Mechanical Properties of Aluminium–Graphite Particulate Composites

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***Abstract*—Aluminium metal matrix composites found to the best alternative with its improved properties in designing the materials to give required properties. The aim of this work is to study the behavior of Aluminium (6061) with graphite composite produced by the stir casting technique. In this paper hardness and tensile strength experiments have been conducted by varying mass fraction of graphite (0%, 3%, 6%, and 9%) with Aluminium. The rockwell hardness testing method was used to determine hardness and universal testing machine is used to find the tensile properties for different compositions of aluminium 6061-graphite particulate metal matrix composite. The maximum hardness and ultimate strength has been obtained at 9% graphite and 6% graphite respectively. Also minimum % elongation was obtained for 6% graphite.**

Keywords— Rockwell Hardness; tensile strength; Aluminium-Graphite Composites.

I. INTRODUCTION

All engineering materials in practice do not have theoretically calculated strength because of defects like cracks, flaws, inclusions and also due to manufacturing defects, etc. Conventional design approach is based on the limiting strength. In service the components will fail before reaching its limiting strength. Hence the fracture based design approach is better than the conventional design.

Metal matrix composites (MMCs) are increasingly becoming attractive materials for advanced aerospace applications but their properties can be tailored through the addition of selected reinforcement. In particular particulate reinforced MMCs have recently found special interest because of their specific strength and specific stiffness [1] at room or elevated temperatures. It is well known that the elastic properties of the metal matrix composite are strongly influenced by micro-structural parameters of the reinforcement such as shape, size, orientation, distribution and volume or weight fraction.

A. Literature Survey

Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla made the modest attempt to develop aluminium based silicon carbide particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material [8]. To achieve these objectives two step-mixing method of stir casting technique has been adopted and subsequent property analysis has been made.

Dunia Abdul Saheb [3] made the modest attempt to develop aluminium based silicon carbide particulate MMCs and graphite particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material.

Neelima Devi. C, Mahesh.V, Selvaraj. N [4] conducted the tensile strength experiments by varying mass fraction of SiC (5%, 10%, 15%, and 20%) with Aluminium. The maximum tensile strength has been obtained at 15% SiC ratio. Also they studied the mechanical and corrosion behavior of the aluminium silicon carbide alloys.

From the literature it is identified that more work has been done on mechanical characteristics of aluminium silicon carbide particulate metal matrix composites. Also some new methods [2][3], Advanced Shear Technology, stir casting were developed to produce the MMCs such as Aluminium silicon carbide and aluminium graphite. Mechanical characterization [4, 5, 6, 7, 8] of aluminium silicon carbide was studied by the different authors and most of the authors compared their results with the unreinforced aluminium alloy.

Aluminium-6061 is widely used for construction of aircraft structures, such as wings and fuselages. There are two different cracks being investigated in aircraft wings, Hairline cracks around fastener holes in the internal wing structure and Cracks at the edges of the vertical web of the feet. If the high loads being applied to the fasteners during assembly, are not adequately accounted for, they will combine with the stresses arising from the interference fit, potentially leading to cracking. The particular type of aluminium alloy used will also affect this joint behaviour where a balance has to be achieved between stiffness, strength and fracture toughness.

The main objective of the present work is to study the hardness and tensile properties of aluminium matrix composites reinforced with graphite particles at varied weight fractions.

II. MATERIALS AND PROCESSING

A. Aluminium 6061 Alloy

Al6061 alloy has the highest strength and ductility of the aluminium alloys with excellent machinability and good bearing and wear properties. Most of the particulate reinforced metal matrix composites are produced by stir casting, although many different processes for fabricating these cast composites are also available which have been reported by various researchers. Since the hardness, ultimate tensile strength (UTS), compressive strength, Young's modulus and ductility of the composite material are all vital properties of a structural material, the present investigation aims at studying these properties in the Al6061 alloy with graphite particulate composites. Table below shows the composition of the Aluminium 6061 Alloy. Chemical composition of the aluminium 6061 is given in table 1.

TABLE I. CHEMICAL COMPOSITION OF ALUMINIUM 6061 ALLOY

Contents							
Si	***Fe***	***Cu***	***Mn***	***Mg***	***Zn***	***Cr***	***Ti***
0.70	0.21	0.28	0.027	0.81	0.019	0.14	0.32

B. Graphite

Graphite exists as one of the giant covalent structures in nature. Graphite is an allotrope of the chemical element carbon and is denoted by the symbol 'C'. Graphite, in the form of fibers or particulates, has long been recognized as a high-strength, low-density material. Graphite has a layered, planar structure. In each layer, the carbon atoms are arranged in a honeycomb lattice with separation of 0.142 nm, and the distance between planes is 0.335 nm.

C. Aluminium graphite

Aluminium graphite is characterized by an outstanding combination of thermal, physical and mechanical properties. A high thermal conductivity goes along with a low coefficient of thermal expansion, which is a considerable advantage in thermally alternated loaded systems. Aluminium graphite has also a lower density than aluminium which leads to mass reductions in packaging when aluminium graphite is used.

D. Processing

The aluminium blocks were melted in the furnace as shown in fig 1. After melting, molten aluminium was super-heated to desired temperature (about 750^0 C). The required amounts of graphite particles were added to the aluminium melts while stirring with stirrer at suitable speed. The molten aluminium-graphite were poured into a split type permanent mould & it was allowed for solidification. The aluminium-graphite alloy bars were taken out from the mould. The specimens were prepared from as-cast alloys for determination of required properties.

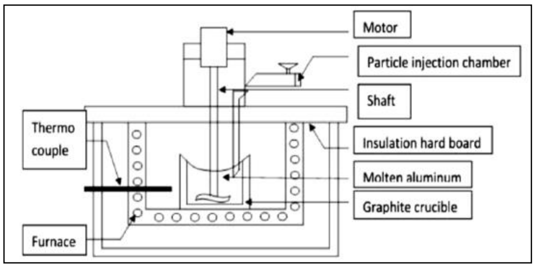

Fig. 1. Schematic view of stirring mechanism for the Fabrication of composites [2, 3]

E. Test Specimens

The test specimens for hardness and tensile test where prepared for aluminium graphite particulate metal matrix composite of 0, 3, 6, and 9% of graphite particles as shown on fig 2 and 3. The dimension of the hardness test specimen is 25mm diameter and dimensions for the tensile test specimen are as per ASTM E8 standards: Nominal Diameter = 12.7 mm, Gauge length = 50.8 mm.

Fig. 2. Hardness test specimen

Fig. 3. Tensile test specimen

III. EXPERIMENTS

A. Rockwell Test

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, where A is the scale letter.

B. Tensile Test

The specimens machined to ASTM standards [4] are allowed for tensile testing using universal testing machine (UTM). The test process involves placing the test specimen in the testing machine and applying tension to it until it fractures. The elongation measurement is used to calculate the engineering strain, ε, using the following equation:

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0}$$

where ΔL is the change in gauge length, L_0 is the initial gauge length, and L is the final length.

The force measurement is used to calculate the engineering stress, σ, using the following equation

$$\sigma = \frac{F_n}{A}$$

where F is the force and A is the cross-section of the gauge section.

The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.

IV. RESULTS AND DISCUSSION

A. Hardness Test Results

The hardness test results are tabulated in table II and graphs are drawn as shown in fig 4.

The hardness test bar graphs for the three compositions are shown in fig 4.1. Al 6061-graphite composite has higher levels of hardness when compared to its principal alloy Al 6061.The bar graph compares Rockwell B hardness values among various compositions and Al 6061. The composite of Al 6061- 9% graphite alloy has highest hardness value= 119 (RHN).

TABLE II. ROCKWELL HARDNESS NUMBER

Composite	Rockwell Hardness Number(Test1)	Rockwell Hardness Number(Test2)
Al-6061	60	60
Al-6061+3% Gr	85	90
Al-6061+6% Gr	86	91
Al-6061+9% Gr	106	132

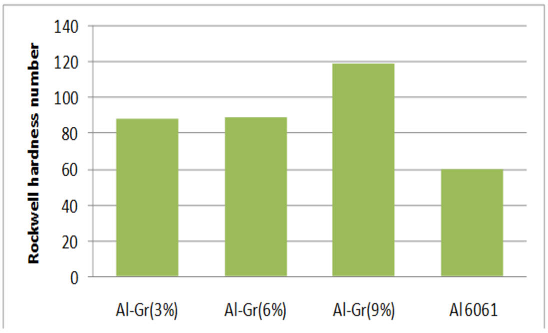

Fig. 4. Average Rockwell hardness for composites and Al 6061

B. Tensile Properties

Al 6061-graphite composite has lower yield strength on comparison with its parent alloy Al 6061. The graph shows the comparison of tensile stresses of aluminium graphite and Al 6061 composite.

In Fig 5, Stress strain diagram is plotted for aluminium 3% graphite and all the points are indicated, ultimate strength was observed to be 81.7 MPa and % elongation = 3.10 %. In fig 6, the stress strain diagram for aluminium 6% graphite, ultimate strength was observed to be 83.2 MPa and % elongation = 2.84 %. In fig 7 stress strain diagram for aluminium 9% graphite, the ultimate strength was observed to be 77.5 MPa and % elongation = 3.07 %.

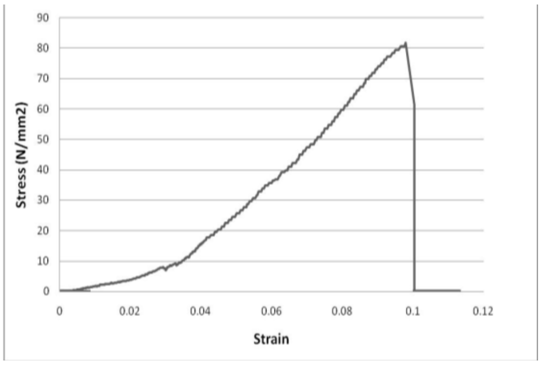

Fig. 5. Stress strain diagram for Al-3% graphite

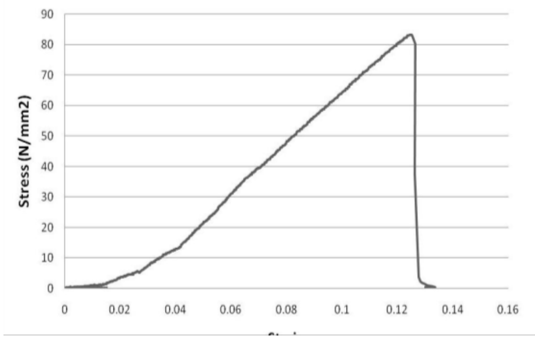

Fig. 6. Stress strain diagram for Al-6% graphite

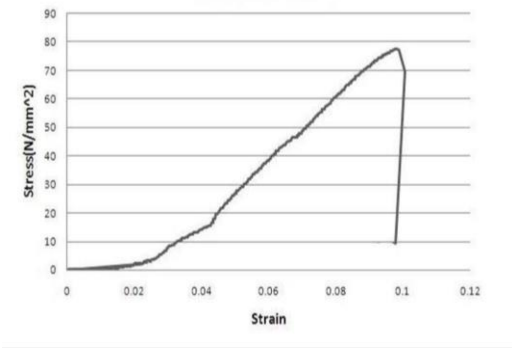

Fig. 7. Stress strain diagram for Al-9% graphite

V. CONCLUSIONS

Based on experiments of Rockwell indentation and tensile testing on aluminium graphite MMCs' the following conclusions are made.

- Considering the tensile tests, the Al 6061-graphite composites have higher yield stresses on comparison with their parent alloy Al 6061. Hence, the tensile strength of the composites has generally increased. The composite with best tensile test result:- Al 6061- 3% graphite, ultimate tensile strength= 83.2 N/mm^2
- The Rockwell hardness test result shows elevated hardness values among all the composites on comparison to Al 6061. Hence, the hardness property has generally

increased. Thus, addition of graphite to the Al 6061 alloy has made it more hard. The composite with maximum value of Rockwell B hardness= Al 6061- 9% graphite, RHN= 119 (RHN= Rockwell Hardness Number)

- From the tensile test, minimum % elongation was found to be of 2.84%, which is for Al 6061- 6% graphite.

REFERENCES

[1] ASM International, "ASM Handbook of Composites" Volume 21, 2001.
[2] N. Barekar, S. Tzamtzis, B.K. Dhindaw, J. Patel, N. Hari Babu, and Z. Fan, "Processing of Aluminum-Graphite Particulate Metal Matrix Composites by Advanced Shear Technology", Journal of Materials Engineering and Performance, ASM International, Feb 2009.
[3] Dunia Abdul Saheb, "Aluminum silicon carbide and aluminum graphite particulate composites", ARPN Journal of Engineering and Applied Sciences, October 2011, Vol. 6, No. 10.
[4] Neelima Devi. C, Mahesh.V, Selvaraj. N, "Mechanical characterization of Aluminium silicon carbide composite", International Journal of Applied Engineering Research, Dindigul, Volume 1, No 4, 2011.
[5] Seah, K.H.W., Sharma, S.C., Rao, P.R and B. M. Girish, B.M, "Mechanical properties of as-cast and heat-treated ZA-27/silicon carbide particulate composites", J.Materials and Design,Vol.16, Issue 5, pp.277-281, 1995.
[6] Shanta Sastry, Krishna, M. and Jayagopal Uchil, "A study on damping behaviour of aluminite particulate reinforced ZA-27 alloy metal matrix composites", J. of Alloys and Compounds, Vol.314, Issue1-2, pp.268-274, 2001.
[7] Prasad. S.V., Asthana, R., "Aluminium-metal matrix composites for automotive applications: tribological considerations", Tribology, vol.17, No.3, pp.445-453, 2004.
[8] Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite", Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009.