Analysis of Aluminium Graphene Composite Material

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Abstract- *Composite materials are combination of different constituent materials which can lead to the desired combination of low weight, stiffness and strength. The composite material thus obtained has superior properties, than their parental ones. Thus these materials become very attractive search for better reinforcement material among the scientific and engineering community. The project mainly focuses on recognising reinforcement materials with improved mechanical properties to satisfy various engineering applications. Graphene are found to be one such excellent reinforcing material which can improve properties of Aluminum Metal Matrix Composites significantly. Graphene have outstanding mechanical and physical properties, which make ideal reinforcement materials for light weight and high strength metal matrix composites (MMC). Processing is a critical step because it controls the microstructure, which turn will determine the properties. Major challenge is to disperse Graphene uniformly in the metal and alloy matrix. Processing method involves different forms of starting materials such as powders. Powder metallurgy is most popular and feasible route to prepare bulk composites. To achieve high densities sintering is used. To obtain uniform Graphene dispersion in metal matrix is main steps for successful processing. Also this study includes composite characterization and microstructures, scanning electron microscope.*

Keywords: Powder Metallurgy, Aluminum, Graphene.

I. INTRODUCTION

A composite material is a system composed of a mixture or combination of two or more macro constituents differing in form and/or material composition and that are essentially insoluble in each other. Composite materials contain a matrix with one or more physically distinct, distributed phase known as reinforcement or fillers, to get required properties. The reinforcement is added to the matrix in order to obtain the desired properties like strength, stiffness, toughness. Metal matrix composites (MMCs) these days are used in many applications and are preferred over monolithic materials, since the general monolithic materials have disadvantage in achieving good combination of strength, stiffness and toughness etc. Now a days the reinforced aluminium matrix composite are gaining publicity because of their low cost with advantages like isotropic properties and the possibility of secondary process aiding fabrication of secondary components.

II. LITERATURE SURVEY:

[1]The approach involves solution-treatment to partially dissolve T-phase particles, cryo- rolling to produce a fine-structure containing high density of dislocations and submicrometer subgrains and aging to generate highly dispersed nano- precipitates.

[2]Variations in friction coefficient, Wear rate, wear debris and electrical contact resistance were studied related to variations in graphite particulate content under different normal loading and sliding speeds. Composites containing the 4wt. % or 6 wt.% graphite particulate exhibited the lowest wear rate and friction coefficient, and these properties were insensitive to the variation in sliding speed and normal loading.

[3] Variations in seizure resistance, friction behavior, wear mechanism, wear particle size, and wear loss were studied related to variations in graphite content of the Aluminum composite material.

[4] The graphitic composites include A356 Al–10% SiC–4% Gr and A356 Al–5% Al_2O_3–3% Gr that are being developed for cylinder liner applications in cast aluminum engine blocks.Main wear regimes, ultra-mild, mild and severe wear were obtained. Nearly at all sliding speeds and loads in the mild wear regime a protective tribo-layer was formed. By increasing the speed and load the tribo-layer covered a larger proportion of the contact surface and became more compact and smoother.

[5] Powder Metallurgy is a term covering a wide range of methods in which materials or powders are made from metal powders. It is a highly developed and reliable method of manufacturing ferrous and non ferrous parts.This work involves the development of metal matrix composite materials by combining the desirable attributes of metals and reinforcements. . Here aluminum Of 2024 issued as metal matrix composite with graphene as reinforced material. 0.25%,0.5%,0.75%,1% of graphene are added to the metal to form composite. This matrix composite has superior qualities

compared too ther matrixes. They have applications in several demanding fields like automobile, superior mechanical as well as tribological characteristics.

[6] Studied the drastic growth as well as progress of metal matrix composites are playing vibrant role in various sectors. Aluminum matrix composites have the impending of less density engineering materials through superior mechanical as well as tribological characteristics . This review article emphasis on the compilation of the work accomplished by various researchers on the aluminum metal matrix composite reinforced with grapheme.

[7] Studied the 1.0 wt.% graphene reinforced aluminum 6061(Al6061) composite was synthesized to investigate the effects of graphene. Dispersion by ball milling technique. The Al6061 powder and graphene were ball Milled at different milling times. The composites were then synthesized by hot Compaction in the semi-solid regime of the Al6061.The Ball milled powder and the fracture surfaces of the composites were analyzed Using the scanning electron microscopy. A maximum enhancement of 47% in Flexural strength was observed when compared with the reference Al6061.[8] Reported the Ni-graphene composite coating on mild steel plates. The electro deposition technique was employed to prepare it. The surface Morphology of Ni and Ni grapheme coatings. The Vickers micro hardness of the Ni–grapheme composite was measured. It showed higher hardness than that of the electro deposited Ni. Tafel curves were also measured; the corrosion Resistance of the Ni–grapheme composite coating was better than that of the Ni coating. It was explained by the author that in the coating material graphene increases the nucleation rate and retards the crystal growth.

III. METHODOLOGY

Graphene reinforced MMC is prepared by using dry compaction powder Metallurgy technique quantity of pure Al taken is 20grams in each sample and Graphene particles required to fabricate the end composite are 0.1%,0.2% and 0.3% by weight. The process for fabrication of the MMC is same for all the Different composition of Graphene. First, pure Al and the Graphene powders are Weighed and then both the powders were mixed using sieve mesh of 70 and100 grade. The ball milling method for mixing the powders was not adopted since it increases the brittle nature of the Graphene in the composite. Then the powder mixture is filled in the die, made according to ASTM standard, with the help of a funnel. The compaction process is done in the Universal Testing Machine at a pressure of 140MPa. Post compaction, the specimen is kept in a nairoviral 100°C for degreasing and moisture removal. Sintering is carried out by keeping the composite at 500°C in a furnace for one hour which induces strength and hardness in the specimen and then slowly cooled in air at room temperature. Since the density of the Al-Gr composite was around 83.6% to the theoretical density, closed die forging was performed on all compositions of Gr to increase the density of the specimens. In closed die forging the specimen is kept in the furnace at 400°C for 30 minutes and then gently hammered because of the brittle nature of the composite. The methodology is described in the form of the table which shows the process flow control to reach the final stage in our project .

STAGE 1: POWDER METALLURGY

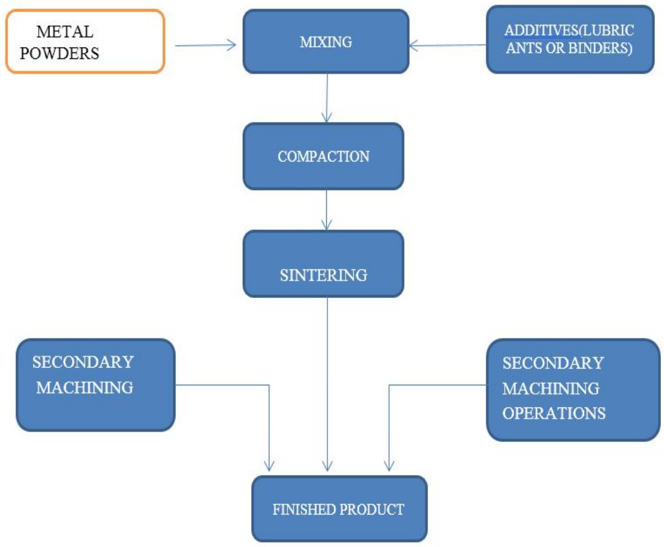

Figure 1.

STAGE 2: TESTING

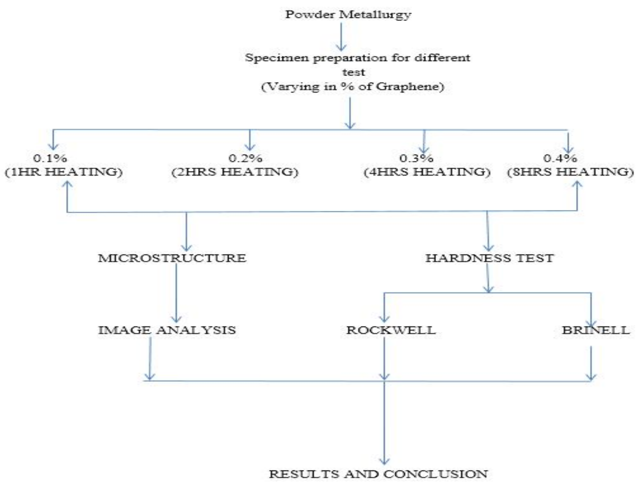

Figure 2.

CALCULATION OF AL-GR COMPOSITES:

The sample of Gr-Al composite was prepared by taking 20gm of Al powder(99.9% pure) and 0.06gm of Graphene powder. The powder was then mixed using sieves of 70 grade and100 grade present in NMIT foundry workshop. The powder mixing was repeated more than 50 times for proper mixing. The powder was compacted using Universal Testing Machine in the Material testing lab of NMIT at different pressures as tabulated below and the corresponding length of the compacted material is given in the table 5.2 as follows:

Volume of Al powder=mass of Al powder/density of Al =20/2.7=7.407cm

Volume of Graphene=mass of Gr powder/density of Graphene =0.06/0.3=0.2cm3

Density of the compacted material=total mass of compact material/volume =20.06/7.607=2.637gm/cm3

Relative density= exp/theoretical=2.17/2.637=82.35%

This signifies that the compacted composite powder contains pores and to Increase density close die forging needs to be done to reach near 100%r elative density.

IV. TEST RESULTS

1. ROCKWELL HARDNESS TEST:

The surface hardness of the specimens was tested using Rockwell hardness testing machine. Two trials for each specimen were taken to get a better view of the surface hardness trend .It was observed that the specimen gave a RHN no in the range of 42 taken from them each of two trials. The RHN no of 44 is obtained for forged specimen .It shows that the surface of specimen is harder than specimen and they both had a harder surface than pure Aluminium specimen .The indentation in the forged specimen is least and is least and specimen.

Scale: L
Indentor : 1/4”ball
Load: 60kgs
Dial: red
Application: Plastic materials: Bakelite, Vulcanised fibre.
Result of Rockwell Hardness Test:

Table 1.

% Graphene	Type of specimen	1st test	2nd test	Mean	RHN
0.1	1 HOUR	41	42	41.5	42
0.2	2 HOUR	42	44	43	44

2. BRINELL HARDNESS TEST:

The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell microscope or optical system across at least two diameters – usually at right angles to each other and these results are averaged (d). Although the calculation below can be used to generate the Brinell number, most often a chart is then used to convert the averaged diameter measurement. Common test forces range from 500kgf often used for non-ferrous materials to 3000kgf usually used for steels and cast iron. There are other Brinell scales with load as low as 1kgf and 1mm diameter indenters but these are infrequently used.
Result of Brienell Hardness Test:

Table 2.

% of graphene	Type of specimen	Diameter of indentor	Diameter of indentation	BHN
0.3	4 hour	10mm	5.8mm	739
0.4	8 hour	10mm	6.2mm	858

BHN CALCULATION:

Load: 250gms
Indentor diameter:10mm
Formulae: BHN=2F/∏D(D-√D2-d2)

1. BHN for 0.3 % Gr-Al composites:

=2*250/3.142*10*(10-√(10)2-(5.8)2)
= 739

2. BHN for 0.4% Gr-Al composites:
=2*250/3.142*10*(10-√(10)2-(6.2)2)
= 858

3. MICROSTRUCTURE:

The distribution of Graphene particles was checked before checking the Microstructure of the specimen .All the specimens with different % of graphene were taken on the testing slide and were observed under the microscope .The particle size was checked and it was found that the grain alignment of the Aluminium-Graphene Composite was similar to that of the Pure Aluminium and the particles were in a stable condition.

The microstructure of Al-Gr Composite shows the distribution of graphene powder throughout the specimen indicated by dark black spots and Al particles which can be seen as bright surface in the grain structure of the specimen being tested. The specimen were prepared using various % of graphene ,i.e. 0.1%Gr, 0.2%Gr ,0.3% Gr by weight of the specimen. The specimen which wastested after the sintering processs how a large fraction of pores on the surface of the specimen. This shows the improper compaction of the powders in the specimen. where as the distribution of graphene is smaller in the specimen which was tested after sintering.This also denotes that the intermolecular gap between the atoms is more which is resulting in the lesser density which further implies the trend of surface hardness and tensile characters of the specimen.

The grain size of the tested specimen is also measured and found out to be a expected. The grain size of test specimen was found to be least and that of die forged test specimen was largest among the specimens.

The image of all four specimens with their grain sizes are shown below.

Specimen 1:

0.1% graphene reinforced in aluminium sintered at 400 C for 1 hour in the furnace. It is cooled at room temperature.

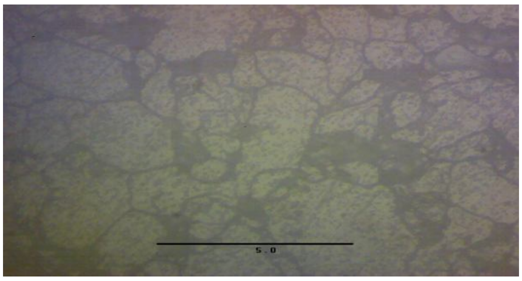

Figure 3. 0.1% Gr-Al composite

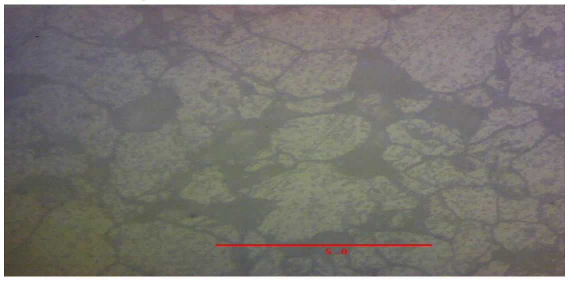

Figure 4. 0.1 % Gr-Al composite

Specimen 2:

0.2% graphene reinforced in aluminium sintered at 400 C for 2 hour in the furnace. It is cooled at room temperature

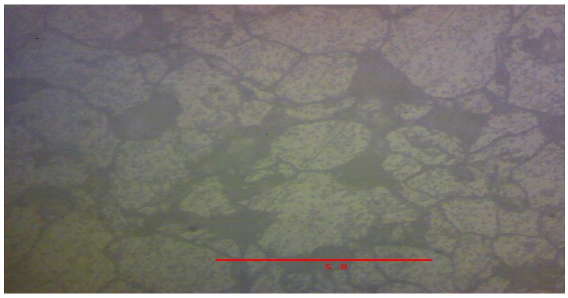

Figure 5. 0.2 % Gr-Al composites

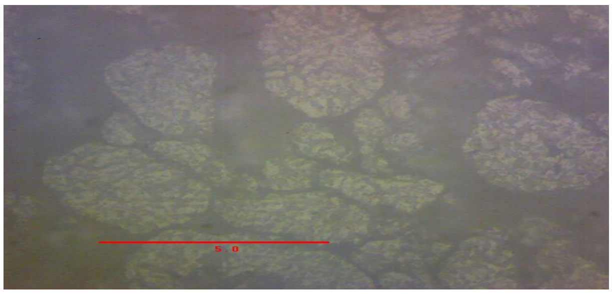

Figure 6. 0.2% Gr-Al composites

Specimen 3:

0.3% graphene reinforced in aluminium sintered at 400 C for 4 hour in the furnace. It is cooled at room temperature.

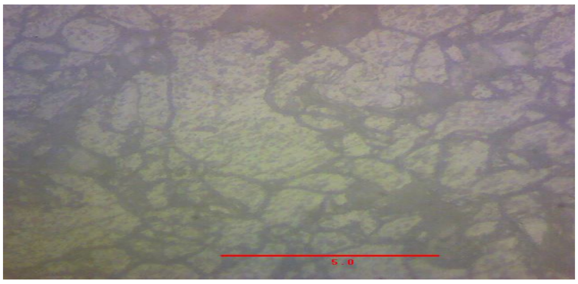

Figure 7. 0.3% Gr-Al composites

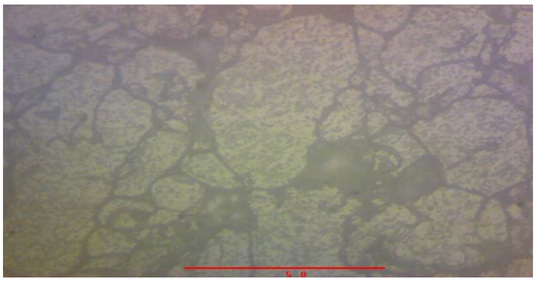

Figure 8. 0.3 Gr-Al composites

Specimen 4:

0.4% graphene reinforced in aluminium sintered at 400 C for 8 hour in the furnace. It is cooled at room temperature.

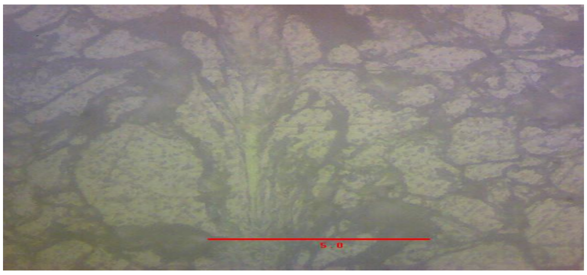

Figure 9. 0.4% Gr-Al composites

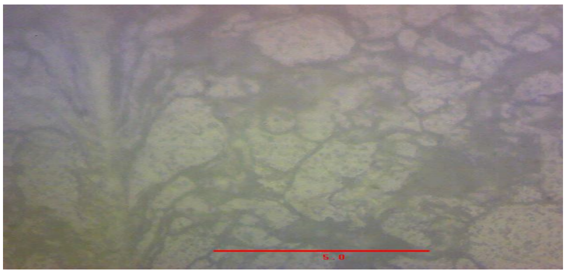

Figure 10. 0.4% Gr-Al composites

DESCRIPTION OF PROJECT WORK:

Graphene reinforced MMC is prepared by using dry compaction powder Metallurgy technique quantity of pure Al taken is 30 grams in each sample and Graphene particles required to fabricate the end composite are 0.1%,0.2%,0.3% and 0.4% by weight. The process for fabrication of the MMC is same for all the Different composition of Graphene. First, pure Al and the Graphene powders are Weighed and then both the powders were mixed using sieve mesh of 70 and100 grade. The ball milling method for mixing the powders was not adopted since it increases the brittle nature of the Graphene in the composite. Then the powder mixture is filled in the die, made according to ASTM standard, with the help of a funnel. The compaction process is done in the Universal Testing Machine at a pressure of 60KN. Post compaction, the specimen is kept in a nairoviral 100°C for degreasing and moisture removal. Sintering is carried out by keeping the composite at 400°C in a furnace which induces strength and hardness in the specimen and then slowly cooled in air at room temperature for different time.

CALCULATION:

From the tests conducted to determine the hardness and Microstructure the following conclusions can be drawn:

- Microstructure of composites shows less pores and uniform dispersion of Graphene than in composites, especially in 0.1% Gr composite .
- Hardness value of 0.1% Gr composite is higher than other samples and even pure Aluminum sample. This is a consequence of increasing the density which results in increased bonding between the particles providing strength and hardness to the material.
- 0.1% Gr composite is the optimum percentage of Gr in the composite samples prepared due to its superior hardness and wear properties and because the other samples (0.2% and 0.3%Gr) developed cracks upon closed die while 0.1% Gr sample did not.
- Increase in Graphene percentage more than 0.1% causes the material to become less and less ductile due to more Graphene particles interfering with Al-A l bonds.
- Composites have superior properties over composites due toincreased density by closed-die forging thus having higher hardness and lesser wear than composites.

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