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Experimental Investigation on Tensile Properties of Al6061-Graphite Particulate Composites

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Abstract
This paper presents the experimental work carried out on the tensile behavior of aluminium 6061 (Al 6061) graphite particulate composites. The required specimen is prepared using stir-casting method with graphite proportions ranging from 3 to 12% by weight. The mechanical behavior of Al 6061 graphite particulate composites produced using stir-casting method was investigated by conducting experiments on universal testing machine (UTM). Tensile specimens were utilized for tensile testing to evaluate the tensile properties. From the experimental tensile test, ultimate tensile strength of 117.34 MPa, maximum percentage elongation of 14.48% is obtained for Al 6061-9% graphite.

Keywords: aluminium-graphite MMC, Al6061-graphite particulates, tensile behavior

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INTRODUCTION

Metal matrix composites (MMCs) are a widely varied group of materials that consist of a metallic alloy as matrix and ceramic as reinforcement in the form of continuously aligned fibers, short fibers, whiskers, platelets, and particles. MMCs are used in automobile/aerospace applications, and also in applications requiring thermal management, wear resistance and weight reductions. So far, the majority of MMCs are based on aluminum, magnesium, and titanium alloys reinforced with alumina (Al_2O_3), silicon carbide (SiC), carbon, or graphite.

Both continuously and discontinuously reinforced MMCs[1] are used in automobile/aerospace applications. The assimilation of the reinforcement in the MMCs increases stiffness and strength of the matrix. However, the improvements in stiffness and strength usually arrive at the expense of ductility.

Particulate reinforced MMCs are not expensive to manufacture than reinforced composites. Accordingly, performance improvement of the matrix comes at lesser expenses with particulate reinforcements compared with fiber aligned reinforcements. In addition, particulate reinforced composites exhibit the isotropic properties,[1] whereas the properties of composites with fiber aligned reinforcements are highly anisotropic. Thus, in applications requiring isotropic properties, less expensive, particulate reinforced composites can do better than fiber reinforced composites. Typically, ceramics and graphitic materials are used as reinforcement phases in particulate reinforced MMCs. Some common reinforcements for aluminium matrices are SiC, Al_2O_3, B_4C, and graphite.

This research work presents the experimental work carried out on the tensile behavior of Aluminium 6061 graphite particulate composites. The specimen are prepared using stir casting method with graphite proportions of 3–12% by weight. The main objective of this research work is to study the tensile characteristics of aluminium-6061 metal matrix composites reinforced with graphite particles at varied weight fractions of graphite (3, 6, 9, and 12%).

LITERATURE AND MATERIALS

The literature survey presents a review of the published material available on the effect of various reinforcement types, their size, and volume fraction, ageing behavior with aluminum-based MMCs are a combination of two phases, matrix and the reinforcement.

Dunia Abdul Saheb[2] uses stir casting to produce the MMCs such as aluminium silicon carbide and aluminum graphite and conducted hardness tests to take a look at various weight fraction of SiC, graphite, and aluminum oxide (5, 10, 15, 20, 25, and 30%), the graphite weight fraction with a pair of 4, 6, 8, and 10% kept all alternative parameters constant and determined that increasing of hardness results increase with weight proportion of ceramic materials. The most effective results (maximum hardness) were obtained at 25% weight fraction of SiC and at 4% weight fraction of graphite.

Alaneme and Aluko[3] utilized the tensile specimens for tension testing to evaluate the tensile properties of the composite Al-SiC for 3, 6, 9, and 12 volume percent of SiC. From the experimental results obtained from both the tests it was concluded that significant improvement in the strength of the Al matrix composites was achieved when 9 and 12% by volume of SiC has used as reinforcement; and the ductility of the composites was not adversely affected at those compositions in comparison with the monolithic alloy.

From the literature it is observed that relatively more work[4–6] has been done on the tensile characteristics of aluminum silicon carbide particulate MMCs. However, a significant scope exists for research on the aluminium matrix composites reinforced with graphite particles. In this backdrop, the current research work is proposed to study the tensile characteristics of aluminium matrix composites reinforced with graphite particles at varied weight fractions.

In this research work, material chosen is Aluminium 6061 as matrix and Graphite particles as reinforcement. The motivation to use these materials for the research work is the density of two materials involved, which are nearly same for aluminium (2.65 g/cc) and graphite (2.2 g/cc). The Al6061-graphite particulate composites have discontinuously reinforced composite properties which are nearly isotropic and also have outstanding combination of mechanical, structural, thermal, and physical properties.

Aluminum graphite particulate MMCs fabricated by solidification methods stand for a group of economical specially made material for the range of structural purpose such as automobile elements, bushes, and bearings. Their utilization are viewed for their better tribological properties such as the low friction coefficient, reduced wear rate, high abduction resistance, high damping capacity, good machinability and their admirable antifriction properties, and wear resistance.

Al-graphite is described by an excellent blend[7,8] of physical, mechanical and thermal properties. Aluminium graphite has lower density than Al60061 which leads to mass reduction also high thermal conductivity, low coefficient of thermal expansion which is an advantage in thermal loading systems.

TENSILE TESTING

Tensile testing deals with various aspects of testing procedures and equipments used. Specimens are prepared and machined as per ASTM standard[9] for tensile test using stir casting technique. Tensile properties of the aluminum 6061-graphite is determined using a universal testing machine (UTM) as per ASTM standard testing procedure.

Stir Casting

Aluminium 6061-graphite specimens are prepared at varied weight fractions of graphite (3, 6, 9, and 12%) using stir casting method.

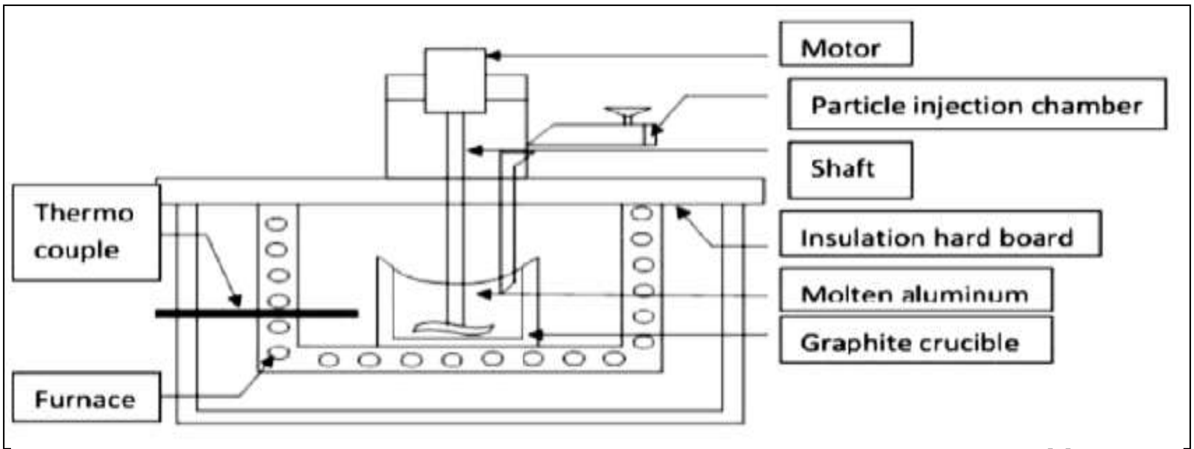

Fig. 1. *Schematic View of Stirring Mechanism Used in the Fabrication of MMC.[4] [Source: www.ijert.org].*

The aluminum blocks were melted in the furnace as shown in Figure 1. After melting, molten aluminum was super-heated to desired temperature (about 750 °C). The required amounts of graphite particles were added to the aluminum melts while stirring with stirrer at suitable speed. The molten aluminum-graphite was poured into a split type permanent mold and it was allowed to solidify. The aluminium-graphite alloy bars were taken out from the mold. The specimens were prepared from as-cast alloys for determination of required properties.

Tensile Testing

The tensile test specimens machined as per ASTM-E8 standards[8] are qualified for tensile testing. Tensile testing is a basic test in which a sample test specimen is subjected to a restricted tensile loading until fracture. By using tensile test, the properties that are measured are ultimate tensile strength, maximum elongation, reduction in area, etc. From the measurement of the above subsequent properties like modulus of elasticity, poisson’s ratio, yield strength, strain hardening characteristics, etc., can also be determined.

Tensile Specimen

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge in the middle. The shoulders are vast so that they can be promptly grasped, while the gauge segment has a smaller cross-section so that the deformation and failure can happen in this area. Figures 2 and 3 show the tensile test specimen before and after testing, respectively. Dimension of the tensile test specimen is as per the ASTM: E8 standard: Nominal Diameter = 12.5 mm, Gauge length = 56 mm.

Fig. 2. *Tensile Test Specimen Before Testing.*

Fig. 3. *Tensile Test Specimen After Testing.*

Tensile Test Results
The various parameters and values obtained for Al6061-graphite in tensile testing carried out on UTM are utilized to calculate stress and strain and are discussed below.

Al6061-3% Graphite

The relationship between stress and strain is depicted in the graph as in Figure 4 and is briefly discussed below.

Stress and strain are calculated from the load, and the elongation respectively. In Figure 4, stress–strain diagram is plotted for Al6061-3% graphite.

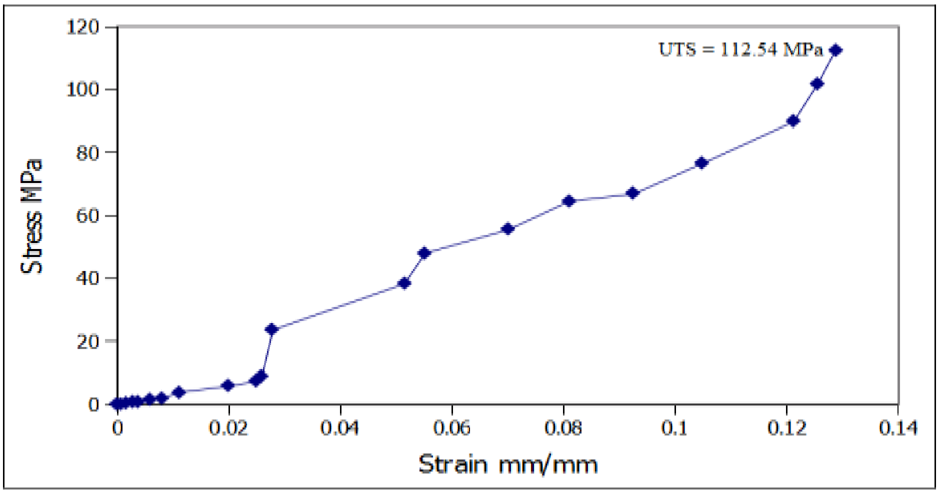

Fig 4. *Stress–Strain Curve for Al6061-3% Graphite.*

Stress and strain values are increases linearly upto the strain value 0.025, i.e., till now material is in elastic state. At strain value of 0.027, it is observed that for the increment of load there is less deformation, i.e., material may be subjected to yield. Later stage material is subjected to plastic deformation. The maximum stress that the material can withstand, i.e., UTS for the MMC is found to be 112.54 MPa.

To calculate the percentage elongation for the Al6061-3% graphite MMC, the maximum deformation was considered which 7.21 mm was and thus % elongation is calculated as 12.87%.

Al6061-6% Graphite

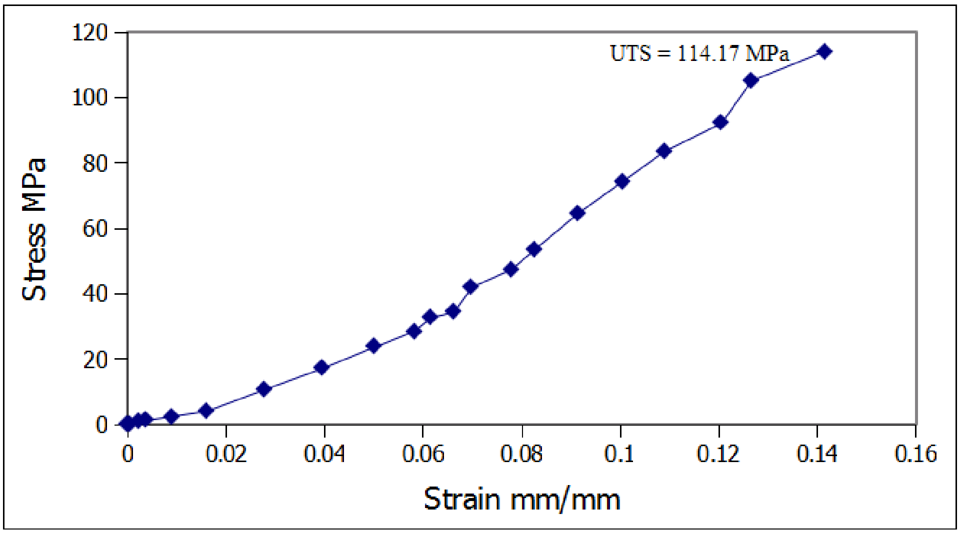

Fig. 5. *Stress–Strain Curve for Al6061-6% Graphite.*

The various parameters and values obtained for Al6061-6% in tensile testing carried out on UTM are utilized to calculate stress and strain. The stress-strain curve is drawn using the experimental results, as shown in Figure 5.

Stress and strain values are increases linearly upto the strain value 0.06, i.e., till now material is in elastic state. After which, it is observed that material is may be subjected to plastic deformation. The maximum stress that the material can withstand, i.e., UTS for the MMC is found to be 117.17 MPa.

To calculate the percentage elongation for the Al6061-6% graphite MMC, the maximum deformation considered was 7.92 mm and thus % elongation is calculated as 14.14%.

Al6061-9% Graphite

The relationship between stress and strain is depicted in the graph as in Figure 6 and is briefly discussed below.

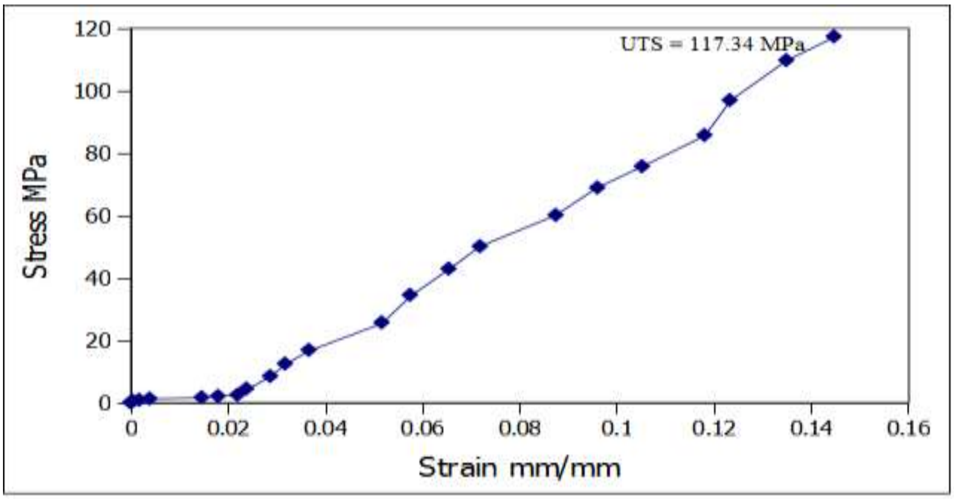

Fig. 6. *Stress–Strain Curve for Al6061-9% Graphite.*

Stress and strain are calculated from the load, and the elongation respectively. In Figure 7, stress–strain diagram is plotted for Al6061-9% graphite.

Stress and strain values are increases linearly upto the strain value 0.023, i.e., till now material is may be in elastic deformation. At strain value of 0.027, it is observed that material is may be subjected to plastic deformation. The maximum stress that the material can withstand, i.e., UTS for the MMC is found to be 117.34 MPa.

To calculate the percentage elongation for the Al6061-9% graphite MMC, the maximum deformation considered was 8.11 mm and thus % elongation is calculated as 14.84%.

Al6061-12% Graphite

Stress and strain are calculated from the load, and the elongation respectively. In Figure 7, stress–strain diagram is plotted for Al6061-12% graphite.

Stress and strain values are increases linearly upto the strain value 0.052, i.e., till now material is may be in elastic deformation. At strain value of 0.0646, it is observed that material is may be subjected to plastic deformation. The maximum stress that the material can withstand, i.e., UTS for the MMC is found to be 115.80 MPa.

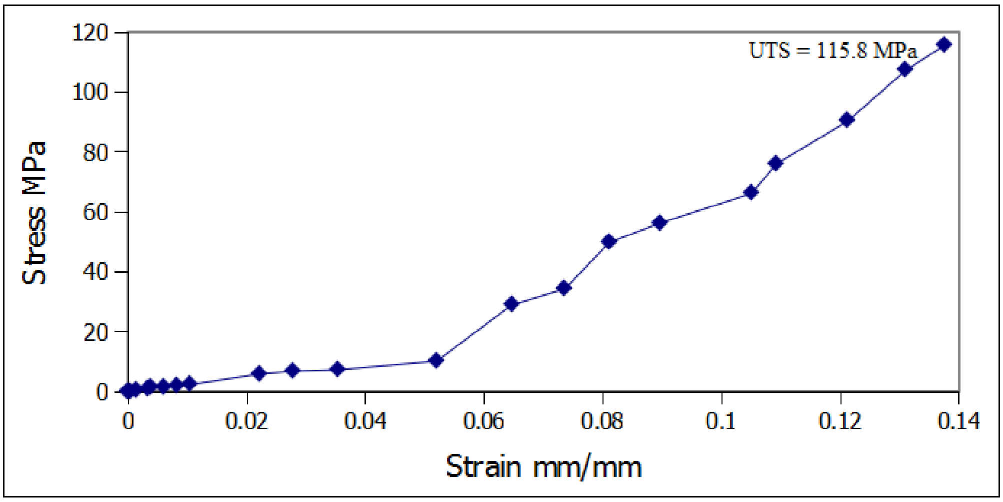

Fig. 7. *Stress–Strain Curve for Al6061-12% Graphite.*

To calculate the percentage elongation for the Al6061-12% graphite MMC, the maximum deformation considered was 7.11 mm and thus % elongation is calculated as 13.76%.

RESULTS AND DISCUSSIONS

This chapter provides the summary of results obtained and the brief discussion of the same. Tensile properties of the aluminum 6061-graphite is determined using a UTM as per ASTM standard testing procedure. The results of the tensile test are listed in the Table 1.

The tensile test specimens are prepared for aluminium-6061 metal matrix composites reinforced with graphite particles at varied weight fractions of graphite (3, 6, 9, and 12%).

Table 1. *Tensile Test Results.*

Sl. no	Composite	Ultimate tensile strength(MPa)	Percentage elongation(%)
1	Al6061-3%Gr	112.54	12.87
2	Al6061-6%Gr	114.17	14.14
3	Al6061-9%Gr	**117.34**	**14.48**
4	Al6061-12%Gr	115.80	13.76

The composite with best tensile test result was found to be Al6061-9% graphite with ultimate tensile strength = 117.34 N/mm^2. From the tensile test, maximum % elongation was found to be of 14.48%, which is for Al6061-9% graphite.

It is observed that the ultimate tensile strength (UTS) improved with increase in graphite weight percent. The increase in UTS is because of the existence of the hard and higher modulus graphite particles embedded in the Al6061 matrix, which act as a barricade to oppose plastic flow when the MMC is subjected to an applied load. Also, the decreased interparticle spacing, due to the increased weight percent of graphite reinforcement, creates increased resistance to dislocation motion, which gives the improved strength to MMCs.

However, for 12% graphite a decrease in the UTS was observed. This decrement may be due to increased particle-matrix interfaces, clustering of graphite particles in the matrix.

It is observed that the percentage elongation increases with increase in graphite weight percent. However, for 12% graphite there is decrease in the percentage elongation. This decrement may be due to increased particles which causes particle clustering.

CONCLUSIONS

Based on an experimental study of Al6061-graphite MMCs the following conclusions are made.

(1) From the experimental tensile test, ultimate tensile strength of 117.34 MPa is obtained for Al6061-9% graphite. Maximum percent elongation is found to be of 14.48%, which is for Al6061-9% graphite.
(2) It is observed that the ultimate tensile strength (UTS) improved with increase in graphite weight percent.

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