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Experimental and simulation analysis of the tensile properties of aluminium alloy hybrid composites reinforced with graphite and boron carbide

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ABSTRACT

In recent years Metal Matrix Composites (MMCs) have attracted much attention due to their excellent mechanical properties such as high specific strength and wear resistance. Some of the typical applications are bearings, automobile pistons, cylinder liners, piston rings, connecting rods, sliding electrical contacts, turbocharger impellers, and space structures. MMCs components need to be formed into the desiderate shapes and finished to the required dimensions and tolerances. In the present work, a brave is consummate to prepare and compare the tensile properties of LM25-Gr and LM25-graphite/boron carbide (B_4C) hybrid composites. The composites were primed to make use of stir casting process in which the quantity of reinforcement is speckled from 4 wt% of Gr and 3wt% of B_4C. The prepared composites are tensile properties were estimated as per the standards. Finite element method was employed in this work. Experimental results were in good agreement with numerical results.

Keywords: LM 25 Aluminum alloy, Gr, B_4C, Stir casting, Tensile Strength, Ansys, Stress, Strain, Deformation

INTRODUCTION

A composite is a structural material that consist combination of two phases is matrix and reinforcement and constituents that are united at a macroscopic level and are not soluble in each other. Both constituents maintain their identity as they do not dissolve or melt in each other, and act in such a way that a new material results whose properties are better than the sum of their constituents. The assimilation of several dissimilar types of ceramic particulates into a solitary matrix has led to the advance of amalgam composites. in addition, using a hybrid composite that includes more than two types of particulates, the recompense of a single type of particulates could harmonize with what is deficient in the other [1]. The matrix material should be carefully chosen depending on its properties and behavior with the reinforcement. As it is the primary constituent in MMC, the matrix alloy should be chosen only after giving careful consideration to its chemical compatibility with the reinforcement, to its ability to wet the reinforcement, and to its own characteristic properties and processing behavior [2]. Aluminum matrix composites (AMCs) are emerging as advanced engineering materials due to their strength, ductility, and toughness. The aluminum matrix is triumph strengthened when it is dispersed with the hard ceramic particles like SiC, Al2O3, and B_4C etc. Aluminum alloys are tranquil the focused of intense studies, as their low density provides additional advantages in numerous applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes [3]. AMCs can

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be manufactured by liquid state processing (stir casting, infiltration, squeeze casting etc.), semisolid processing and powder metallurgical route. Strong interface bond between reinforcements and matrix is required to obtain the high strength of composites. Interface bond is formed by reaction or mutual dissolution during casting. Therefore, good wetting of the reinforcements is necessary during casting [4]. The mechanical properties of MMCs generally depend on the microstructures of the materials, such as particle size effect [5, 6]. The optimization of the mechanical properties of composites is based on the knowledge of the relationship between the microstructure and the macroscopic response of MMCs. Up to now, though a considerable volume of literature regarding the microstructure and macroscopic mechanical behavior exists [7–10]; their micromechanical behavior between particles and matrix has not been examined in detail. From the design perspective as well as structure aspect, it is imperative to develop a detailed understanding of the micromechanical and elastic-plastic properties of MMCs. Finite element method is used to solve physical problems involving complicated geometries, loading and material properties which cannot be solved by the analytical method. This method is extensively used in the field of structural mechanics, fluid mechanics, heat transfer, electrical and magnetic field problems. Finite Element Method (FEM) and Analysis (FEA) are two of the very popular engineering applications offered by existing CAD/CAM systems [11]. In this work, the deformation, stress and strain distribution of the specimen was carried out using the ANSYS software. The objective of the present work is to study the development and mechanical properties analysis of Aluminum LM25- graphite/boron carbide (B_4C) Metal Matrix Composite Using FEA.

MATERIALS AND METHODS

Material selection

LM25 aluminum alloy having a density of 2.68 gm/cm3 and protuberant properties like weight, toughness, heat conduction etc., be chosen as the base matrix due to its usage in automotive pistons. For the purpose of increasing the wear resistance of this piston alloy, B_4C particles of 200 mesh sizes were choosing as reinforcement. This B_4C has the lower density (2.52 gm/cm3), higher hardness relative to SiC and Al2O3, excellent chemical and thermal stability [12], which makes it as a suitable reinforcement to improve the wear performance of the alloy. This graphite density 2.26 g/cm3 and the hardness of the composites decrease as the % of graphite (Gr) increases [13]. The graphite is also selected as the reinforcement material and it has the density of 2.26 g/cm3 and the hardness of the composites decreases as the % of graphite (Gr) increases [14]. The spectroscopy analysis was carried out for LM25 aluminum alloy and its chemical composition was given in Table 1.

Table 1 Chemical composition of LM25 aluminium alloy

Elements	Si	Fe	Cu	Mn	Mg	Cr	Ni	Sn	Ti	Pb	Ca	Sb	Zn	Al
%	7.23	0.73	0.12	0.14	0.29	0.02	0.02	0.01	0.02	0.01	0	0	0.14	Balance

Stir casting process

Stir casting process was used for the fabrication of the composite due to its cost-effectiveness [15]. Primarily matrix material was tended to the graphite crucible and melted in an electric resistance furnace. The melting of the alloy takes place in an inert gas atmosphere, which avoids chemical reaction and produces a sound casting. Subsequently attaining the molten metal condition, preheated reinforcements were added regularly to the molten metal and stirred continuously at 350 rpm for 6 minutes to ensure uniform distribution of reinforcement particles of molten metal. The molten metal was then poured at the temperature of 760°C into preheated (300°C) steel molds of dimensions 100 × 14 mm and allowed to solidify.

Tensile strength

The micro tensile test was conceded out in harmony with ASTM B-557M standards by means of different specimens as a dimension of 50 mm length and the gauge length of 30 mm as shown in Figure 1 for each MMC's family. The cast specimens are prepared by the machining as per the standard. The micro-tension was conceded out for elongation, load capacity, tensile properties, with respect to the speed, for the sample, tensile readings recorded. The digital tensometer among two perfunctory seize is used to hold the tensile specimen as shown in Figure 2.

Figure 1 Tensile test specimen

Figure 2 Micro Tensile Test - Digital tensometer

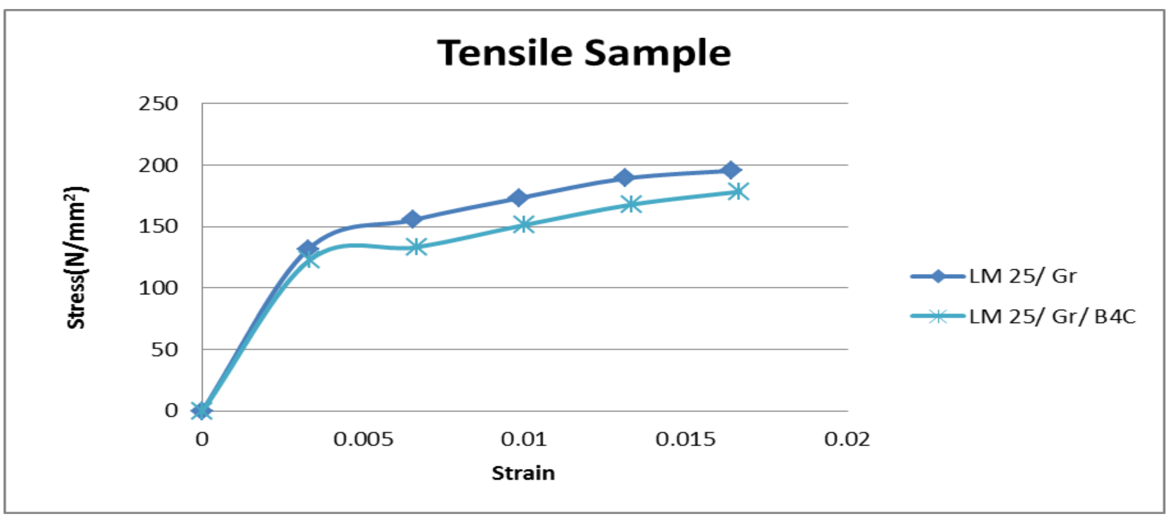

Figure 3Stress vs strain curve of LM 25/Gr and LM 25/Gr/ B_4C MMC's

From Figure 3, it demonstrates that the tensile strength of the composites augmented with augmenting in B_4C reinforcement, and the tensile strength is additional in hybrid composites than single reinforcement. Figure 3 shows the variation in micro tensile strength with the MMC's. While increasing the reinforcement of graphite (4%) and boron carbide (3%) load value increase gradually.

NUMERICAL ANALYSIS OF TENSILE SPECIMEN

Deformation analysis of tensile specimen

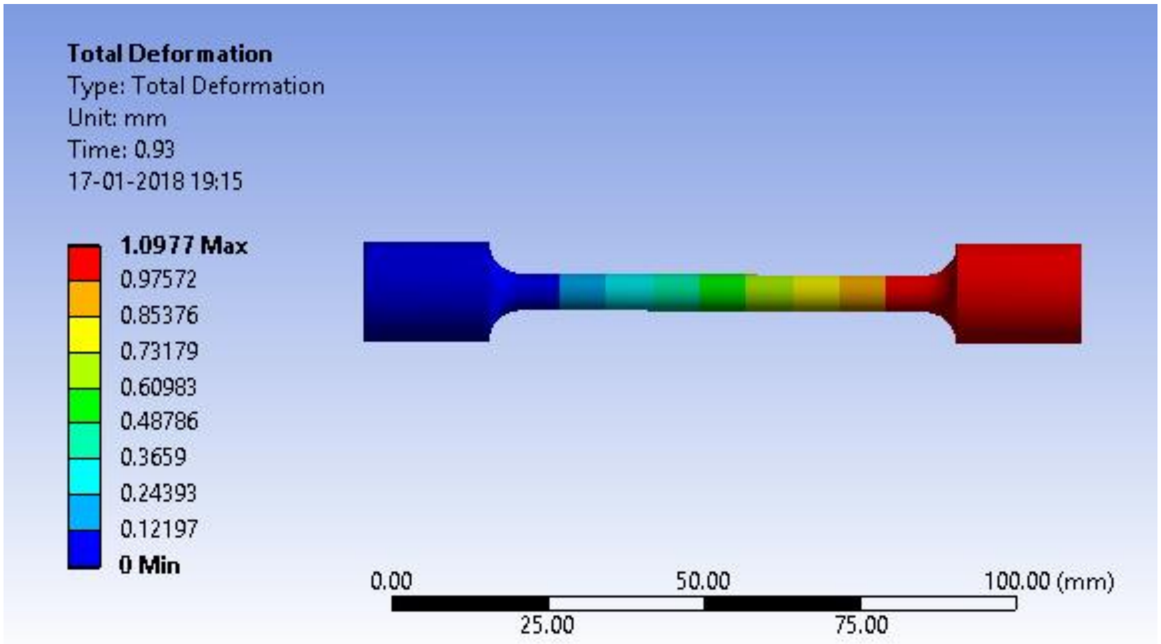

Figure 4 Deformation Plot

Deformation analysis is done to compare the result between the experimental and numerical deformation using the ANSYS software. From these results, the percentage of errors is calculated. The input load is taken from the compressibility test an experimental result and Young's modulus and the Poisson's ratio are calculated through the formula. The result of deformation is shown below. The deformation analysis has a deformation value of 1.0977mm. The deformation study is used to compare the numerical and experimental results by giving the compressive strength as the input load. Due to the presence of unwanted impurities like oxygen, the result variable is caused by the experimental analysis while deformation compares through the ANSYS software.

Stress analysis of tensile specimen

Stress analysis is done to compare the result between the experimental and numerical stress using the ANSYS software. From these results, the percentages of errors are calculated. The input load is taken from the tensile test experimental result and Young's modulus and the Poisson's ratio are calculated through the experimental results. The results of stresses are shown in figure xx. The stress analysis has a maximum stress value of 194.94 N/mm2. The stress analysis is used to compare the numerical and experimental results by giving the tensile strength as the input load. The presence of unwanted impurities like oxygen is one of the reasons for the result variation caused by experimental analysis while stress compares through the ANSYS software.

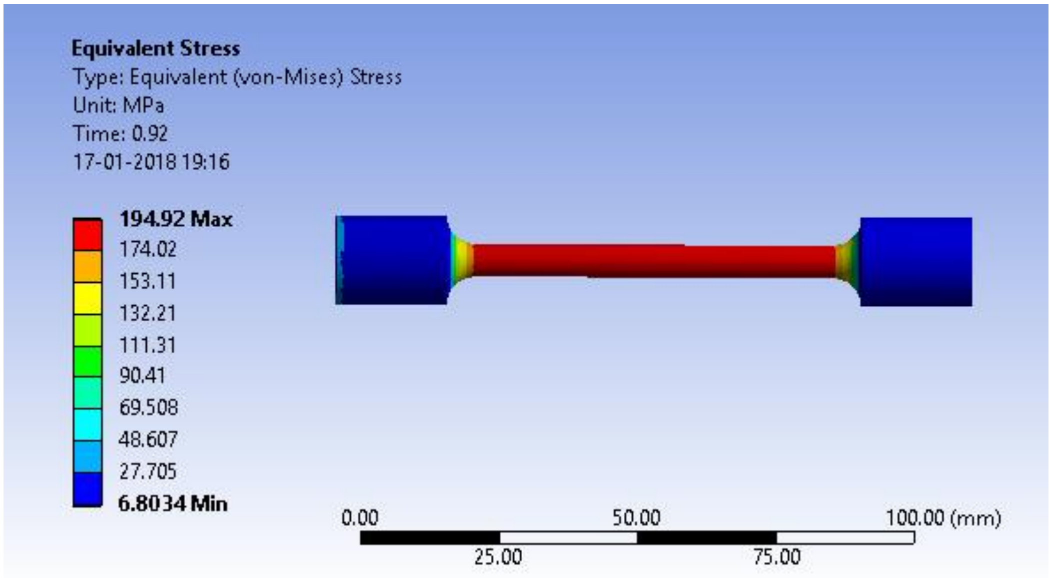

Figure 5 Equivalent Stress Plot

Strain analysis of tensile specimen

Strain analysis is done to compare the result between the experimental and numerical strain using the ANSYS software. From these results, the percentage of error is calculated. The input load is taken from the compressibility test experimental result and Young's modulus and the Poisson's ratio are calculated through the experimental results. The result of strain analysis is shown below. Strain analysis has a maximum strain value of 0.000975. The strain analysis is used to compare the numerical and experimental results by giving the compressive strength as the input load. Due to the presence of unwanted impurities like oxygen, the result variable is caused by comparing experimental analysis strain through the ANSYS software.

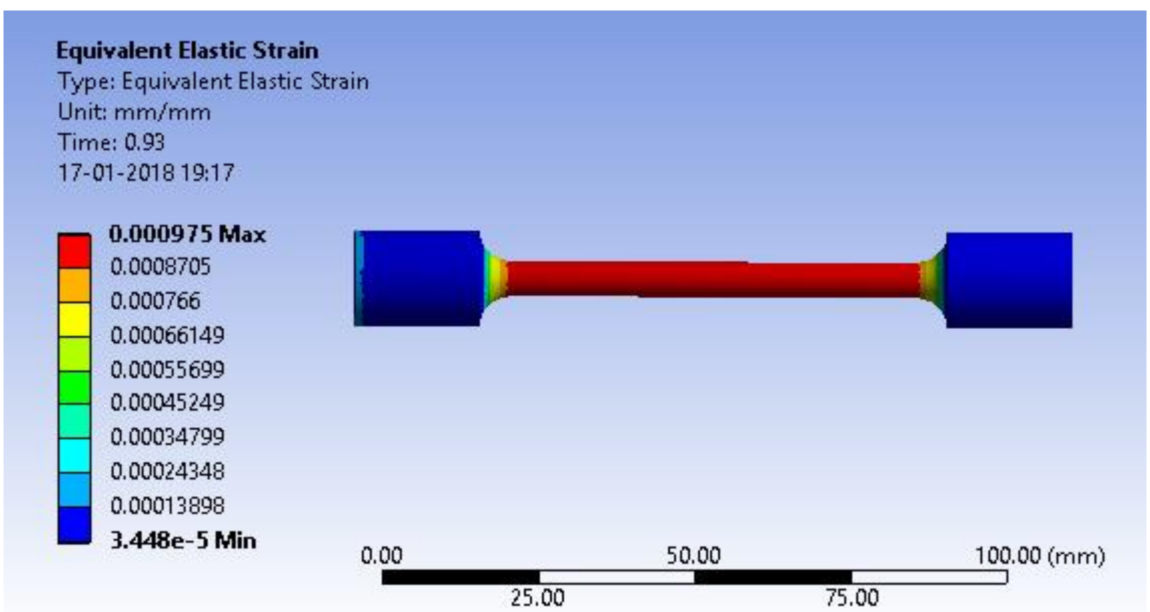

Figure 6 Equivalent Strain Plot

CONCLUSION

- The manufacturing and investigation of tensile properties of LM25/Gr and LM 25/Gr/ B_4C composites were done by stir casting method for different volume fractions.
- The material was fabricated with percentage 3% Gr, and 3% B_4C using stir casting method.
- The tensile strength of Gr and Gr/ B_4C reinforced hybrid particulate aluminum composites was deliberated and the maximum tensile strength observed is195 N/mm2 at 4% of Gr and 3% of B_4C for both experimental and simulations methods
- When the percentage of reinforcement of B_4C increases, mechanical and metallurgical properties of the composite materials were increased accordingly.
- Finite element analysis was conducted for various mechanical tests. The numerical results show that it is in good agreement with experimental results.

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