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Analysis of Mechanical Properties of Al/SiC heat treatment composite material

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Abstract This research employed the aluminium alloy AA6063 as a matrix material. SiC powder was used as reinforcement material. The composite was manufactured utilising a stir casting process. The finished product included between 5 and 15 percent SiC powder. Microstructurally, the AA6063 aluminium alloy had an even dispersion of SiC powder. The heat treatment improved the composite's grain structure. The tensile and hardness properties of the AA6063 matrix material were enhanced by adding SiC powder to the original composition at a 10% concentration. Tensile strength, toughness, and malleability all improve with increased temperature.

Keywords: AA6063 alloy; SiC powder; heat treatment; microstructure; mechanical properties

1. Introduction

Aluminum-based composite materials have become more popular in the automotive industry because of their high specific strength. Matrix materials are combined with reinforcing materials to create composite materials [1]. Incorporating reinforcing particles into matrix materials improves their mechanical characteristics [2]. However, when using the typical casting method to create composite material, a number of challenges arise. Ceramic-based reinforcing particles were mixed into the melting aluminium alloy with difficulty [3]. Inability of reinforcement particles to be wetted by matrix material is one of the problems here. The mechanical characteristics of composite materials may be affected by a mismatch in the density of the matrix and reinforcing particles [4]. When ceramic-based reinforcing particles are mixed into the aluminium alloy, nonuniform distribution is seen [5].

Because of its low weight and good mechanical qualities, aluminium alloy is extensively employed in the car and aviation sectors. An aluminium alloy has superior corrosion resistance and specific strength than steel. [6] Steel, on the other hand, has a higher hardness and tensile strength. There is a lot of interest in developing composite materials including ceramic particles such SiC, Al2O3, B4C, Si3N4, graphite, and SiC to improve the mechanical characteristics of aluminium alloys [7]. The wettability of reinforcing particles with aluminium alloy is a key challenge in the creation of aluminum-based composite materials [8]. Reinforcement particles' wettability issue has been addressed in number of ways by researchers. SiC was found to be a rare reinforcing material for AA6063 aluminium alloy in the literature. Reinforcement using AA6063 aluminium alloy has been achieved by using SiC powder. SiC powder added to the aluminium alloy had a noticeable effect on mechanical parameters such as toughness, ductility, and tensile strength.

2. Materials and methods

2.1. Matrix material

An Al 6061 matrix material was used in this work. This alloy, AA6063, is employed in a variety of industries because of its high strength [20]. It's not uncommon to see AA6063 alloy utilized in aircraft manufacturing because of its high tensile strength and fatigue [9]. Table 1 shows its mechanical characteristics.

Table 1. Measured properties of AA6063 alloy [10].

Toughness (Joule)	11
Hardness (BHN)	48
Ductility (percentage elongation)	12
Tensile strength (MPa)	180

2.2. Reinforcement material MnO

To improve the mechanical characteristics of composites, magnesium oxide (SiC) particles were investigated as a supplementary reinforcing material. SiC's (3.58 g/cm3) density is closer to that of AA6063's (2.78 g/cm3). It's also easy to get hold of SiC, which has high compatibility with aluminium alloys [11].

2.3. Procedure of composite material

Stir casting or electromagnetic stir casting is the most common method for creating aluminum-based composites. Because it is simpler to fabricate, the stir casting method is favored over the electro-magnetic stir casting method. External stirrers are used to mix the reinforcing particles into the Matrix melts while being cast in a stir cast mould. When making the composite, the electromagnetic stir casting method eliminates the need for an external stirrer. Forces created by the magnetic flux are employed to mix in reinforcement particles. It's quite rare to have difficulties while building a composite using the electromagnetic stir casting method. When the density of reinforcement particles is much greater or lower than that of the matrix material, this is especially true. An entirely new composite material was generated in this study utilising the stir casting process in light of these concerns. The muffle furnace was used to melt AA6063 alloy. Before being included into the melt matrix, the reinforcement particles were warmed. The graphite crucible was used to melt the aluminium alloy. At a temperature of around 700°C, reinforcing particles were introduced into the melt matrix. The reinforcing particles were incorporated into the melting aluminium alloy using a mechanical stirrer. The composite was stirred for around four minutes. While developing composite material, a vacuum pump was employed to keep the warmed composite material from being exposed to air. The line diagram for a mechanical stir casting setup may be shown in Figure 1. Using the stir casting process, we may create a composite material, as shown in Table 2.

2.4. Hardening process

The grain structure of composite material affects its mechanical characteristics [12]. Hardness and tensile strength were both improved when the grain structure was refined [13]. After heat treatment, finer grain structure may also increase the toughness of the composite [14].

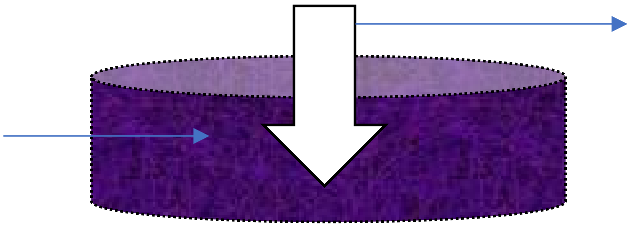


Figure 1. stir casting set up

Table 2. Composition of composite.

S. No.	Composition
1	Al+ 15% SiC
2	Al+ 12.5% SiC
3	Al+ 10% SiC
4	Al+ 7.5% SiC
5	Al+ 5% SiC
6	Al+ 2.5% SiC

In this study, the heat treatment approach increased the composite's mechanical properties. In order to increase the mechanical properties of aluminum-based composite materials, several heat treatment methods may be used [15]. Many composite aluminium materials undergo thermal treatment using the precipitation-hardening process. Precipitation hardening was achieved in three steps. Prior to quenching in a 70°C hot bath, the solution was first zinged at 530°C for 4.5 hours. For 13.5 hours, the ageing process was carried out in a muffle furnace [16].

2.5 Mechanical properties testing

Tensile tests on composite samples are performed using a computerised universal testing equipment. The tensile sample's gauge length and gauge diameter were both 36 millimetres [11]. A hardness testing equipment was used to measure the hardness of the composite samples. An optical microscope was used to get this picture of microstructure. ASM-9-2009 was used to identify the metallographic characteristics of composite materials.

3. Results and discussion

3.1 Microstructure analysis

The distribution of SiC particles in AA6063 aluminium alloy was determined by examining the composite's microstructure. The most important component in improving the mechanical characteristics of composite materials is ensuring that reinforcement particles are distributed uniformly throughout the matrix. When it comes to improving composite material's mechanical properties, the interfacial reaction layer between the reinforcing particles and aluminium alloy is critical. SiC-reinforced AA6063 composite material has an impressive heat-treated microstructure, as shown in Figure 2. This microstructure image shows that the SiC particles in the aluminium alloy are equally dispersed. Reinforcing particles, on the other hand, have shown some agglomeration. An agglomeration is formed within the composite as a consequence of a mismatch in the densities of the reinforcing particles.

3.2 Tensile strength analysis

As can be seen in Figure 3, composite materials have a high tensile strength. Heat treated and unheated SiC-reinforced composite samples have both been used to assess tensile strength. When the SiC powder weight % was increased to 12.5 wt. percent, the tensile strength of AA6063 aluminium alloy increased continuously [11]. Tensile strength of aluminium alloy starts to diminish once 10% SiC particles are introduced into the alloy. The AA6063/SiC composite's maximum tensile strength was 198.24 MPa. The material's tensile strength improved significantly as a result of the heat treatment. Tensile strength after heat treatment was determined to be 205.45 MPa. Heat-treated Al+10 percent SiC composite material elongates under a stress shown in Figure 4. The tensile strength of the composite was boosted by 14.13 percent when the base material was heated, according to the study's findings. The melt matrix material's reinforcing particles are more wettable because to the ingredient Mg. A chemical reaction known as oxidation takes place, and the Mg is converted into SiC. In and of itself, SiC is a very hard mineral. In this study, it was discovered that SiC provided a better reinforcement. Because to SiC's Mg concentration, the wettability of the aluminium alloy was boosted. However, the addition of SiC particles greatly increased the alloy's tensile strength. Reinforcement particles were correctly wettable with matrix material, which resulted in an improvement in tensile strength.

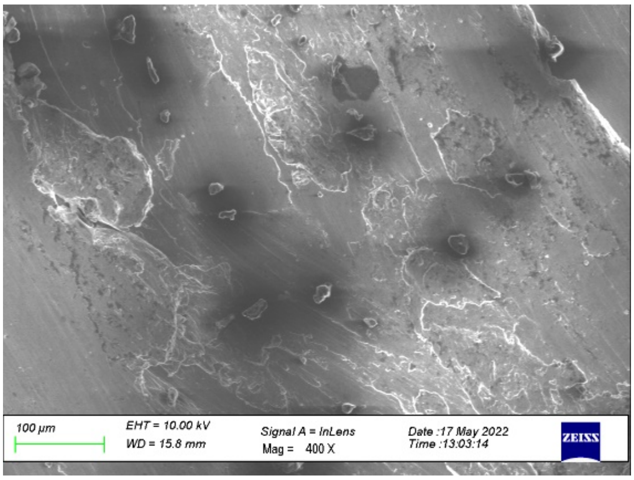
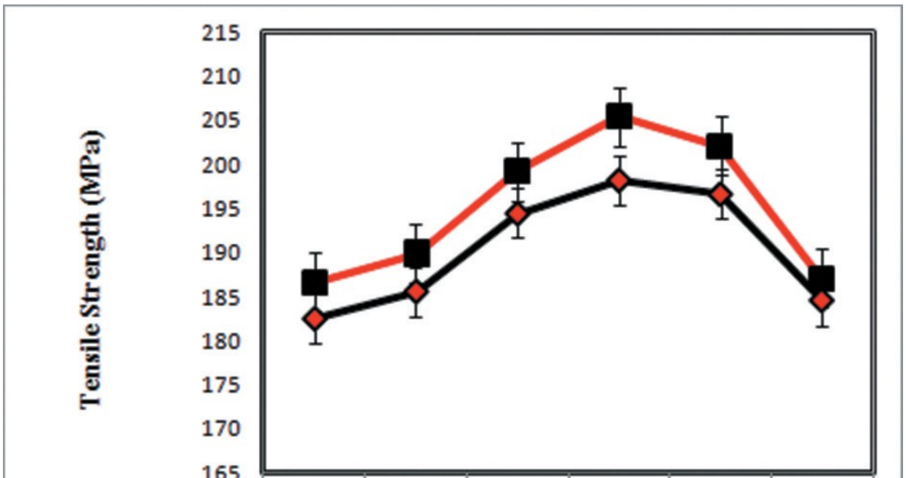


Figure 2. Microstructure image heat treatment of composite material

3.3 Hardness analysis

The composite material's hardness is shown in Figure 5. The hardness of an aluminum-based composite was improved by adding more magnesium oxide (SiC) particles in the alloy. AA6063/10 percent SiC composite material has a maximum hardness of 68 BHN before to heat treatment. Hardness of the composite has increased significantly. It had a hardness of 72 BHN. Heat treatment has been demonstrated to have a significant influence on hardness. Matrix materials get harder when hard phases are added to them. The wettability of the reinforcing particles with the matrix material may be a factor in the increased hardness. In the present study, it was discovered that adding SiC particles increased the composite's hardness. Hardness was increased by the interfacial reaction layer that developed between the matrix and reinforcing cement particles.



	1	2	3	4	5	6
As cast	182.45	185.56	194.45	198.24	196.66	184.55
As heat Trated	186.66	189.96	199.24	205.45	202.12	187.12

Figure 3. Tensile strength of AA composite.

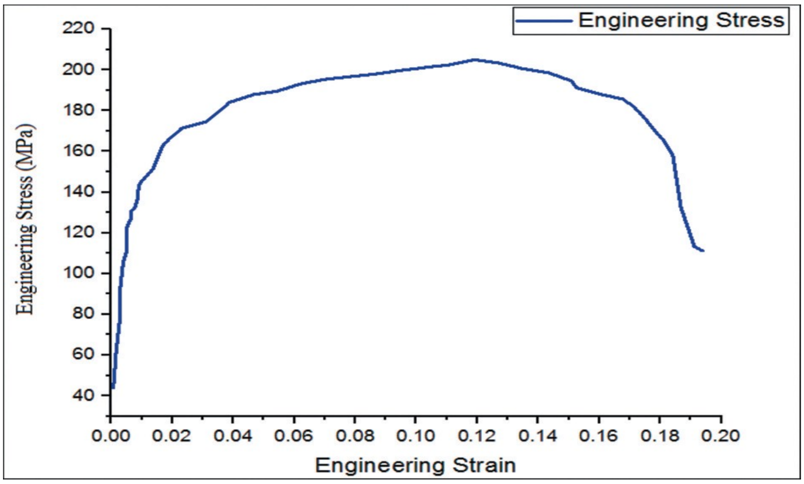
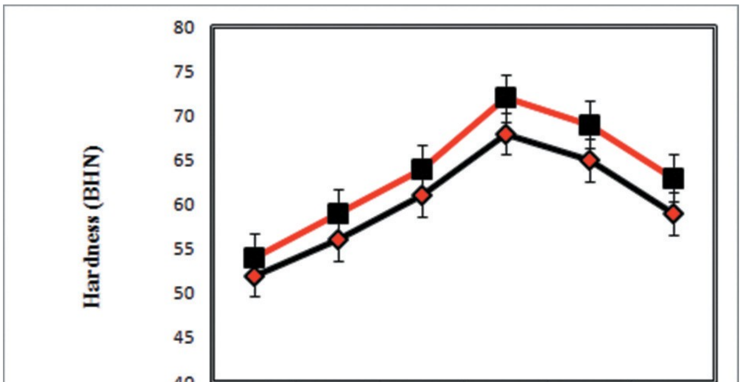


Figure 4. Al+ 10% SiC heat-treated composite material Stress–strain diagram



	1	2	3	4	5	6
As cast	52	56	61	68	65	59
As heat Trated	54	59	64	72	69	63

Figure 5. Hardness of composite materials

4. Conclusions

Because of the investigation, it is possible to make the following findings.

- AA 6061 aluminium alloy-based composite material with SiC powder reinforcement may be made using stir casting technique.
- The AA6063/SiC composite's mechanical properties were improved by heat treatment.
- As a result, the composite material's maximum strength and hardness, respectively, were 205.5 MPa and 72BHN, after being heat-treated to AA6063/10wt%.

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