IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 32-38

Aluminium 6061 Reinforced with Graphene Nano-Particles for Aeronautical Applications

Ansari Abullais[1], Ansari Abdul Mannan Saeed[2], Ansari Md. Tarique[3],
Shaikh Irfan[4], Quraishi Zaid Haidar[5], Prof.Mahvi Malik Shahzad[6]
[1,2,3,4,5,6]*(Mechanical Engineering, MMANTC, Mansoora, India)*

Abstract: *Composite materials are frequently chosen for engineering applications because they have desirable combination of mechanical characteristics. Development of hybrid metal matrix composites has become an important area of research interest in material science. In this project a modest attempt has been made to develop Aluminium 6061 based Graphene Nano particulate MMCs. The Aluminium based Graphene nano-particulate MMCs are finding increased application in aerospace, automobile, space, underwater and transportation applications because of its light weight and Non-reactive nature. In this project, an effort is make to enhance the mechanical properties of AMCs by reinforcing Aluminium matrix with varying weight proptions of Graphene nano-particals 0%, 0.2%, 0.5%, 1%, 3%. The stir casting method was used to form Al-Graphene composite. Aluminium alloy matrix varying proportions of Graphene nano-particles were fabricated according to ASTM standards. The microstructure tensile strength, compressive strength, impact strength and hardness of fabricated AMCs are analyzed.*

Keywords: *Aluminium 6061 ,Composite Material, Graphene Nano Particle,Nano Technology*

I. Introduction

Scientists are continuously trying to improve various properties of materials. This produces new category of materials called composite materials; they are composed of a combination of distinctly different two or more micro or macro constituents that differ in the form of composition and it is insoluble in each other. Composite materials have a continuous, phase called the matrix; and a dispersed,non-continuous, phase called the reinforcement. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. In a composite, each material retains its original properties but when composited it yields superior properties which cannot be obtained separately. Such types of material are developed to satisfy proper mechanical properties which cannot be derived from conventional materials. And also composites meet the requirements of specific design and function, along with the desired properties.

According to matrix constituent, composites are classified into organic-matrix composites, metal matrix composites (MMCs) and ceramic-matrix composites.Among these composites, MMCs provide significantly enhanced properties such as higher strength, specific modulus, damping capacity, stiffness, good wear resistance and weight savings. The major disadvantage of MMC usually lies in the relatively high cost of fabrication and of the reinforcement materials.

II. Literature Survey

[1]Sunil Kumar[2018] In this study, the orientation of aluminium atoms over the graphene substrate along with mechanical properties of aluminium/graphene nanocomposites have been investigated using molecular dynamics simulation. The following conclusions may be drawn.It has observed that lower potential energy aluminium atoms aggregate and formed a cluster near the graphene substrate.The orientation or crystallization of aluminium atoms have observed as {111} planes of the face centered cubic (fcc) at aluminium/graphene interface. Graphene substrate has been acting as facilitator for aluminium crystallization.The young modulus and yield strength found higher during tensile deformation along the normal axis (Z-axis) of grapheme substrate compared Y- and X-axis. These results implies that the nanosubstrates affects the nature of the metal atoms response to stress which affect the mechanical properties of metal/nanocomosite. In addition, further analysis of the aluminium/graphene nanocomposite and its impact on the various properties will also help to provide a greater understanding to reduce failures in metal nanocomposite systems.

[2]Ajay Janakrao Puri et.al [2017] He concluded that, Aluminium is finding wider applications in different industries due to low weight. Aluminium is remarkable for the low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium metal matrix composites are studied on large scale now a day to find their superiority in different properties with respect to pure aluminium. This paper mainly focuses on aluminium metal matrix composite having Sic as a reinforcement and effect of reinforcement on different properties.

III. Experimental Work

Aluminium 6061 (Al 6061)

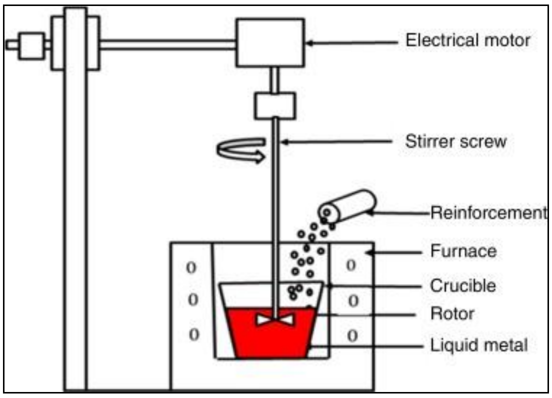
Name	Properties
Chemical formula	Al
Appearance	Silvery Grey Metallic
Density	2700 kg/m^3
Melting point	923 Kelvin
Boiling Point	2743 Kelvin
Thermal conductivity	166 W/Mk
Brinell Hardness	160-550 MPa
Tensile strength	310 MPa
Yield Strength	275 MPa

Graphene Nano-Particles

Specifications	Value
Purity	Above 99 %
Thickness	5-10 nm
Length	5-10 micron
Density	3.1 g/ cm3
Number of Layer	Average No.of Layer 4-8
Surface Area	200-210 m2/g
Thermal Conductivity	5000 W m-1 k-1
Elastic modulus	0.25 TPa

Stir Casting Process

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase ceramic particles, short fibres) is mixed with a molten matrix metal by means of mechanical stirring. This is the most prominently used technique (it is also referred to as the vortex technique) is attractive because of simplicity, low cost, flexibility, most sized economical for large components to be prepared as well as production of near net shaped components. This process involves the introduction of pre-treated ceramic particles into the vertex of molten alloy created by the rotating impeller.



Stir Casting Process

Stir Casting is characterized by the content of dispersed phase is limited (usually not more than 30 % Vol) and distribution of dispersed phase throughout the matrix which is not perfectly homogeneous. There are local clouds (clusters) of the dispersed particles (fibres) and there may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrixphase. The technology is relatively simple and low cost. Distribution of dispersed phase may be improved if the matrix is in semi-solid condition.The method using stirring metal composite materials in semi-solid state are called as rheocasting. High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase. The figure given above shows the stir casting setup.

Specimen Preparation

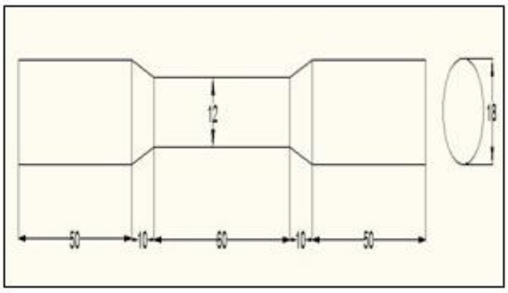
Aluminium was melted in a crucible by heating it in a pit furnace at 800°C for three hours. The furnace temperature was first raised above the liquidus temperature of Aluminium near about 750°C to melt the Al completely and was then cooled down just below the liquidus to keep the slurry in Semi solid state.stirring was carried out with the help of radial drilling machine for about 15 minutes at stirring rate of 300 RPM. At this stage, the Grapheme nano particles were added manually to the vortex. In the final mixing processes the furnace temperature was controlled within 700 ± 10°C. After stirring process the mixture was pour in the mould to get desired shape of specimen . The presence of reinforcement throughout the specimen was inspected by cutting the casting at different locations and under microscopic examination. Same process was used for specimens with different compositions of Al 6061-Graphene Compositions of samples are shown in Table.

Sr.NO	**Specimen**	**Aluminium 6061 (gm)**	**Graphene Nano Particle (gm)**	**Graphene Nano Particle (%)**
1	NP0.0	170	0	0
2	NP0.2	169.66	0.34	02
3	NP0.5	169.15	0.85	0.5
4	NP1.0	168.3	1.7	1
5	NP3.0	164.9	5.1	3

Tensile Test

This is one of the most widely used mechanical test to evaluate certain properties of the metal. It has a great importance in many engineering application like machine design, manufacturing etc. The tensile test is generally performed in Universal Testing Machine (UTM). This test provide data on the strength and ductility of metals under uniaxial tensile forces. The tensile strength of a metal is essentially its ability to withstand tensile load without failure. In tensile test, a metallic sample is subjected for a gradually increasing stress or load which is uniaxial but in opposite direction. The sample get first elastically deformed and then plastically deformed, finally fractures in two pieces. Tensile testing of Aluminium- Silicon carbide metal matrix composite (MMC) will be conducted by making the five samples according to ASTME8-08 as shown in fig. The tensile test can be carried out on standard sample or nonstandard metallic samples. Generally the specimen has a circular cross-section or it may have rectangular or square cross-section as well, which is prepared from a plate or sheet metal.
Testing was performed on computerized universal tensile testing machine and all samples with different reinforcement percentage to check them under tensile loading. UTM and loading of sample over machine is shown in Figure. The samples after test were break as shown in Figure.

Computerized UTM machine



Specimen as per ASTM E8M-08

Specimen before tensile test

Specimen after tensile test

Compression Test

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size as oppose to tensile strength, which withstand loads tending to elongate." Compression loads are opposite to tensile loads i.e. the direction of loading. In the case of tensile test we use load but in opposite directions while in case of compression test we use the loads uniaxially but in same direction. The same universal testing machine is used for this test. Generally this test carried out for brittle metals and non-metals which are very good in compression. This test is mainly used for the materials such as cast irons, concrete, blocks, bricks, ceramic products.

Computerized UTM machine

Specimen before Test

Specimen after Test

Impact Test

The impact toughness of a material can be determined with a Charpy impact test.Many engineering metals have to withstand impact forces or suddenly applied loads during a service. Impact properties are not directly used in fracture mechanics calculations, but the economical impact tests continue to be used as a quality control method to notch sensitivity and for comparing the relative toughness of engineering materials. For both tests, the specimen is broken by a single overload event due to the impact of the pendulum.

Impact Testing Machine

Specimen before test

Specimen after test

Hardness Test

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting or bending. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface. Figure shows the Brinell hardness test machine.

Specimen after hardness test

Hardness testing Machine

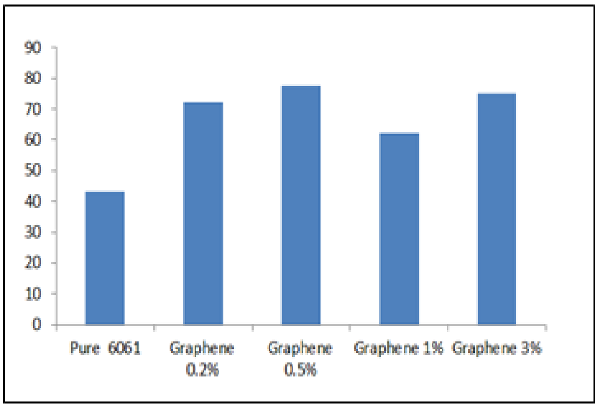
IV. Results and Discussion

Tensile Test Result

Tensile tests were used to assess the mechanical behaviour of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 6mm and gauge length of 30 mm. Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract.

Table 01 Tensile Strength of all Samples

Sr. No	Sample	Tensile strength (MPa)
1	Np 0.0	43.131
2	Np 0.2	72.200
3	Np 0.5	77.699
5	Np 1.0	62.222
6	Np 3.0	74.949



Comparison of Tensile strength

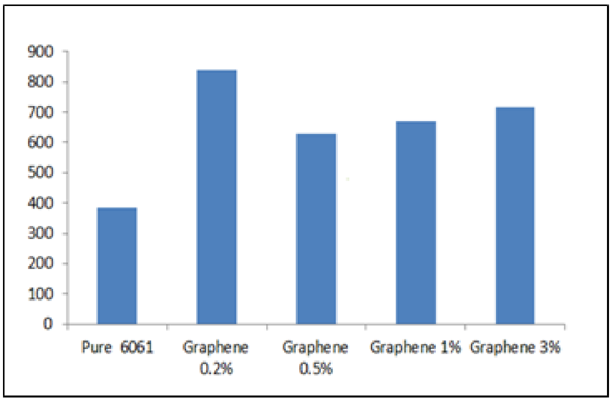
As shown in above Figure the tensile strength of Np1.0 goes on decreasing which is due to not proper mixing of Graphene in the aluminium 6061 matrix which is due to improper mixing of Graphene with aluminium 6061 and may be due to manufacturing defects.

Compressive Strength Test Results

Compression test are used to determine how a product or material reacts when it is compressed, squashed, crushed or flattened by measuring fundamental parameters that determine the specimen behavior under a compressive load these include the elastic limit, which for „Hookeans" materials is approximately equal to the proportional limit, and also known as yield point or yield strength, young"s modulus and compressive strength.

Table 02 Compressive strength of all Samples

Sr. No	Sample	Compressive strength (Mpa)
1	Np 0.0	383.625
2	Np 0.2	837.722
3	Np 0.5	627.093
4	Np 1.0	668.653
5	Np 3.0	713.984



Comparison of compressive strength

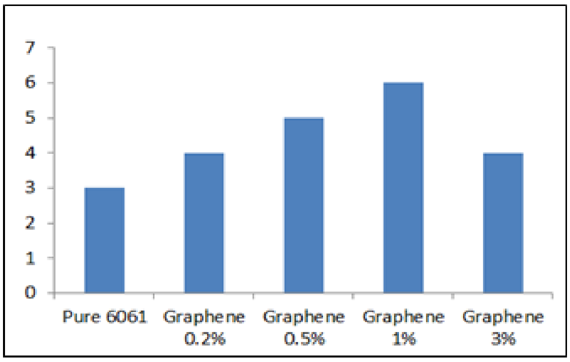
From the Figure it is asses that as the percentage of Graphene increases the compressive strength also increases.

Impact Test Results

The impact toughness of a material can be determined with a Charpy or Izod test.Impact properties are not directly used in fracture mechanics calculations, but the economical impact tests continue to be used as a quality control method to notch sensitivity and for comparing the relative toughness of engineering materials. For both tests, the specimen is broken by a single overload event due to the impact of the pendulum. As top pointer is used to record how far the pendulum swings back up after fracturing the specimen. The impact toughness of a metal is determined by measuring the energy absorbed in the fracture of the specimen.

Table 03 Energy absorbed by all Samples

Sr. No	Sample	Energy Absorbed (Joule)
1	Np 0.0	4
2	Np 0.2	5
3	Np 0.5	7
4	Np 1.0	8
5	Np 3.0	6



Comparison of Energy absorbed

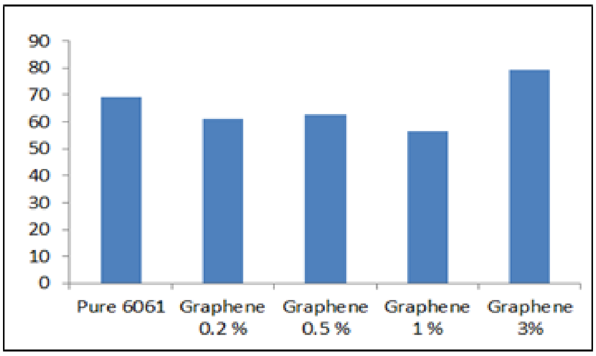
From Figure it is observed that the energy absorbed goes on increasing from Np0.0 to Np1.0 and it lower for the Np3.0 . From the impact graph of samples we can come to a point that toughness increases with reinforcement. Surprisingly percentage of reinforcement is not making remarkable influence on toughness.

Hardness Test Results

Hardness is the resistance of a material to localized deformation. The term can apply to deformation from indentation, scratching, cutting or bending. In metals, ceramics and most polymers, the deformation considered is plastic deformation of the surface. For elastomers and some polymers, hardness is defined at the resistance to elastic deformation of the surface. The lack of a fundamental definition indicates that hardness is not be a basic property of a material, but rather a composite one with contributions from the yield strength.]

Table 04 Energy absorbed by all Samples

Sr. No	Sample	BHN
1	Np 0.0	4
2	Np 0.2	5
3	Np 0.5	7
4	Np 1.0	8
5	Np 3.0	6



Comparison of BHN

V. Conclusion

The conclusions drawn from the present investigation are as follows:

The results confirmed that stir die cast aluminium 6061 with Graphene-nano particle reinforced nano-composites is clearly superior to base aluminium 6061 in the comparison of tensile strength, Impact strength as well as compressive strength. Aluminium matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of Graphene-nano particles.

It appears from this study that UTS and Yield strength trend starts increases with increase in weight percentage of Graphene nano particle in the matrix. It has been observed that as percentage of Graphene nano particle increases compressive strength also increases. Impact strength is increase by adding Graphene nano particle.

References

[1]. Sunil Kumar "Graphene Engendered aluminium crystal growth and mechanical properties of its composite: An atomistic investigation" CSIR-National Metallurgical Laboratory, Jamshedpur, 831007, India.

[2]. Linghui Yang et.al. "Fabrication and corrosion resistance of a graphene-tin oxide composite film on aluminium alloy 6061" Shanghai Key Laboratory of Materials Protection and Advanced Materials in Electric Power, Shanghai Engineering Research Center of Energy-Saving in Heat Exchange Systems, Shanghai University of Electric Power, Shanghai 200090, China.

[3]. D.V.Lohar "Literature Review of Graphene Composites" International Journal of Innovative Research in Science, Engineering and Technology An ISO 3297: 2007 Certified Organization Volume 6, Special Issue 1, January 2017 International Conference on Recent Trends in Engineering and Science (ICRTES 2017)20th-21st January 2017 Organized by Research Development Cell, Government College of Engineering, Jalagon (M. S), India.

[4]. Prashantha Kumar "Processing and Characterization of Al 6061 – Graphene Nanocomposites" Juniour research fellow Professor School for Mechanical engineering, VIT University, Vellore-632014, India.

[5]. Deepak Kumar Gupta et.al. "Synthesis and Characterization of Graphene Oxide Nanoparticles and their Antibacterial Activity" Centre for Converging Technologies, University of Rajasthan, Jaipur School of Science, Suresh Gyan Vihar University, Jaipur-302017, Rajasthan, India Semiconductor and Polymer Science Lab, Department of Physics, University of Rajasthan..

[6]. Pulkit Garg et.al. "Structural and Mechanical Properties of Graphene reinforced Aluminum Matrix Composites" Department of Ceramic Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi-221005 (INDIA) 2Department of Mechanical and Automation Engineering, A.S.E.T., Amity University, Uttar Pradesh, Noida-201313 (INDIA).

[7]. Li-Wu Fan et.al. "Heat transfer during melting of graphene-based composite phase change materials heated from below" Institute of Thermal Science and Power Systems, Department of Energy Engineering, Zhejiang University, Hangzhou 310027, People's Republic of China.State Key Laboratory of Clean Energy Utilization, Zhejiang University, Hangzhou 310027, People's Republic of China Department of Mechanical Engineering, Auburn University, Auburn, AL 36849, United States Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, People's Republic of China

[8]. Kesong Hu et.al "Graphene–Polymer Nanocomposites for Structural and Functional Applications" appear in: Progress in Polymer Science.

[9]. Perry T.Yin et.al. "Design, Synthesis, and Characterization of Graphene−Nanoparticle Hybrid Materials for Bioapplications" Department of Biomedical Engineering, Department of Chemistry and Chemical Biology, Department of Materials Science and Engineering, Institute for Advanced Materials, Devices, and Nanotechnology (IAMDN), Rutgers, The State University of New Jersey, Piscataway, New Jersey 08854, United States.

[10]. Jingyue Wang et.al "Reinforcement with graphene nanosheets in aluminum matrix composites" State Key Laboratory of Metal Matrix Composites, Shanghai Jiao Tong University, Shanghai 200240, China.The Faculty of Engineering, University of Wollongong, Wollongong, NSW 2522, Australia. Received 12 November 2011 revised 3 January 2012 accepted 9 January 2012. Available online 16 January 2012.