Synthesis and Mechanical Characterization of Titanium dioxide and Graphite Reinforced Al6061 Composites

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Abstract

Aluminium based composite are getting a vast scope nowadays because of its properties and availability. In the present work, Aluminium 6061 is reinforced with Titanium dioxide (TiO_2) and Graphite particles. Stir casting is used to produce composites with different weight percentages of graphite (2%, 4%, and 6%) and titanium dioxide (3%, 6%, 9% and 12%). A microstructural analysis of the produced composites shows that the particles are well distributed throughout the matrix. The inclusion of reinforcement improves the qualities compared to the parent metal alone in terms of hardness and tensile strength. From the experimentation, 6% TiO_2 and 4% graphite produce a superior property than any other compositions.

Keywords: Graphite, TiO_2, Composite, Aluminium, Reinforcement, stir casting

1. Introduction

Composite is made up of two or more non-reactive materials that are in separate phases and do not combine to form a homogenous mixture. This distinguishes it from alloying, etc. Although composites research has been going on for a while, it is still in its early stages. This is due to the fact that there are many different types of reinforcement available and that the process parameters have not been optimised. Moreover, composites are made of many materials, each of which contributes to the final product's qualities and provide a superior option to conventional materials. There are several ways to create metal matrix composites, including extrusion, stir casting, and powder metallurgy. Stir casting will be a simpler and more affordable approach to make composites, among others.[1]

2. Composite Preparation

The composites are fabricated in the present work using the stir casting process. Al6061 is the matrix material and Titanium dioxide & graphite particles as reinforcements. The properties of Al6061, titanium dioxide and graphite are shown in table2.1, table 2.2 and table 2.3 respectively. The process involves weighing the necessary quantity of aluminium, placing it in a crucible, setting the temperature to 710° C, and maintaining that temperature for 10 minutes to guarantee the metal is completely melted. Hexacholoroethane tablets are used to expel gas during this time. To get rid of moisture, the necessary weight percentage of reinforcement is weighed and heated to 400° C [3]. And the mould is warmed to 200° C to reduce casting flaws. The melt is swirled at 300–400 RPM to generate a vortex after it has reached a fully liquid condition, and hot reinforcement is added while churning. The slag is removed after 10 minutes of stirring, and then the melt is poured into the permanent moulds. Solidified preforms are machined to appropriate ASTM specifications and tested for various characteristics.

Table2.1Propertiesof Aluminum 6061alloy

Property	**Value**
Density	2.70 g/cm³
MeltingPoint	650°C
ThermalExpansion	23.4 x10^{-6}/K
Modulusof Elasticity	70GPa
ThermalConductivity	166W/m.K
Tensilestrength	260MPa
Brinellhardness	95 BHN

Table 2.2 Properties of Titanium dioxide (TiO_2)

Properties	**Value**
APS	40-60µm
Molecular Formula	TiO2
Molecular Weight	79.93g/mol
Density	4.23g/cm3

Table2.3 PropertiesofGraphite(Gr)

Properties	**Value**
Density	2.7g/cm^3
Porosity	0.7-53%
Modulusof Elasticity	8 - 15GPa
Compressivestrength	20-200MPa
Flexuralstrength	6.9-100MPa
Thermalconductivity	25-470W/mK

3. Experimentation on Mechanical Properties

3.1 Tensile Strength Test

The tensile examinations are performed using computerized universal testing machine according to ASTM standards. The tensile properties, such as yield strength, tensile strength and % elongation are determined from the stress-strain curves. Fig 3.1 shows the Computerized UTM and Fig. 3.2 shows the prepared tensile specimens in ASTM – E8 standard. Three set of tests are conducted and the average value is taken to calculate the mechanical properties of the Al 6061 base material and different weight percentages of reinforcement composite materials.

In the beginning of the experimentation, Aluminium 6061 is reinforced with titanium dioxide with various weight percentages of 3%,6%,9% and 12% respectively. Tensile strength of the base aluminium 6061 and aluminium 6061 reinforced with various weight percentages titanium dioxide is shown table 3.1

Fig 3.1Computerised UTM

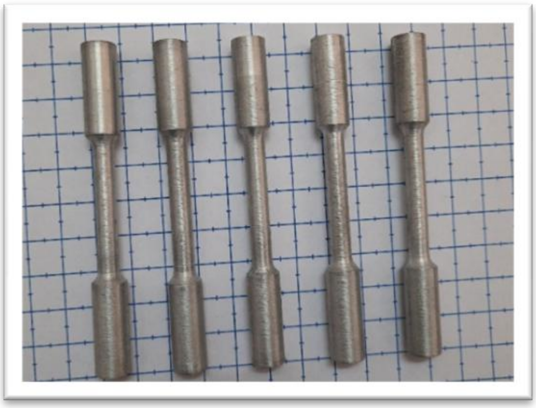


Fig 3.2Tensile test specimens

Table 3.1 Tensile strength result of Al6061 + TiO_2

Sl. No	Composition	Tensile Strength (MPa)
1	Al6061	118.78
2	Al6061 + 3% TiO_2	126.89
3	Al6061 + 6% TiO_2	142.75
4	Al6061 + 9% TiO_2	132.20
5	Al6061 + 12% TiO_2	108.56

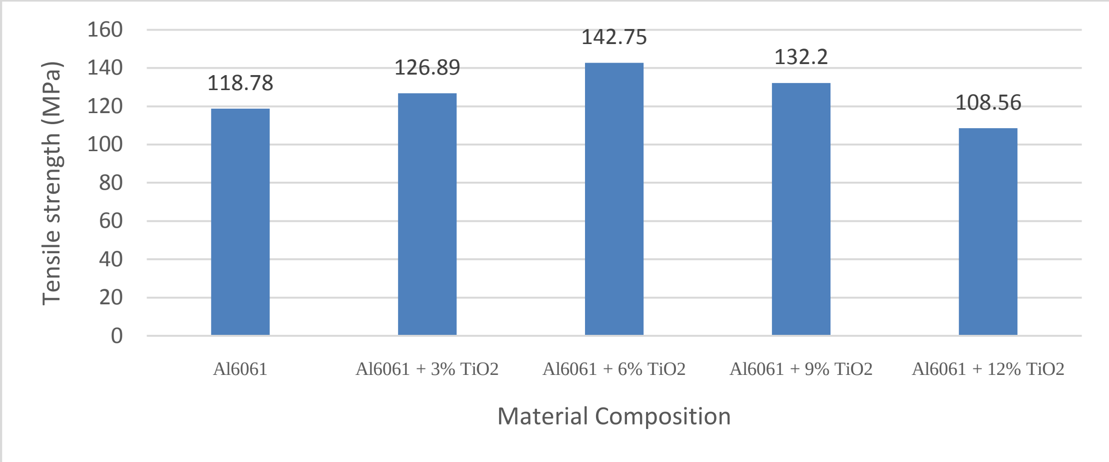


Fig 3.3Variation of Tensile Strength Al6061 with reinforcement % of Titanium dioxide TiO_2

It is found that increasing the titanium dioxide (TiO_2) content up to 6% by weight enhances the strength of the composite as shown in figure 3.3. Tensile and yield strengths may be enhanced due to the toughness of the titanium dioxide. As a result of the matrix's random distribution of particles, this creates a limitation in the plastic flow, resulting in improved tensile and yield strength of the composites. Tensile strength is increased from 118.78 MPa to 142.75 MPa by adding 6% of TiO_2 reinforcement with the base Al6061 alloy and the increment is about 20.18%. Further adding TiO_2 reinforcements above 6% the tensile strength decreases, this is because the matrix and reinforcing components are not sufficiently bonded.

3.2. Hardness Test

Micro Vickers hardness tests are conducted to evaluate the hardness of the composite material. The specimens are prepared according to ASTM E92-17 standards [5]. Micro Vickers hardness tester is used to analyse the micro-hardness of base Al 6061 material and Al6061 reinforced with various percentages of titanium dioxide. A metallographic surface is typically needed for the surface being investigated, and the finish is obtained by emery paper with grit sizes of 100, 220, 400, 600, and 1000. For approximately 25 seconds, a 100-gram weight is applied to the specimen.Fig.3.4 shows the hardness test specimens.

Fig 3.4 Hardness Test Specimens

Table 3.2 Hardness test result of Al6061+ TiO_2

Sl.No	Composition	Hardness Value
1	Al6061	102.5
2	Al6061 + 3% TiO_2	120.8
3	Al6061 + 6% TiO_2	132.4
4	Al6061 + 9% TiO_2	124.5
5	Al6061 + 12% TiO_2	98.2

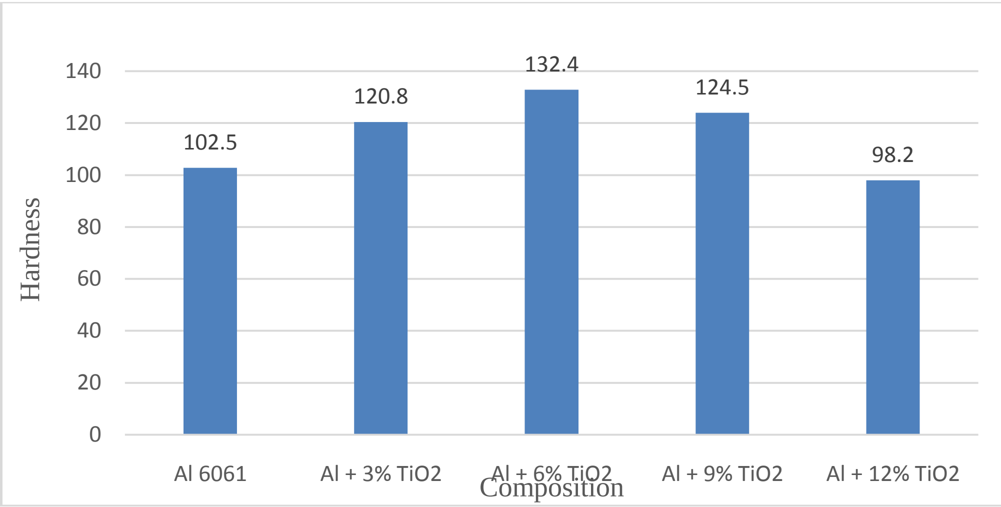


Fig 3.5 Variation of hardness of Al6061 with reinforcement % of TiO_2

Figure 3.5 shows the hardness test results and its shows that with the addition of titanium dioxide (TiO_2) to the base metal Al6061 hardness is increased from 102.5 to 132.4 with the addition of 6% of TiO_2 and declines with 9% of TiO_2 reinforcement. The composite's hardness is increased by incorporating titanium dioxide particles into an aluminium matrix. Titanium dioxide, the reinforcing material is resistant to indentation and so enhances hardness significantly. And it is noticed that with the further addition of Titanium dioxide above 6 % weight, the hardness decreased, this is due to the amalgamation of reinforcement particles and decreased wettability in the base matrix. Based on the Tensile test and hardness test, Al6061+ 6% TiO_2 composite material yields good result.

Further Al6061+ 6% TiO_2 composite material is reinforced with graphite particles with the weight % of 2, 4 & 6 and Tensile test and hardness test is carried out for all the specimens. The results of tensile test and hardness test of the hybrid MMC material is tabulated in the table 3.3 and table 3.4

Table 3.3 Tensile Test result of Al6061+ TiO_2+Gr

Sl.No	Composition	Tensile Strength (MPa)
1	Al6061 + 6% TiO_2 + 0% Gr	142.75
2	Al6061 + 6% TiO_2 + 2% Gr	144.05
3	Al6061 + 6% TiO_2 + 4% Gr	148.85
4	Al6061 + 6% TiO_2 + 6% Gr	132.39

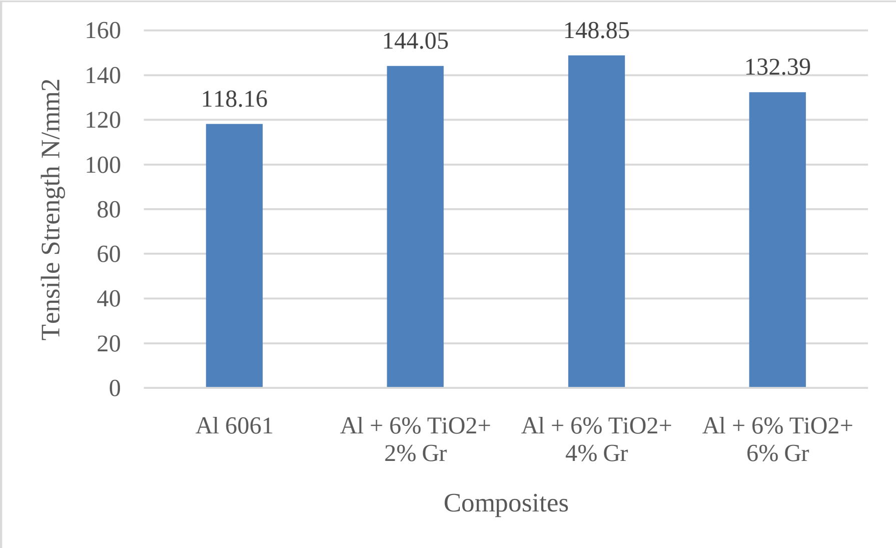


Fig 3.6Variation of Tensile Strength of Al6061 + 6% TiO_2 with reinforcement % of graphite

Table 3.4 Hardness test result of Al6061+ TiO_2+Gr

Sl. No	Composition	Hardness Value
1	Al6061 + 6% TiO_2 + 0% Gr	132.4
2	Al6061 + 6% TiO_2 + 2% Gr	136.2
3	Al6061 + 6% TiO_2 + 4% Gr	142
4	Al6061 + 6% TiO_2 + 6% Gr	124

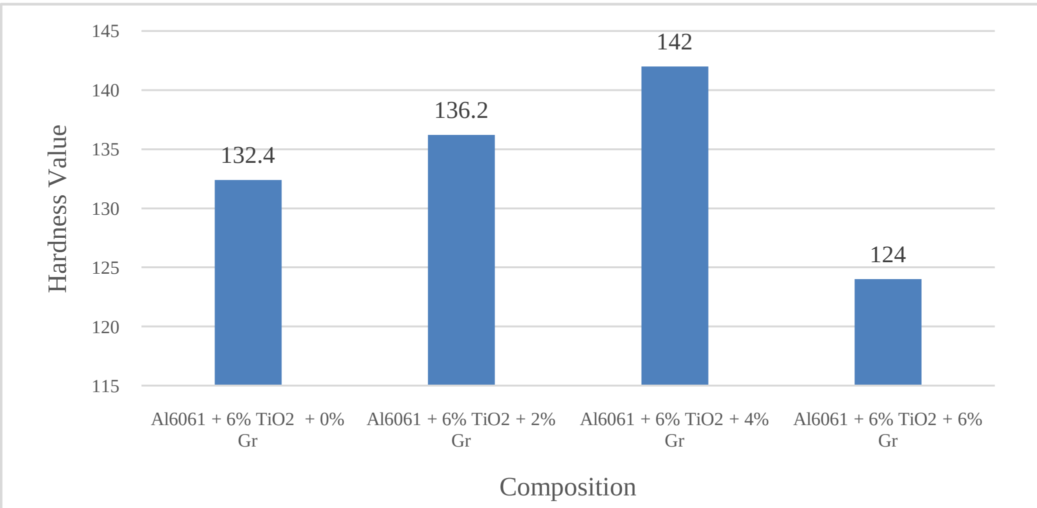


Fig 3.7 Variation of hardness of Al6061 + TiO_2 with reinforcement % Gr

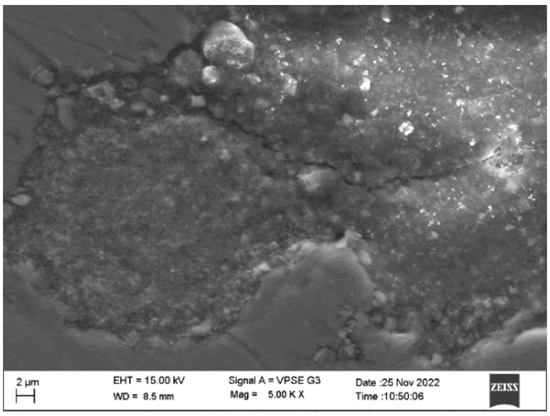
Figure 3.6 and Figure 3.7 represents the tensile test and hardness test results.In the test it is found that with the addition of 4% weight of graphite to the Al 6061 + 6% TiO_2, the tensile strength increased from 142.26 MPa to 148.85 MPa and hardness increased from 132.4 to 142, due to the good bondage between the graphite and TiO_2 with the base metal. Addition of more graphite particles above 4% weight into the Al 6061 + 6% TiO_2, the graphite particles leads to rejection from the melt and also amount of porosity increased with increasing the graphite reinforcing particles.

4.Microstructural Characterization Of Al6061,Al6061+$Tio_2$and Al6061+TiO_2 +Gr Hybrid Composite

Present research Scanning electron microscope (SEM) are used to analyze the microstructural characterization of base metal aluminum alloy 6061, Al6061+TiO_2 and Al6061+TiO_2+Gr material**.**

4.1 scanning electron microscope

The scanning electron microscope (SEM) and a type of electron microscope that employs a high-energy electron beam in a raster scan pattern, images the sample's surface. Atoms and electrons inside the sample interact to create signals that provide information about its surface topography, chemical composition and other properties including electrical conductivity



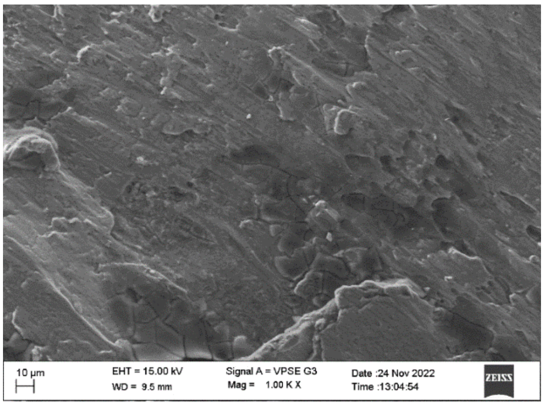


Fig 4.1SEM Image of Al6061+6% TiO_2 Fig 4.2SEM Image of Al6061+6% TiO_2 + 4%Gr

The shape and reasonably uniform dispersion of the particles inside the matrix are evident from the microstructure data to indicate technique employed to prepare the composite is effective. White colour dots in Figure 4.1 indicate the presence of TiO_2 particles. Figure 4.2 depicts the dispersion of graphite particles in combination with the TiO_2 particles. Black patches indicate the presence of graphite particles. The reinforced particles employed in the current study have good mixing, gathering and bonding via grains to provide a robust, uniform particle distribution.

Conclusion

With the addition of reinforcement particles, the mechanical property of the aluminium 6061 is improved. Adding 6% weight titanium dioxide to the base metal Al 6061, the tensile strength is increased by 20.39% and hardness is increased by 29.17% compared to the base metal. In the hybrid MMC, graphite mixed in 4% weight to Al 6061 + 6% TiO_2, yields better result with the increase in tensile strength by 4.2 % and hardness by 7.2% compared to Al 6061 + 6% TiO_2 materials. A decent distribution of reinforcements is shown in SEM images. There is a decrease in tensile strength for 9% of Titanium dioxide reinforcement, which may be caused by the cluster of reinforcements.EDAX elemental analysis confirmed the presence of aluminum, titanium dioxide and graphite.

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