MECHANICAL AND TRIBOLOGICAL PROPERTIES OF AA-7075 AND GRAPHENE REINFORCED METAL MATRIX COMPOSITES

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***Abstract*: In this paper, the work report deals with the Investigations made on microstructure and Mechanical behaviour and Tribological properties of 4 different weight percentage of Aluminium alloy (7000 series) with Graphene nano powder composites. Aluminium matrix composite having Nano graphene is fabricated by liquid stir casting method. The microstructure of the composites was examined by Scanning Electron Microscopy and EDS. Further, mechanical behaviour of composites was studied. Tensile properties like hardness, ultimate tensile strength; yield strength and wear were evaluated as per ASTM standards. Microstructure observation revealed uniform distribution of reinforcement particles in the matrix and particulates were confirmed by EDS and SEM. The analysis gives the result that the ultimate tensile strength, yield strength and the hardness of composites increases with increases the percentage of graphene and the wear test results reveals that as the percentage of graphene increases wear rate decreases**

***Keywords*: Aluminium alloy, Nano Graphene, Ultimate Tensile Strength, Yield Strength, Hardness, Stir casting, wear rate.**

Introduction

Metal Matrix Composites MMC's give numerous additional advantages to the designers, because of their structural rigidity, strength and dimensional strength. They are outstanding at mechanical properties and tribological characteristics. MMC's are made of a metallic matrix, ceramic matrix or metallic phase .Ceramic reinforced might be Al2o3, Sic and boron carbide. Though Metallic Reinforcements are tungsten, beryllium etc... MMC's are utilized for Space Shuttle, Airlines, Bikes, and Vehicles etc... MMC's are suitable and reasonable for cutting edge basic, and wear applications. Comparing with unreinforced aluminum composites MMCs show huge change in Physical properties & Mechanical properties the metal matrix development is robust and tough. The initial MMC's are light metal matrix composites and the common materials used are the Aluminum, Magnesium, Titanium and their alloys. Aluminum oxide, boron carbide and commonly used fibers and reinforcement. At the point when the metals are strengthened with reinforcement the Physical and Mechanical properties will enhance for example, strength, thickness, solidness, wear and hardness, and electrical properties.

Literature Reviews

B.Saijagadesh [1] This work reveals the synthesis of Al-graphene MMC's and here 0.25%,0.5%,0.75%,1% of graphene are added to the Aluminum 2024 to form the matrix. The matrix has high quality compared to other matrix. In this the author preferred to study tensile, impact flexural and hardness test so that he concluded that the hardness is shown maximum by pure aluminium and the minimum hardness is by 0.5% graphene sample. The pure Al-2024 shows the maximum flexural stress of 52.9847mpa and also high tensile strength is shown by 0.75%.

Pulkit Garg, Pallav Gupta [2], this work reveals, effect of sintering temperature and mechanical characteristics of Al-graphene MMC's has investigated. Adding graphene as reinforcement in aluminum increases the strength of Al-matrix. Strength of composite increases with increase the wt% of graphene. This paper shows the effect of sintering temperature on density, phase, microstructure, hardness and compressive strength of graphene reinforced aluminum matrix composites containing 0.1%, 0.3% and 0.5% of graphene respectively. This is used to find XRD, SEM and Compression strength.

Muhammad Rashed, Aitao Tanga, [3]. They study the microstructure and mechanical properties before and after extrusion. The experiment reveals that Al-0.25% graphene composites shows the excellent mechanical properties compare to pure Al, 0.5% and 0.1% before extrusion the 0.25%composite shows 14% improvement in ultimate strength. The extruded matrixes showed different trends. The ultimate strength of composites of 0.25%, 0.5% graphene has lower than the monolithic matrix. So that the superior mechanical properties (failure strain) of Al-0.25% graphene attributed to 2-D type and also the corrosion rate increase as graphene % increases

Jinghang Liu, Umar Khaan, Jonatan Colman, [4]. The work deals with the study of preparation of reduced graphene oxide and graphene nano sheets reinforcement with Al-metal matrix. Here the powder synthesis are made to prepare the sample by 1 hour stirring time to get sufficient for completely clearly dispersion for 0.7%,0.15%, 0.3% Gr-Al dispersion in acetone. Here the microstructure and mechanical properties were studied.

S. Ventatesan and M. Antony Xavier [5]. This work involves the preparation of aluminium –graphene MMC's by deals with the mechanical behavior of AMMC with different wt% of 0.33%, 0.55%, and 0.77% by stir casting method. They concluded that as graphene percentage increases, tensile strength decreases except 0.33% and also the hardness of 0.77% leads to decreases compare to base metal. The SEM analysis reveals the 0.33% of graphene shows homogeneous dispersion.

D.Hari Madhava Swamy, Manjunatha L.H [6]. "Fabrication and analysis of aluminium –Graphene MMC's using powder metallurgical technique". The work deals the Al-Gr MMC's are synthesis by varying percentage of 0.1%, 3.8%. The experimental result gives that the wear of aluminium is strongly depends on the graphene composites and decreases with increases graphene percentage. The SEM analysis shows the good distribution of both Al-graphene components.

Experimental Work

Materials:-

Aluminium 7075

Aluminium 7075 is an aluminium alloy, with zinc as the primary alloying element. It is a strong material by strength comparable to many steels, and has good fatigue strength and average machinability. It has lower resistance to corrosion than other aluminium alloys, but has significantly better corrosion resistance than the 2000 alloys. It is relatively high cost material.

Element	Aluminium	Silicon	Iron	Zinc	Copper	Manganese	Magnesium	Titanium	Others
%by wt	87.1-91.4	Max 0.40	Max 0.50	5.1-6.1	0.18-0.28	Max 0.30	2.1-2.9	Max0.20	Max 0.15

Table 1:-Composition of Al-7075 Alloy

Graphene

Graphene is an allotrope of carbon that exists as a two-dimensional planar sheet.
One way to think of graphene is as a single atomic graphite layer.
Graphene is technically a non-metal but is often referred to as a quasi-metal due to its properties being like that of a semi-conducting metal.

Preparation of Composites

The process of stir casting starts with placing empty crucible in the furnace. The heater temperature is then gradually increased up to 800°C. Aluminium alloy is cleaned to remove dust particles, weighed and charged in the crucible for melting. Required quantities of reinforcement powder are weighed on the weighing machine. Reinforcements are heated for 4 minutes at a temperature of 500°C. After five minutes the scum powder is added which forms a scum layer of impurity on liquid surface which to be removed. Heater temperature is then gradually increased to 800°C. At this heater temperature stirring is started and continued for five minutes. Stirring rpm is 300 RPM with the help of speed controller. Preheated reinforcements are added during five minutes of stirring. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured is 0.5 gram per second. Stirrer rpm is then gradually lowered to the zero. Then molten composite slurry is poured in the metallic mould without giving time for reinforcement to settle down at crucible bottom. Mould is preheated at 500°C temperature for ten minutes before pouring the molten slurry in the mould. This is necessary to maintain slurry in molten condition throughout the pouring. While pouring the slurry in mould the flow of the slurry is kept uniform to avoid trapping of gas, also distance between crucible and mould plays a vital role in quality of casting.

Testing of Composites

The microstructure study was carried out on the prepared composites using Vegas Tescan made scanning electron microscope. The test sample is 10 -12 mm in diameter cut from the castings and polished thoroughly, for etching the sample Keller's reagent was used.

The brinell test is the method to measure the specimen on a microscopic scale. The test is conducted by differencing the test force and ball size we can test the different metals. By applying a load of 250 kg and dwell time of 30 seconds the experiment is made. The indentation depth values recorded and experimental hardness was determined. The indentation test was repeated for 3 times for each composite and the average value is considered.

Tensile and Compressive specimens were machined. The tensile specimens of circular cross section with a diameter of 9 mm and gauge length of 45mm were prepared according to the ASTM E8 standard testing procedure by Universal Testing Machine

Figure 1:- Hardness Test Specimen

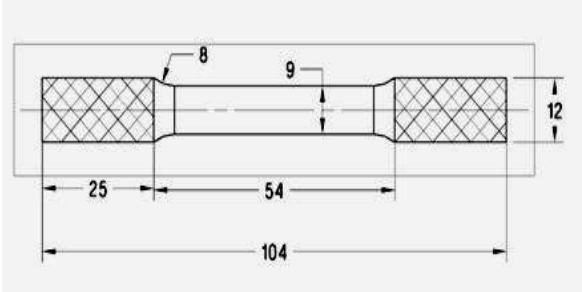

Figure 2:- Tensile Test Specimen

Results and Discussion

Microstructure Study

Microstructure study is analysed on prepared composite with SEM. The test specimens of 8mm in diameter are cut from the prepared castings and it is polished and then finally it is etched with Keller's reagent in order to get good results. The specimens were visualized at different magnifications to show the presence of reinforcement. The microstructures of all the samples of 0.25%, 0.5%, 0.75% and 1%graphene are made.

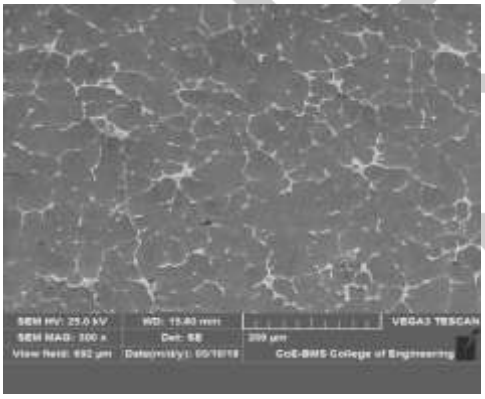

Figure 3a:- Al+0.25% graphene

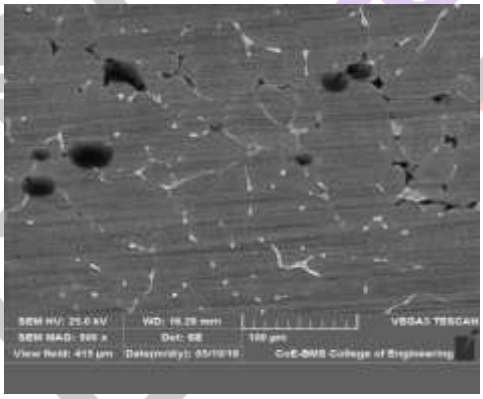

Figure 3b:- Al+0.5% graphene

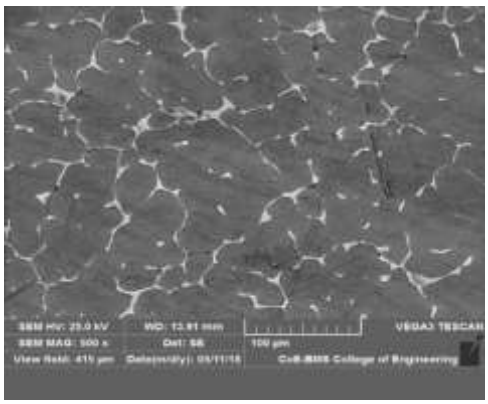

Figure 3c:- Al+0.75% graphene

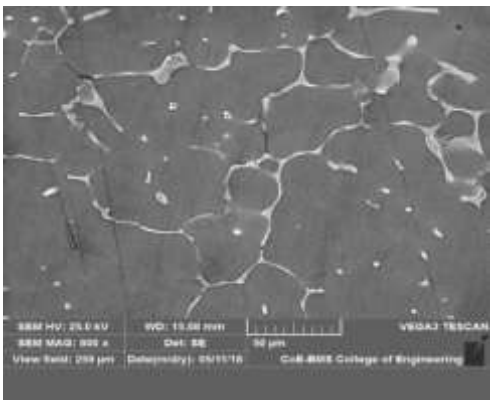

Figure 3d:- Al+1% graphene

Figure3.a) shows the clear picture of aluminium 7075 reinforced with 0.25% of graphene using stir casting process. The typical microstructure of aluminium 7075 shows the primary aluminium matrix in white phase and the graphene distribution in the dark gray colour and there is no voids or dislocation and porosity found from the specimen. The image reveals there is a uniform distribution of graphene in aluminium alloy.

Figure3.b) This SEM study reveals that the improper distribution of aluminium 7075 and graphene MMC's. The common casting defect like blowholes, porosity, voids are present in the composites so it will affect the mechanical properties of the composites.

Figure3.c) This picture shows that there is an excellent bonding and the good interfacial bonding between the aluminium 7075 and graphene MMC's so that it improves the tensile strength and hardness of the materials. Here the aluminium matrix is in white phase and there is no porosity or voids.

Figure3.d) the microstructure analysis shows a uniformly distribution of aluminium – graphene composites. The common defects like porosity, voids are not seen here and the graphene are in small grain size so that properties of graphene increases

EDS EVALUATION

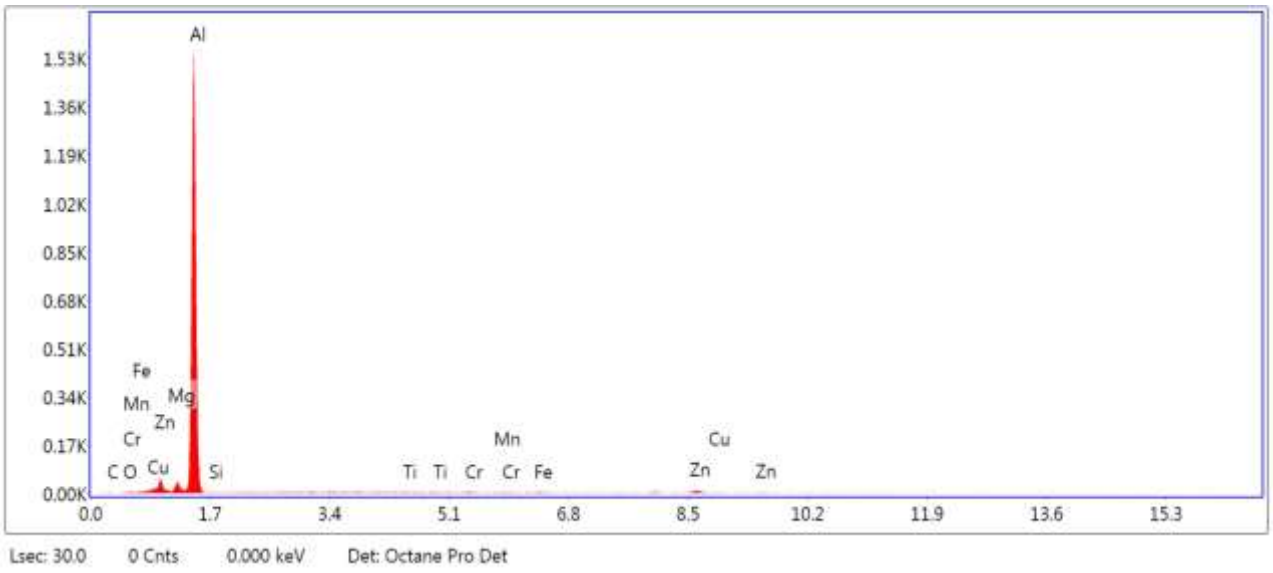

Fig 4a:-EDS of Aluminium Alloy

The above graph represents the aluminium alloy composites. In the figure we are able to see the maximum percentage of aluminium along with some percentage of zinc so that it confirms that the material taken for this present work is aluminium alloy 7000 series

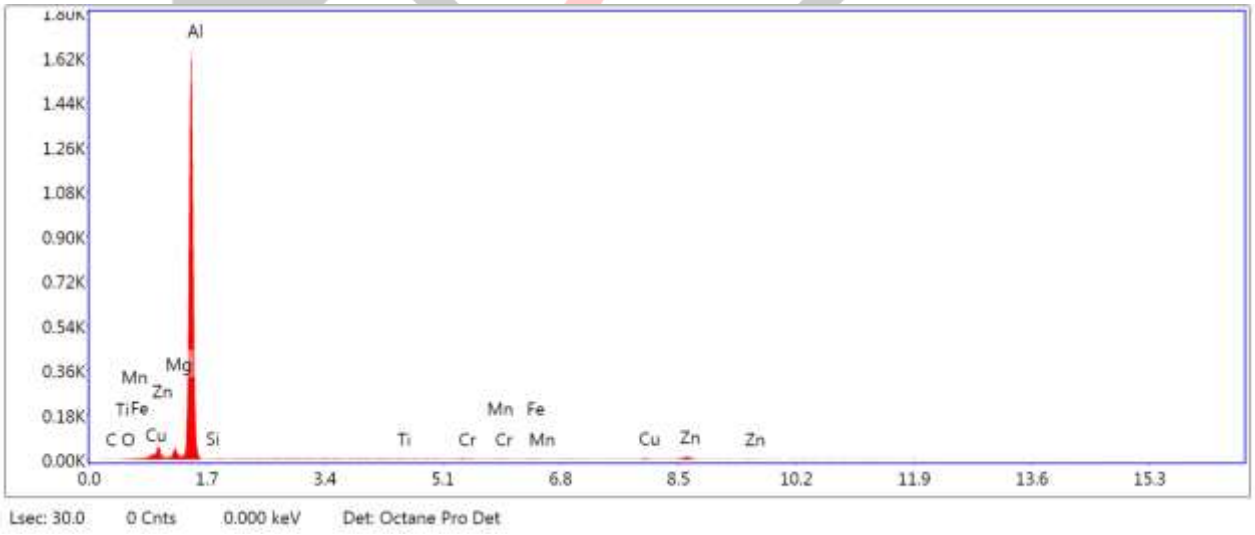

Fig 4b:- EDS of Al-Graphene

In the above graph, the figure there is a presence of carbon and zinc with minute percentage of mn, mg and cr which indicates that graphene is present in the form of carbon and it confirms that the reinforcement added is present in the aluminium alloy

Ultimate Tensile Test

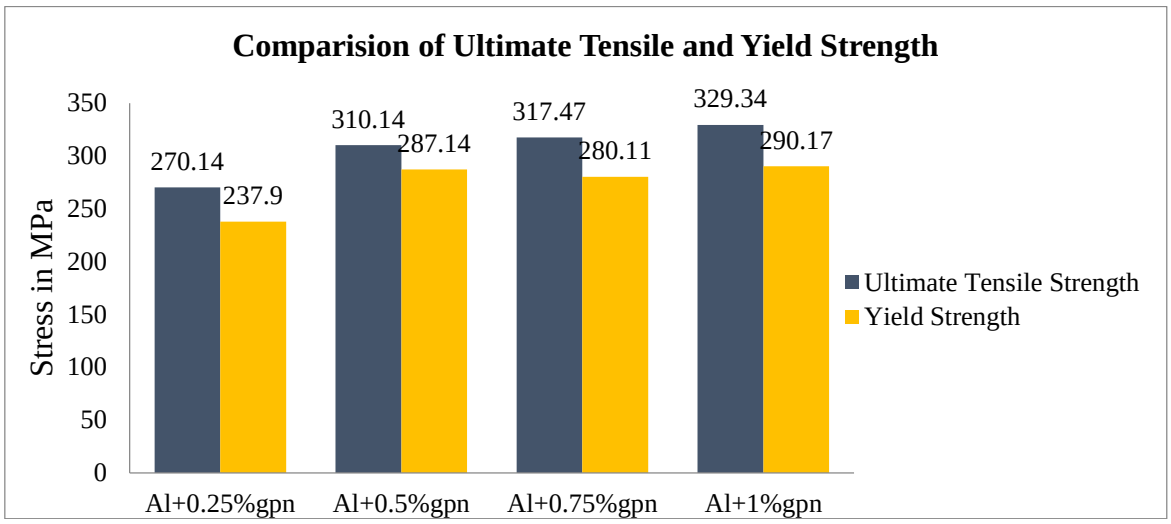

Figure 5:- Tensile Test Result

The variation of ultimate tensile strength with varying wt.% of graphene is shown in chart . The ultimate tensile strength and yield strength were increased with increasing graphene content. The graphene particles in the matrix alloy provide protection to the softer matrix this interaction between the dislocations and graphene results in an improved strength

Hardness test

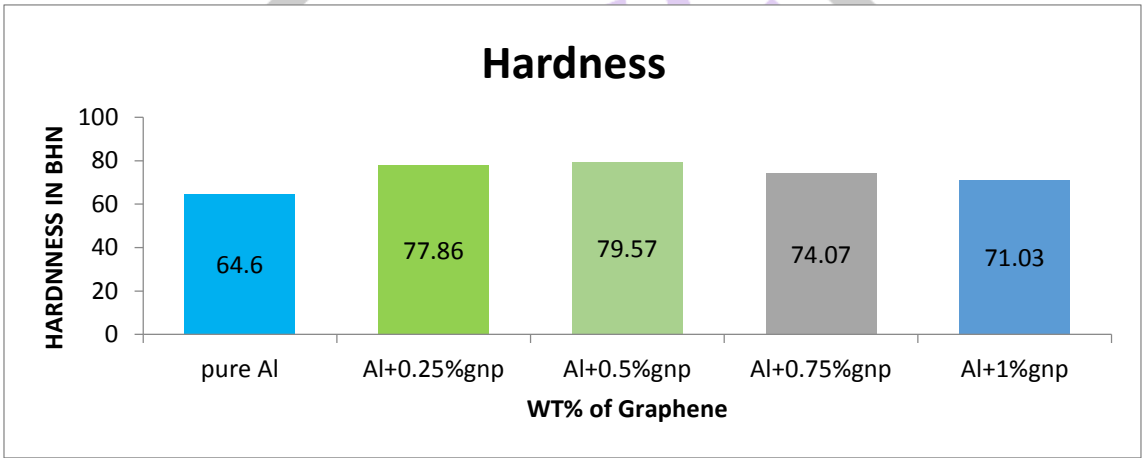

Figure 6:- Hardness Test Result

From the results as the graphene percentage increases the hardness is increases up to 0.5% and then hardness is decreases for 0.75% and 1% this shows the ductility property I.e., as the graphene percentage increases the material become more ductile, hence hardness decreases.

Wear Test:-

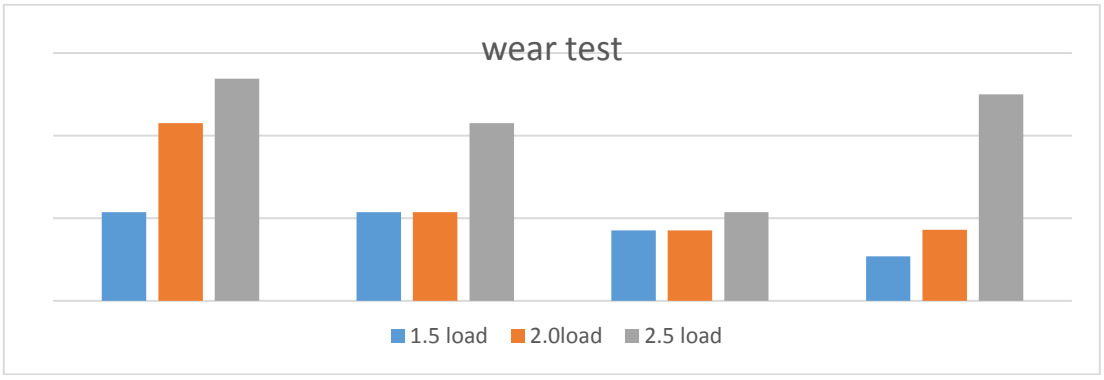

Figure 7:- Wear Test Result

The wear test result shows that as the percentage of graphene increases the wear resistance also increases. But in 1% of graphene the wear rate is change

Conclusions

The mechanical properties and tribological characteristics investigations of the aluminium alloy with graphene reinforcement materials produced by stir casting are remarked as below:

- The liquid metallurgy technique was successfully adopted in the preparation of aluminium alloy reinforced with graphene.
- The microstructure studies revealed that the uniform distribution of reinforcement (graphene) is observed and in some specimen voids and porosity is present because of improper casting
- The ultimate tensile strength and yield strength and wear resistance of the composites is increases as the wt.% of graphene increases.
- Improvement in the hardness of the aluminium metal matrix composites due to increases in graphene percentage in the composites.

References

[1] S Venkatesan and M. Anthony Xaviour *" mechanical behaviour of aluminium metal matrix composites reinforced with graphene particulates by stir casting method"* journal of chemical and pharmaceutical science

[2] Lee C, Wei X.D, Kysar, *"measurements of elastic properties and intrinsic properties of monolayer graphene",* science.321, 2008,385-388

[3] Pai B C, Rohatgi P K. *"production of cast aluminium graphite composites using pellet method"*, journal of material science, 13, 1979, 329-335

[4] Istif, M T Tuncel, A.S Dalkili*c "pin on disk test for aluminium graphene metal matrix composites"*

[5] Xin Gao, Hongyan Yue, Erjun Guo, Hong Zhang, Xuan Yulin, " preparation and tensile properties of homogeneous dispersed graphene reinforced aluminium matrix composites "Elsevier journal paper.

[6] D.Hari Mahadev Swamy, Dr. Manjunath L H, *"Development and characterization of aluminium graphene metal matrix composites using powder metallurgy route"* IISN.

[7] Yang-Ha-Jeong, Huynh Ngoc Tien *"Material properties of graphene/ aluminium metal matrix composites fabricated by friction stir processing"* www. Researchgate.net/ article in international journal of precision engineering and manufacturing

[8] Muhammad rashad , Fusheng Pan,Zhengwen Yu, Muhammad Asif, Han Lin , Rongjian Pan. *"Investigation on microstructure, mechanical and electrochemical properties of aluminium composites reinforced with graphene nanoplates"* www.sciencedirect.com.

[9] Morrish Kumar, Manjunatha L.H. *"Fabrication and analysis of aluminium –graphene metal matrix composites using powder metallurgy technique"*.

[10] Meysam Tabandeh Khorshid, Emad Omrani,Pradeep L,Menezes,Pradeep K.Rohat. *"Tribological performance of self-lubricating aluminium matrix nanocomposites: role of graphene nanoplates".* Elesvier journal paper.

[11] B Sai Jagadish *"Synthesis and charecterization of aluminium 2024 and graphene metal matrix composites by powder metallurgy".*SSRG international journal of mechanical engineering.

[12] Victor Volkov, Svetlana Eliseeva, Alexxander Pimenov, Alex *Shvarev "Electrochemical properties of aluminium – graphene composites anodes*". International journal of electrochemical science, www.electrochemsci.org

[13] X M Du, R Q Chen, F G *Liu "Investigation of graphene nanosheets reinforced aluminium matrix composites".*

[14]Lin C B, Chang RJ, Weng WP, A study on process and tribological behaviour of Al-Graphene composites,wear.217,1998,167-74