manufacturing can be varied in order to enhance the required properties. Despite the varieties, be that as it may, Aluminium composites offer incredible thermal conductivity, high shear strength, magnificent wear resistance, high-temperature activity and non-combustibility.

The chemical composition of Al 8011 alloy consists of various materials as listed in Table 1.

| Material | Weight % |
|----------|----------|
| Fe       | 1        |
| Si       | 0.9      |
| Mn       | 0.3      |
| Zn       | 0.1      |
| Cu       | 0.1      |
| Ti       | 0.08     |

Table 1. Chemical Composition of Al 8011 alloy
Silicon carbide (SiC) is made up of tetrahedra of carbon at the core and shared silicon atoms with tough bonding in crystal lattice. This results in a very hard and sturdy material. SiC is not affected by any acids or alkalis up to around 900°C. When exposed to air, SiC reacts with air and form a Silicon oxide coating at 1300 °C and is able to be utilized till 1650 °C. The low thermal expansion and high thermal conductivity gives this material an outstanding thermal shock resistant quality. The strength of Silicon Carbide ceramics vary with grain boundary impurities. SiC particles reinforced Aluminium, are one of the generally known composites due to their predominant mechanical properties.

4. Sample Preparation
Table 2 shows the samples with different weight percent proportions of 8011 Al alloy and SiC that are casted.

| Samples | Aluminium | Silicon carbide |
|---------|-----------|----------------|
| 1.      | 100%      | -              |
| 2.      | 90%       | 10%            |
| 3.      | 80%       | 20%            |
| 4.      | 70%       | 30%            |

Total weight of each sample = 145.8 g.

MMC can be a manufacture by utilizing a few procedures which can be a solid, liquid and vapour phase. Stir casting (Liquid state) procedures were generally used to fabricate AMMCs. In stir casting technique, MMCs are manufactured by dispersing the preheated reinforcement material into high temperature molten matrix material by applying stirring activity and pouring the combined material into the die and it is made solidified as shown in Figure 1. To manufacture the enormous number of MMC parts, stir casting is the most efficient way of fabrication in fluid state.

5. Experimental Method
The prepared composite samples are investigated for their mechanical properties and are compared with the pure aluminium.

5.1 Tensile Test
Tensile test is a basic test for evaluation of mechanical property in which the sample is subjected to a tensile load till it fails. It results in the direct measurement of ultimate strength, elongation and reduction in area of the sample. As per the ASTM B557 standards, the prepared samples as shown in Figure 2 were subjected to tensile test and the results were noted.

![Figure 2. Samples for Tensile Test](image)

![Figure 3. Wear Test Samples](image)

5.2 Hardness Test

Hardness is the opposition offered by the material for contained deformation. This term can be applied for indentation or scratching or bending. Hardness measurement is done in Vickers Hardness Testing Machine. The microhardness test was carried in Micro Vickers Hardness Tester which has a testing load series of 10 gms to 1 kg load and testing scale used is HV. The prepared samples were subjected to a load of 0.5 kg with reside time 10 sec in three locations of each sample.

5.3 Wear Test

Wear is associated to interactions between the sliding or rolling surfaces specify the subtraction and deformation of material on contact surface as a result of sliding or rolling actions. Wear test was carried in Pin on disc for ASTM G99 standard with the samples shown in Figure 3.

6. Results and Discussion

The experimentation on the prepared samples are conducted and the results are discussed as follows:

6.1 Tensile Test

Figure 4 shows that the casted pure Al 8011 alloy has the maximum tensile strength of 142.8 MPa. When adding 10% Silicon Carbide to Al 8011 alloy, the tensile strength of the 90% Al 8011-10% SiC metal matrix composite improves to 146.13 MPa as shown in Figure 5. This shows that there is a slight improvement in the tensile strength. In the same manner, Figure 6 shows the ultimate tensile strength of 20% SiC to 80% Al alloy particles as 155.63 MPa. The 70% Al 8011-30% SiC metal matrix composites have the maximum tensile strength of 162.61 MPa when compared to the remaining composites and pure alloy as shown Figure 7, due to the uniform reinforcement of the Silicon Carbide particles, this 70% Al 8011-30% SiC has the highest tensile strength.
6.2 Hardness Test

The microhardness test was carried in Micro Vickers Hardness Tester which has a testing load range of 10 gms to 1 kg load and testing scale used is HV. The prepared samples have undergone a load of 0.5 kg with reside time 10 sec in three locations of each sample. Figure 8 indicates the mean value of micro hardness was enhanced with the accumulation of weight percentage of ceramic (SiC) particle into the aluminium matrix.

![Figure 8. Hardness values of samples](image)

6.3 Wear test

Tribological properties of the produced samples were evaluated by conducting test on Pin and Disc set up. A load of 9.81 N was applied for a period of 600 seconds throughout the experiment for all the samples.

![Figure 9. Wear rate](image)
Casted Pure Al has a wear rate of 318 micrometers when subjected to a load of 9.81 N for a period of 600 seconds with a coefficient of friction of 0.320 as shown in Figure 5.5. The wear rate of 200 micrometers was drastically reduced as shown in Figure 5.6 for 10% SiC + 90% Al from the Pure Al alloy. Again with 20 wt.% of SiC and 80 wt.% Al 8011 alloy a wear rate of 123 micrometers is observed Figure 5.7. The minimum wear rate of 71 micrometers was observed in Figure 5.8 for 30 wt.% SiC and 70 wt.% Al 8011 alloy composite material. The wear resistance enhances by increasing the proportion of SiC to Aluminium matrix.

7. Conclusion
Aluminium alloy based Silicon Carbide Metal Matrix Composite have successfully fabricated by die casting. The addition of silicon carbide particles to the pure metal enhances the mechanical properties tensile strength, hardness and wear resistance of the composites. From this experimental study, it is noted that the higher the percentage of reinforced SiC, the higher is the tensile strength and hardness value with lower wear rate is observed. The sample with 70% Al + 30% SiC has the tensile strength of 162.61 MPa and the Vickers hardness of 103.1 H.V with the wear rate of 71 micrometers is observed.

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