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Examining the Mechanical Properties of Al-SiC Metal Matrix Composites Produced Using the Stir Casting Method

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Stir casting, Wear Test, Hardness Test, Tensile Test, and Silicon Carbide.

Research Article

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Abstract

Aluminum metal matrix composites have great corrosion resistance, light weight, and durability. Because of these characteristics, metal matrix composites made of aluminium can be used in a variety of automotive, marine, and aviation applications. The mechanical characteristics, microstructures, and wear properties of silicon carbide metal matrix composite aluminum are investigated in this study. In the current investigation, the matrix was aluminum and the material used for reinforcement was silicon carbide (30 microns). The various compositions in volume fraction—100% Al -0%Sic, 96.5% Al -3.5%Sic, and 93% Al -7.0%Sic—were selected. Stir casting was utilized in the fabrication process. Analysis was done on the produced composites microstructures, Vickers hardness, tensile strength, and wear behaviour. The hardness, tensile strength, and weight % of an aluminum (Al) matrix were all improved by the addition of silicon carbide (SiC) reinforcements, as indicated by the results. By observing the microstructure, silicon carbide (SiC) particle collection and The Al matrix's non-homogeneous distribution was verified. In aluminum matrix composites, porosities were seen in the microstructures and increased as the weight percentage of silicon carbide (SiC) reinforcements increased. A pin-on-disc wear test discovered that the Al matrix had been reinforced with silicon carbide (SiC) particles, improving wear rate.

1. Introduction

A composite material is produced through the blending of two or more component elements, each of which has unique physical or chemical characteristics. There are many reasons why this new material might be preferred over traditional materials, some of which include its increased strength, reduced weight, or lower cost. In the last few years, scientists have also been actively incorporating sensing, actuation, computation, and communication into composite materials—often referred to as robotic materials. Composites consist of a mixture of elements with various compositions. These materials even maintain their individual identities in their composite form; that is, they do not entirely fuse or conjugate into one another. Because they have better wear resistance, a greater specific strength, and a higher specific modulus than regular reinforced alloys, they are becoming increasingly popular. Silicon carbide is an externally inserted reinforcing particle that was used in this evaluation. The many reinforcements that increase the tensile strength, hardness, density, and wear resistance of aluminum and its alloys are utilized, including silicon carbide, aluminum oxide, titanium carbide, boron carbide, and SiC reinforcement. Metal matrix composites with continuous or discontinuous fibers melted into a metal mixture yield a mixture with a very high modulus. Since the previous few decades, a lot of industrial applications have focused on MMCs because of their unique qualities, such as their cost-effectiveness and strength-to-weight ratio.

Stir casting is a technique used in the production of the composite matrix. Hybrid Aluminum Metal Matrix Composite is the name given to the hybrid composite that is created as a result of this formation (HAMMC) [1-2]. The tensile strength and elongation at break of the EPDM/CB composites increased up to 11 MPa and 480% with the addition of 10 phr CB, respectively. In addition, it was revealed that the vulcanization parameters were also enhanced [3]. Investigates the effect of pumice, known as Karakaya pumice, and taken from the Isparta-Gölcük region, on clay's unconfined compressive strength and swelling pressure. [4]. Algebra becomes important in school when we learn to work with variables, expressions and equations. [5]. Microstructures of pure and additively mixed clayey soil specimens were investigated for this purpose. X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses were performed on compacted soil specimens [6]. Composite materials are advanced engineering materials with superior properties to traditional materials. One of the most important disadvantages is the high cost of composite materials. Therefore, producing composite materials from the first to the last stage is a very important process [7]. Aluminum matrix composites (AMC) can be produced via powder metallurgy, semisolid processing, and liquid state processing. [8]. Aluminum 6061 is often used as the matrix in MMC because of its special mechanical and chemical properties characteristics include its weight in relation to other metals, corrosion resistance, and indentation resistance [9-10].

An affordable technique for producing aluminum matrix composites is stir casting. Several factors in this procedure affect the mechanical properties of the composites. [11-12]. The hardness of the material rises with the percentage of filler material (silicon carbide). Compressive strength rises as filler material proportion rises. [13-14].The weight fraction of the reinforced particles used to make the MMCs bars and circular plates ranges from 5% to 20% [15-16]. To remove porosity, cast specimens are heat-treated under different conditions. Using image analyzer and X-ray computed tomography methods the porosity in the casting was assessed. [17-18]. The study compares the qualities of AMMCs with industry norms and finds remarkable results [19-20]. This paper outlines an attempt to use stir casting to generate a hybrid metal matrix composite with silicon carbide and titanium diboride reinforcement in an Al 6061 matrix. [21-22]. Microstructural studies reveals that ultrasound assisted in situ method improves the dispersion of TiB2 particles and reduces the porosity level [23]. Nowadays, composites are profoundly thriving as the replacement of ferrous alloys [24]. Al-SiC Metal Matrix Composites have been used more and more in recent years because of their special qualities, which include low density, high specific modulus, high hardness, high fatigue strength, high strength, and low weight. [25-26]. Aluminium is one of the lightest engineering materials [27]. Al2O3, SiC reinforcement in an aluminum 6061 matrix improves the metal matrix composite material's overall properties [28-30].

2. Materials Selection and Fabrication Process

2.1 Matrix Selection:

Matrix is the basic component of the composite. Many matrix materials is capable of producing metal matrix composites. however the most common ones are aluminum and its alloys. Aluminum alloys are reinforced with both soft and hard reinforcements, including Si-rice husk, graphite, MgO2, SiC, etc. Alloys like alloy 356; alloy 6063; and aluminum 6061 are commonly used. The base substance, The material utilized as the matrix is aluminum 6061 alloy. The pure aluminum 6061 alloy is displayed in the image (Fig. 1) below.

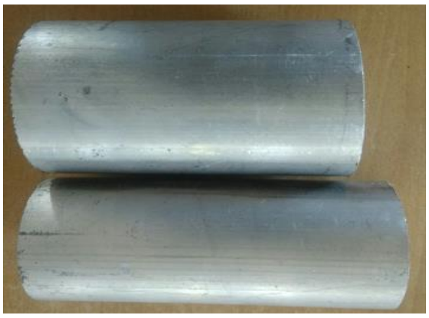


Figure 1. Matrix Material-Al6061

2.2 Reinforcement Selection

Silicon carbide can be used as reinforcements in a range of materials because it provides the strength, hardness, high fracture toughness, and extremely high resistance to crack propagation of the design structure. In this investigation, powdered silicon carbide (SiC) is used as AMMC reinforcement. The pure SiC powder is displayed in the image (Fig 2) below.

Figure 2. Reinforcement Material -SiC

2.3 Composites Producing Process

Aluminum matrix composites (AMC) reinforced with silicon carbide (SiC) was made via stir casting. Stir casting is a liquid state technique used to create composites, whereby mechanical stirring combines a molten matrix metal with a dispersion phase (SiC particles).Following that, normal casting procedures are used to cast the liquid composite material.. Stir casting is used to create the metal matrix hybrid composite of aluminum-silicon. For this, we have selected 1250 grams of aluminum 6061 alloy and the appropriate percentages of powdered SiC (0%, 3.5%, and 7.0%). The strength of mixing, the situation under which the particles are wet with the melt, the velocity of solidification, and the relative density all affect how the particles are distributed in the final solid. Aluminum melt temperature at 1000°C for 3 to 4 hours .The addition of SiC is done while maintaining the melt temperature at 700°C. A mild steel turbine stirrer is used to agitate the melt. To improve the wet ability, the stirring is continued for five to seven minutes at an impeller speed of 700 rpm. The permanent metallic mold is heated and filled with the melted material. A constant 680°C pouring temperature is maintained. After that, the melt is given time to harden in the mold. One obtains the metal matrix composites. Table 1 lists the compositions of Al-SiC MMC. Stir casting technique and sample setup for experimentation as depicted in figure 3 and figure 4.

Table 1. Compositions of Al-SiC Metal Matrix Composites

Samples	Al 6061(%)	SiC (%)
1	100	0
2	96.5	3.5
3	93	7.0

Figure 3. Experimental setup-Stir Casting Process

Figure 4. Al6061-Sic MMC's Samples

3. Experımental Testıng and Results Dıscussıon

After production, each specimen was put through the following mechanical tests, which are listed in detail in the tabular 2 column below; utilizing workshop equipment to evaluate its mechanical properties:

Table 2. Mechanical Properties Testing and Equipment's Details

Testing	Equipment used
Tensile Test	Universal Testing Machine
Hardness Test	Vickers's Hardness Testing Machine
Microstructure	Scanning electron microscopy
Wear Test	Pin on disc Method

3.1 Tensile Test

A universal testing machine is used to test specimens for tensile strength. For the purpose of performing the tensile test on the sample specimen, the specimen's minimum diameter of 10 mm and its length of 120 mm were taken into consideration. In a tensile test, an object is positioned between two grippers at opposite ends and is gradually pulled apart until it breaks. The following graph (figure 5) shows the correlation between the weight percentage and tensile strength of silicon carbide (SiC) reinforcements in composites that were produced. Tensile studies have demonstrated that the tensile strength of aluminum matrix composites (AMCs) rises with the weight percentage of SiC. Table 3 shows the outcomes of the various tensile test values. Figure 6 illustrates specimens taken from the Tensile Test.

Table 3. Tensile Test Results

Samples	Tensile Strength Mpa
Al- 0 % SiC	122
Al- 3.5 % SiC	129
Al- 7.0 % SiC	148

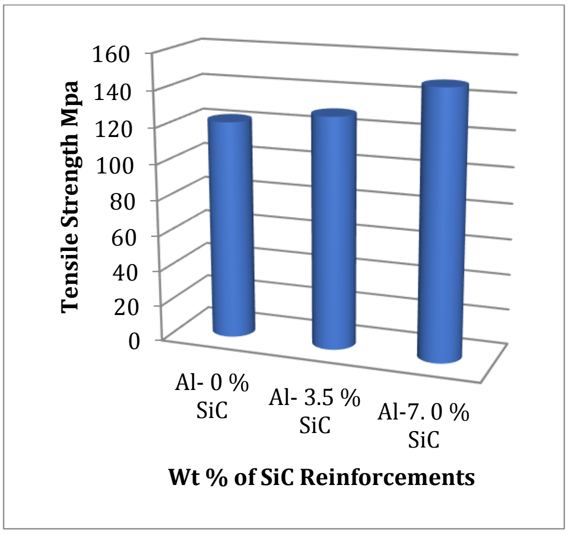


Figure 5. Wt % of Sic Reinforcements Vs Tensile Strength

Figure 6. Tensile Tested Specimens.

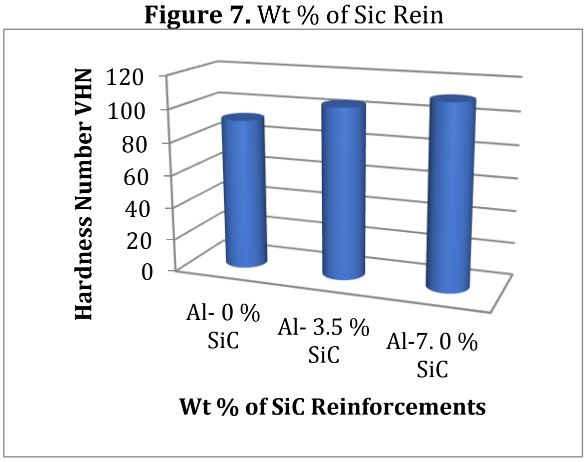
3.2 Hardness Test

Hardness is the ability of a material to withstand surface indentation. The micro hardness of a composite indicates the strength of the interfacial connection between the reinforcing particles and matrix. The materials' Vickers hardness was determined using a Future Tech FV 800 Vickers hardness testing apparatus. Bakelite was used to mount the samples so that when the load was applied, they would not move. For ten seconds, a material was impressed with a diamond indenter at a weight of 1000 kgf. Table 4 shows the outcomes of the different tensile tests. Figure 7&8 displays specimens from the Tensile Test. It is a reasonable observation that the hardness value of produced specimens rises as silicon carbide reinforcing particles grow in number.

Table 4. Hardness Test Results

Samples	Hardness Number (VHN)
Al- 0 % SiC	92
Al- 3.5 % SiC	104
Al- 7.0 % SiC	111

Figure 7. Wt % of Sic Rein



forcements Vs Hardness Number(VHN).

Figure 8. HardnessTested Specimens.

3.3 Microstructure Test

The objects under evaluation underwent morphological analysis using a scanning electron microscope to detect internal surface defects like blow holes, fractures, as well as the build-up of reinforcement (SEM). In SEM, reflected electron bombardment creates a picture. The microstructure of a stir-cast composite 6061 aluminum alloy containing varying weight percentages is investigated by means of scanning electron microscopy of silicon carbide. The microstructure of MMCs was investigated with a scanning electron microscope, as illustrated in Figures 9, 10, and 11. The SEM scans show that there are particles in the SiC of different dimensions and forms. The SiC particles are spread quite consistently, according to the SEM images, although there are sporadic cracks, blowholes, porosity, and other casting faults in the matrix. All of the microstructures had porosities. This occurred as a result of air becoming trapped in the melt between the silicon carbide (SiC) particles that were added to the melt during casting. Thus, a bigger degree of porosity was produced by increasing the weight percentage of silicon carbide (SiC) particles since they trapped more air.

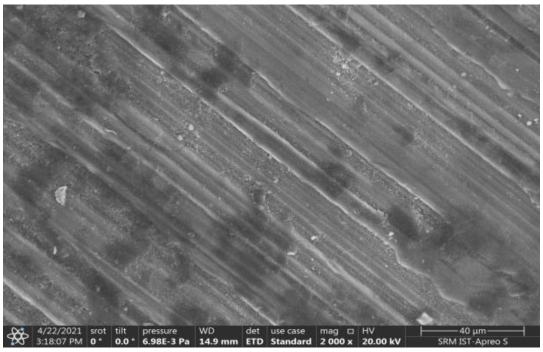


Figure 9. Microstructure of Samples 1

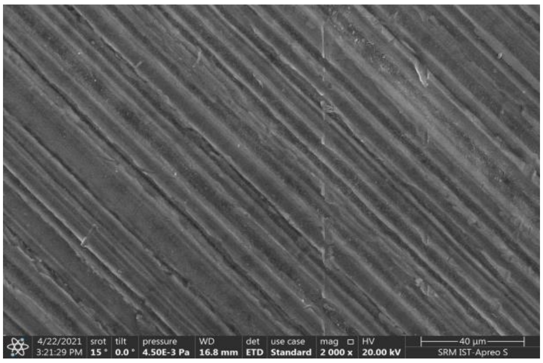


Figure 10. Microstructure of Samples 2

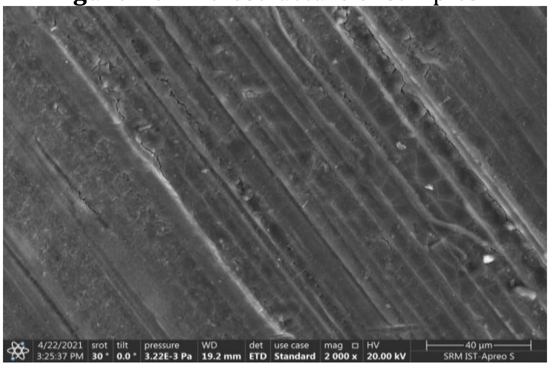


Figure 11. Microstructure of Samples 3

3.4 Wear Test

Using the pin-on-disc method, a wear test was conducted. at room temperature with dry sliding conditions. The pin was pressed up against the counter face of a 55mm worn track diameter revolving steel disc (EN31). By using a dead weight loading mechanism, the pin was forced up against the disc. Every specimen conducted a wear test with normal loads of 20 N and a sliding velocity of 3 m/s. The identical conditions as previously described were used for wear tests, with a total sliding distance of about 1500 meters. The pin samples were 50 mm long and 8 mm in diameter. Prior to the test, the pin samples were sanded with emery paper (80 grit size) to ensure that their surfaces made good contact with the steel disc. As test samples shown in Figure 13 and worn track were cleaned with acetone before and after each test, and the samples were weighed using a microbalance to an accuracy of 0.0001 gram. From Figure 12 noticed that, Wear Rate gets better with an increase of weight percentage for aluminum matrix composites (AMCs) reinforced with silicon carbide (SiC). Table 5 shows the outcomes of the different Wear rates. In line with this, the material's hardness increases by 0–7.0%. In the wear test, the material wears 1g for 300 seconds at a disc speed of 1500 rpm, indicating that it is more wear-resistant than pure aluminum. As the percentage of SiC reinforcement increases, the wear rate gets better.

Table 5: Wear Test Results

Samples	Wear Rate(mm^3/m)
Al- 0 % SiC	0.156
Al- 3.5 % SiC	0.148
Al- 7.0 % SiC	0.145

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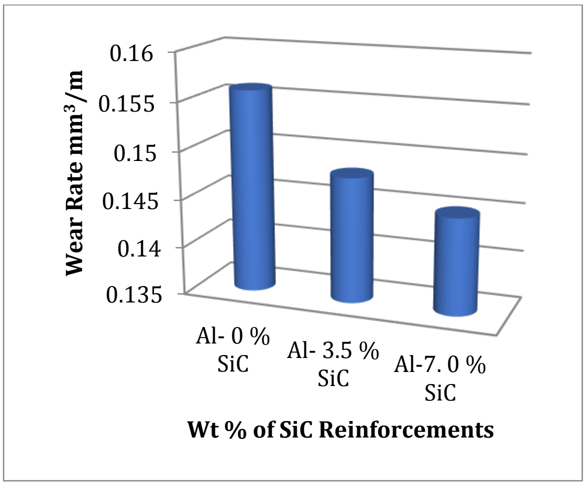

Figure 12. Wt % of Sic Reinforcements Vs Wear Rate

Figure 13. Wear Tested Specimens.

4. Conclusion

In this experiment, aluminum matrix composites (AMCs) with varying silicon carbide (SiC) contents (0% wt, 3.5% wt, and 7.0% wt) were produced via stir casting technology. The produced composites' microstructural properties, hardness, tensile strength, and wear parameters were evaluated. Tensile strength improves as reinforcement content increases; specimens with 7.0% SiC exhibit good strength in comparison to specimens with 0% and 5% SiC of Al-SiC material. It is found that the material's composition (Al93%, SiC-7.0%) yields a higher degree of hardness than the Al-SiC composite material's 0% and 3% SiC content. Silicon carbide (SiC) particles were seen to disperse and cluster non-homogeneously in the Al matrix within the microstructures. Porosities existed in the microstructures. With a percentage rise in SiC, the composite's wear rate decreases. Aluminum matrix composites (AMCs) reinforced with silicon carbide (SiC) exhibited superior hardness, tensile strength, and wear rate in comparison to unreinforced aluminum, as per the previously mentioned findings.

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Author contributions

Sathiyaraj Subramanian: Conceptualization, Methodology, Material selection , Fabrication.
Venkatesan Sendrayan: Experimental Testing, Writing-Original draft preparation, Results and Discussion .
Kumaran Pachaiyappan: Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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