Effect of Graphene Reinforcement on the Mechanical Properties of Aluminium 6061 Nanocomposite Prepared by Stir Casting Method

Devendra Kumar Suryawanshi[1] Abhishek Gupta[2]
[1]Student [2]Associate Professor
[1,2]Department of Mechanical Engineering
[1,2]Shri Shankaracharya Institute of Engineering & Technology, Durg, India

Abstract— Aluminium based nanocomposites are the new generation of composites due to their attractive properties like high ductility, high conductivity, light weight and high strength to weight ratio. Also the only recognized two dimensional material in the world, Graphene, has encouraged irresistible responses in the field of research due to its unexpected potential in the form of reinforced composites. Graphene having properties such as strength (tensile strength ≈ 130 GPa) and less density. But various problem occurred while it is used as a reinforcement like homogenous dispersion and clusters formation which causes decrease in mechanical strength. In the current research work, Effect of Graphene reinforcement compared to individual on mechanical properties of Aluminium 6061 nanocomposites have been planned to be evaluated. Micro hardness, tensile and microstructure analysis are to be analyzed for the developed nanocomposite. The reinforcement material is selected as Graphene. For the dispersion of the reinforcement into the aqueous solution containing ultrasonic liquid processor is employed. The first step involved the dispersion of a fixed weight % of Graphene (0.1 %, 0.3 %, & 0.6 %) in an acetone solvent. After sonication Stir casting method is employ to fabricate Aluminium metal matrix composites reinforced with graphene. Further tensile test, hardness test and SEM observation were conducted for characterization of the specimens.

Key words: Graphene; Nano-Composites; Aluminium 6061; Stir Casting; Hardness Test; SEM

I. INTRODUCTION

MMCs are a perfect example of new metals which were created to enhance properties of parent materials. They are metals or alloy reinforced with particles or fibers of some different metal or material. In recent years, one of the most dynamic areas of research in materials is Composites. Composite materials are suitable for various applications like in aerospace sector, defence and many industries. MMC's are specially gauged with Aluminium and its alloys as a matrix in the aspect of light high strength and weight. There is a great demand for traditional engineering materials with excellent strength, light weight, and increased resistance to wear in aerospace, civil and sliding components of automobile sectors. This leads to the development of aluminium matrix composites (AMCs)Aluminium is the most utilized metallic alloy as matrix material in the development of MMCs due to its high availability, low density, good corrosion resistance, high thermal and electrical properties and its high ductility and malleability makes it easy to machine.

Nanocomposites being the new age materials for todays advanced world and still a lot more potential to be discovered with analytical and experimentation techniques. Light weight metals with high strength being high on demand in automotive, aerospace and military industries, Aluminium based metal matrix reinforced with graphene makes it a very good material to meet such demands. Aluminium known for being a lightweight metal, graphene for its stiffness, toughness, low density, hardness and tensile strength makes these a perfect combination to create a light nanocomposites. Stir casting method is more economical to produce such kind of nanocomposites.

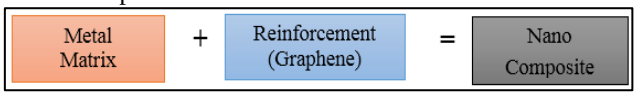

Fig. 1: Composition of Composites

II. LITERATURE REVIEW

- They fabricated titanium matrix composite in which graphene was reinforced by a powder metallurgy technique where graphene 0.5%wt. were mixed and was fabricated by wet method. Microstructure investigation shows homogeneous distribution of graphene powder in TiC and the sample with 0.5%wt. graphene shows better results on its strength and without ductility being lost (Zhang et.al (2017)).
- They made an attempt to create laminates of aluminium matrix reinforced with functionally graded CNT material by an extraordinary powder metallurgy route. The CNT content varied from 0.1 to 0.6%wt. in the composite matrix and detailed investigation was carried out for the mechanical properties of functionally graded composites. From one end of the sample to the other, there is a continuous variation in the material property and as a result there was an increase of 127% seen for 0.5%wt. of CNT in the laminates formed. (Udupa et.al (2015)).
- Ramesh et al fabricated reinforced Al 6061 alloy with TiO2 and got noteworthy improvement in wear resistance and hardness properties (Ramesh et al, (2005)).
- They observed that rutile owns greater physical and engineering characteristics. Comprehensive survey on various literatures revealed that no detailed findings are available for powder metallurgy processed Al−SiC−TiO2 (rutile) hybrid composites. P/M is widely adapted for achieving uniform distribution of reinforcing phase within the matrix and to produce near net shaped components (Tromans et al, (2002 – 2004)).
- With the numerous improved fabrication facility now a days MMCs has great characteristics as well strength, specific modulus of elasticity, damping properties and wear resistance as compared to the unreinforced alloys. Aluminium alloys are used in many engineering applications due to their light weight and high strength characteristics (Saheb et al, (2001)).

- Hansang Kwon et al discussed functionally graded carbon nanotubes (CNT) and nano Silicon carbide (nSiC) reinforced aluminium (Al) matrix composite materials were fully densified by a simple ball milling and hot-pressing processes. The nSiC was used as a physical mixing agent to increase dispersity of the CNT in the Al particles. It was observed that the CNT was better dispersed in the Al particles with an nSiC mixing agent compared to without it used (Kwon et al, (2009)).
- They found density of crack and wear characteristics of SiCp reinforced Al-MMC fabricated by DMLS process have been studied. Mainly, size and volume fraction of SiCp have been varied to analyse the crack and wear behavior of the composite. The study has suggested that crack density increases significantly after 15 volume percentage (vol. %) of SiCp (Ghosh et al, (2011)).
- Deuis R.L et al. explored that that the Al-Si alloys and AMMCs have found application in the fabrication of numerous automotive engine components where adhesive wear is a predominant process. For adhesive wear, the influence of applied load, sliding speed, wearing surface hardness, reinforcement fracture toughness and morphology are critical parameters in relation to the wear regime encountered by the material. In this review contemporary wear theories, issues related to counter face wear, and wear mechanisms are discussed (Deuis et al, (1997)).
- Hybrid composites are those composites which have a combination of two or more reinforcements. Performance of hybrid composites is a weighed sum of the individual components in which there is a more favourable balance between the inherent advantages and disadvantages (Qutub et al, (2013)).
- Out of many methods stir casting is known for its simplicity and cost effectiveness. Aluminium composite made by different powder metallurgy processes like HSBM, SSBM and LSBM gave the tensile strength of 408MPa, 376MPa and 367MPa respectively with 31%, 33% and 41% enhancement on aluminium (Xu et al, (2017)).
- It is also seen that the mechanical properties are affected by dispersion of reinforcement. Proper dispersion can be achieved by reducing the viscosity of molten metal matrix. For example, in this experiment Al has proper dispersion of SiC at 8000 C as compared to 7500 C (Liu et. al., (2012)).

III. Gaps in the Literature

Even though a lot of experimental observation has been done related to Aluminium 6061 and other additives and reinforcements, but the available literature shows very less attention has been focused on the application of Graphene in such alloys.

- Till now many research papers have been written on metal matrix composites focusing on their different properties. Very few research works have been done on aluminium metal matrix composites reinforced with graphene
- None of the researchers conducted on experiment by taking graphene (0.1 %, 0.3 %, and 0.6 %) as a reinforcement with the base material aluminium.

IV. Experiment Procedure & Testing

The overall objective of the work is to explore the properties of the advanced materials like graphene and its implementations as reinforcement for alloys. The main objectives are as follows

- Preparation of the aluminium 6061 metal matrix composites reinforced with graphene by employing stir casting approach.
- When the fabrications finish, prepare the specimens for mechanical characterization according to ASTM standards.
- Exploring mechanical properties of Aluminium 6061 reinforced with Graphene.
- Studying about the potential failures of such material systems.
- Microstructure analysis of the composites by using SEM imaging system.

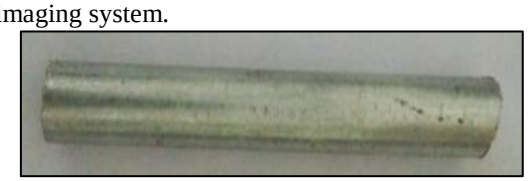

Fig. 2: Aluminium 6061 Billets used as a Base Material

Preparation of Aluminium 6061 reinforced with graphene based metal matrix samples for determination of their mechanical properties and microstructure analysis was successfully done using stir casting for -

- Al 6061
- Al 6061 + 0.1 wt. % Graphene.
- Al 6061 + 0.3 wt. % Graphene.
- Al 6061 + 0.6 wt. % Graphene.

After that for we prepared the specimen as per the ASTM standards by using EDM and milling operation. Then we performed tensile test, hardness test and SEM test for mechanical and microstructural characterization. The process of stir casting is employed as concluded from the literature along with Ultrasonic Liquid Processor methods for homogeneity of materials which help to remove formation of clusters.

V. Result

A. Tensile Test

Following are the results obtained from the tensile test for all the 4 samples which is digitally displayed on the screen.

Sample	Ultimate Tensile Strength (MPa)
Al 6061	68
Al 6061+0.1 wt.% Graphene	139
Al 6061+0.3 wt.% Graphene	54
Al 6061+0.6 wt.% Graphene	46

Table 1: Tensile Strength of The Nanocomposites.

Tensile test reveals that increasing of graphene wt. % decreasing tensile strength except 0.3 wt. % of graphene. The results of tensile test on the samples revealed that addition of 0.3 wt. % graphene leads to increase the tensile strength by 50 wt. % which is illustrated in table 5.1.

The maximum tensile strength obtained for the pure Aluminium 6061 specimens was 68 MPa. The maximum tensile stress obtained for the sample with the composition Aluminium 6061 reinforced with 0.1 wt. % graphene in was observed to be 139 MPa which shows significant growth in the tensile strength upon comparing to the first specimen which is pure aluminium. The maximum tensile strength for third specimen which contains 0.3 wt. % of graphene as reinforcement in Aluminium 6061 is 54 MPa. The maximum tensile strength for the sample containing 0.6 wt. % of graphene as reinforcement in Aluminium 6061 was 46 MPa. So, according to the data we can conclude that the maximum tensile strength of the sample increase by increasing the graphene up to certain percentage in it after that the values of tensile strength is decreases.

B. Rockwell Hardness Test

Sample	Reading 1 (HRB)	Reading 2 (HRB)	Reading 3 (HRB)	Average Hardness (HRB)
Al 6061	58.3	62.5	59.2	60
Al 6061+0.1 wt.% Graphene	99.8	101.6	104.8	102
Al 6061+0.3 wt.% Graphene	91.5	93.7	95	93
Al 6061+0.6 wt.% Graphene	89.8	86.8	87.7	88

Table 2: Rockwell Hardness of Various Al 6061 Nano Composites

Above results show that by using graphene as reinforcement in Aluminium 6061 increases the hardness. It is also observed that when Aluminium 6061 is reinforced with 0.1% of graphene, the hardness value increases and further by increasing the composition of graphene in the samples the value of hardness decreases. Than it shows the value of hardness depends upon the reinforcement and also on their weight percentages as it can be seen that the hardness of the samples increased as compared to parent aluminium and then decreases after 0.1 wt. % graphene that means more quantity of reinforcement causes decrement in the hardness of the composites.

C. SEM Test

Following are the images produced for all the 4 samples using SEM test-

1) *Sample 1 – Aluminium 6061*

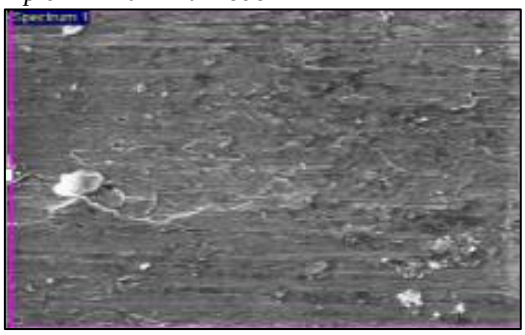

Fig. 3: Microstructures of Sample 1

2) *Sample 2 – Aluminium + 0.1 wt. % Graphene*

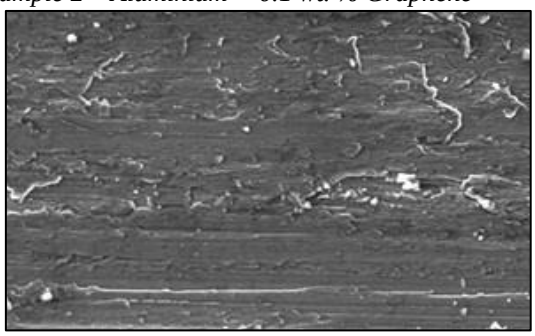

Fig. 4: Microstructures of Sample 2

3) *Sample 3 – Aluminium + 0.3 % Graphene*

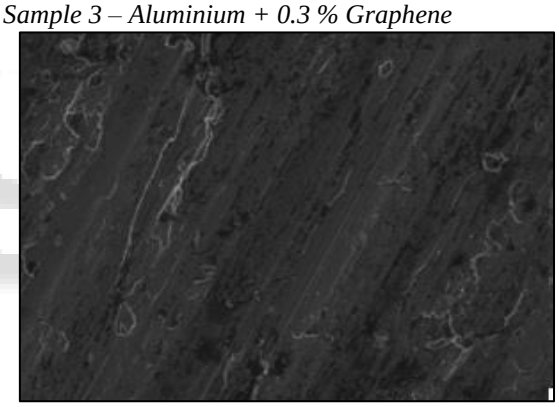

Fig. 5: Microstructures of Sample 1

4) *Sample - 4 Aluminium + 0.6 wt. % graphene*

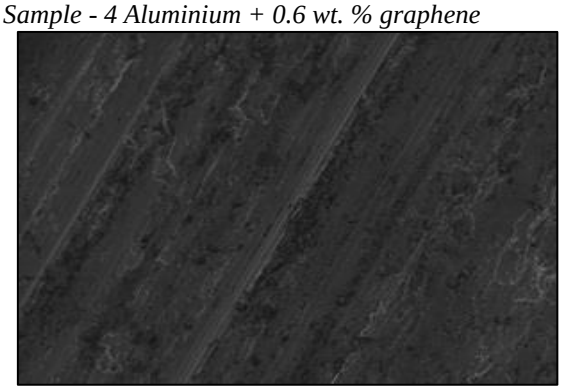

Fig. 6: Microstructures of Sample 1

VI. CONCLUSION

– In the present work, Aluminium 6061 metal matrix composites reinforced with 0.1 %, 0.3 %, and 0.6 % were fabricated by using stir casting method followed by ultrasonic liquid processor for determination of their mechanical properties and microstructure analysis.

Without porosity and defect free nanocomposites were reported from the SEM images.

- Preheat of reinforcement before adding it to the molten aluminium in stir casting process assures good particle distribution in the fabricated samples which can be observed in the SEM images.
- Uniform distribution and homogenous dispersion of reinforcement in the prepared samples were increased knowingly through ultrasonic liquid processor as observe in the SEM images.
- Mechanical properties such as tensile strength, hardness test and scanning electron microscope test were obtained and analysed.
- Results obtained from the tensile test shows that the addition of graphene as reinforcement improves the tensile strength of the Aluminium 6061 nanocomposites.
- Rockwell hardness test explored that the hardness of the sample improved with increase in the graphene content as a reinforcement in the sample up to 0.1 wt. % and then upon increasing the reinforcement content hardness values decreases.
- An increase in the Graphene content causes an increase in the tendency of initiation of crack and propagation at the interface between Graphene and matrix.

REFERENCES

[1] Zhang Cao, Xudong Wang, Jiongli Li, Yue Wu, Haiping Zhang, Jianqiang Guo, Shengqiang Wang, Reinforcement with graphene nanoflakes in titanium matrix composites, Journal of Alloys and Compounds, Volume 696, 2017, Pages 498-502, ISSN 0925-8388.
[2] Udupa G, Rao SS, Gangadharan KV (2015) Fabrication of Functionally Graded Carbon Nanotube-Reinforced Aluminium Matrix Laminate by Mechanical Powder Metallurgy Technique - Part I. J Material Sci Eng 4:169.
[3] Ramesh, C. S., Khan, A. A., Ravikumar, N., & Savanprabhu, P. (2005). Prediction of wear coefficient of Al6061– TiO2 composites. Wear, 259(1-6), 602-608.
[4] Tromans, D., & Meech, J. A. (2002). Fracture toughness and surface energies of minerals: theoretical estimates for oxides, sulphides, silicates and halides. Minerals Engineering, 15(12), 1027-1041.
[5] Tromans, D., & Meech, J. A. (2004). Fracture toughness and surface energies of covalent minerals: theoretical estimates. Minerals engineering, 17(1), 1-15.
[6] Saheb, N., Laoui, T., Daud, A. R., Harun, M., Radiman, S., & Yahaya, R. (2001). Influence of Ti addition on wear properties of Al–Si eutectic alloys. Wear, 249(8), 656-662.
[7] Kwon, H., Estili, M., Takagi, K., Miyazaki, T., & Kawasaki, A. (2009). Combination of hot extrusion and spark plasma sintering for producing carbon nanotube reinforced aluminium matrix composites. Carbon, 47(3), 570-577.
[8] Ghosh, S. K., & Saha, P. (2011). Crack and wear behavior of SiC particulate reinforced aluminium based metal matrix composite fabricated by direct metal laser sintering process. Materials & Design, 32(1), 139-145.
[9] Deuis, R. L., Subramanian, C., & Yellup, J. M. (1997). Dry sliding wear of aluminium composites—a review. Composites Science and Technology, 57(4), 415-435.
[10] Al-Qutub, A. M., Khalil, A., Saheb, N., & Hakeem, A. S. (2013). Wear and friction behavior of Al6061 alloy reinforced with carbon nanotubes. Wear, 297(1-2), 752-761.

