DEVELOPMENT AND CHARACTERIZATION OF ALUMINUM - GRAPHENE METAL MATRIX COMPOSITES USING POWDER METALLURGY ROUTE

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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 basically focuses on identifying reinforcement materials with better mechanical properties to satisfy various engineering applications. Graphene are found to be one such excellent reinforcing material which can improve properties of Aluminium 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. Achieving uniform Graphene dispersion in metal matrix is main criteria for successful processing. Beside, included in this study composite characterization and microstructures, scanning electron microscope (SEM), X-ray diffraction (XRD).
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.[1] Metal matrix composites (MMCs) these days are used in many applications and are highly preferred over monolithic materials, since the conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density etc. Now a days the particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Recently, there has been interest to develop AMMCs based on the use of Aluminium Alloy; Aluminium Alloy is conventionally applied for the design of medium strength window and door profiles and other architectural design works. The choice of Aluminium Alloy is informed by its local availability and lower cost of processing. Many techniques were developed for producing particulate reinforced MMCs, such as powder metallurgy and squeeze casting. The particulate composite can be prepared by mixing aluminium and graphene as reinforcement.[2] Powder metallurgy is defined as mixing different metal powders to form finished and semi-finished components by compressing it. After compressing material is subjected to heating at elevated temperature in a furnace under a progressive atmosphere is done, so as to obtain satisfactory strength, density without losing essential shape. The powder metallurgy technique involves four major steps: Powder manufacture, Powder blending, compacting, and sintering. The matrix material and the reinforcement material used in this process of powder metallurgy are aluminium and graphene.[3] Aluminum (Al) fine powder was selected as the matrix material. Al powder of 200 mesh size. It has excellent mechanical properties and conductivity. Graphene was selected as reinforced material. Graphene has been successfully implemented and is recommended for following areas. Although the main users are: Industries covering-Composite /Structural materials, Paint &Coating, Energy, Biomedical, Electronics etc.

II. EXPERIMENTAL DETAILS

2.1 Materials Used

Table 1 Al material

Material	Density
Aluminum	2.7 g/cc

Material	Graphene
Tensile Strength	>5 Gpa
Thermal conductivity	3000 watts/m-k 6 watts/m-k
Tensile Modulus	>1000 Gpa
Electrical Conductivity	107 Siemens/m 102 Siemens/m

Table 2 Technical parametric of Graphene

The powder metallurgy process was used as a fabrication method. The cast samples were characterized by SEM and microstructure was carried out to analyses the partial distribution pattern, and XRD study was used to identified the various elements present at the different parts of the samples. Density was carried out before sintering and after sintering of the composites.

2.2 Fabrication of Die & Punch

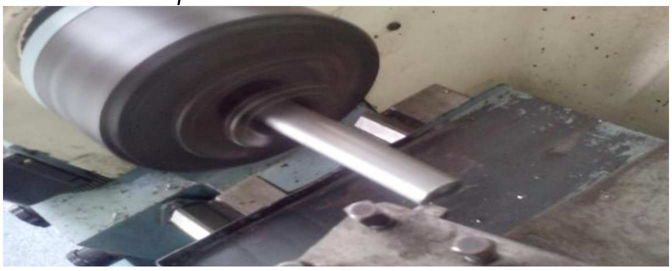

Fig 2.2a Facing operation

Fig 2.2b Finished die

The die is made up of mild steel. Die have punch, bottom plate and body. The specification of The die has hole of diameter 25 mm and length 130 mm.

2.3 Blending, compaction and sintering

Mixing is an operation of blending of various powders of same creation or different grains of same powder while blending is limited to the through blending of powders of more than one material, however both the terms are ordinarily utilized for any of the procedure. Al/Graphene powders were prepared by mechanical mixing process. The mechanical mixing process produced uniform mixture of AL and Graphene powder. Al/Graphene were place in ball milling set up consist of steel balls 10 mm diameter, the process of mixing is continued for a duration of 2 hr at 200rpm in order to get uniform mixing for different composition of Al/Graphene materials or composites. Compaction is a procedure by which the metal powders are squeezed into compacts of craved shape with satisfactory quality to withstand discharge from the devices and ensuing taking care of up to culmination of sintering with no breaking. Compaction process of powder was uniaxial proceed in a die under a load of 80-85 KN using Universal Testing Machine (UTM). As shown in the fig below. Al/Graphene compacted specimens 20 mm length and 25 mm diameter. The work part after pressing is called compacted green specimens. Asshown in the fig.

Fig 2.3a Metal Powder Compaction

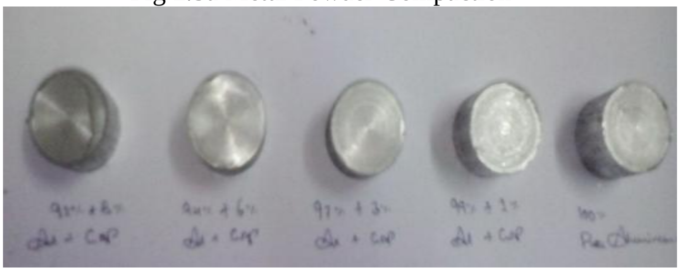

Fig 2.3 b Green specimen

Sintering all in all might be characterized as the warming of free or compacted total of metal powders beneath the dissolving purpose of base metal with or without the use of outer weight so as to change into more thick material by entomb particulate holding. Hence, it might be considered as dynamic move occurring without liquefying from the condition of metallic particles to enormous state which ought to be free from porosity and have physical and mechanical properties.

Sintering. Sintering results in solid holding between particles bringing about quality, densification and dimensional control. Sintering process when all is said in done is connected with procedures, for example, expulsion of ingested matters, development of molecules by dispersion, recrystallization and grain development, arrangement of grain limit and shutting of voids present in the grain minimized. All in all thickness, mechanical quality, pliability, electrical and warm conductivities are favoured by expanded measure of sintering.

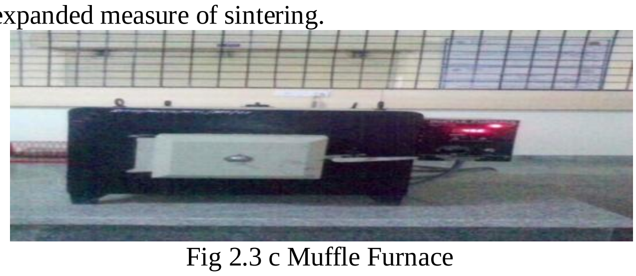

Fig 2.3 c Muffle Furnace

The compacted specimens are placed in the muffle furnace and subjected for heating for about 8 hr at a recrystallization temperature of 450 degree Celsius. Then after cooling purpose kept the specimens using that muffle furnace only in 40hr. as shown fig 2.3 c

III. RESULTS & DISCUSSION

3.1 Microstructure

The micro structural characteristics of composites are as shown in the fig 3.1.1 to 3.16. Reasonably uniform distribution of the Graphene particles in the Al fine Powder matrix is evident. The microstructure of the composites clearly reveals the morphology of Graphene dispersoid particles of irregular shapes. The close inter particle of the dispersoid phase was observed for Al-6% wt Graphene. Microstructure or metallography is an experimental control of analysing and deciding the constituents and the underlining structure of the constituents in metals, compounds and composite materials. The examination of structure might be done over an extensive variety of length. Scales or amplification levels, going from a visual or low amplification (5x to 55x) examination to amplification more than 1000.000X with metallurgical magnifying instruments.

Fig 3.1.1a Al before sintering at 20x

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Fig 3.1.2a Al+1% Grp before sintering at 20x

Fig 3.1.2b Al+1% Grp after sintering at 20x

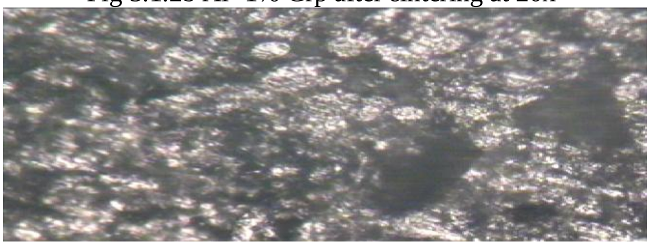

Fig 3.1.3a Al+3% Grp before sintering at 20x

Fig 3.1.3b Al+3% Grp after sintering at 20x

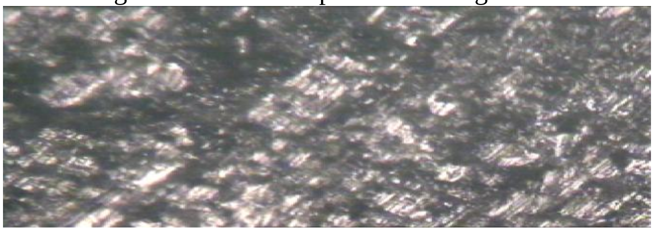

Fig 3.1.4a Al+6% Grp before sintering at 20x

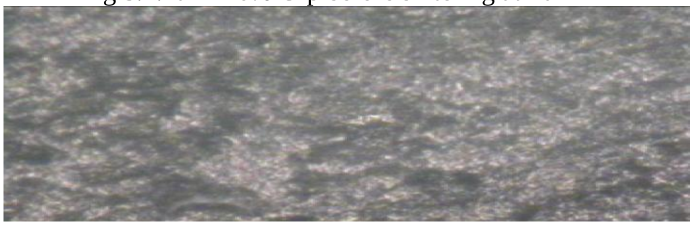

Fig 3.1.4b Al+6% Grp after sintering at 20x

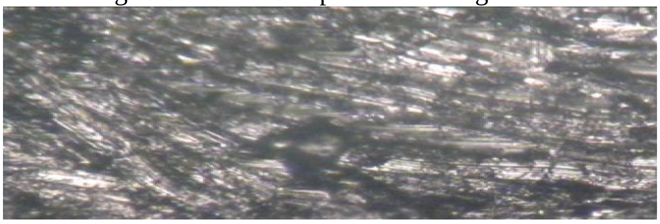

Fig 3.1.5a Al+8% Grp before sintering at 20x

Fig 3.1.5b Al+8% Grp after sintering at 20x

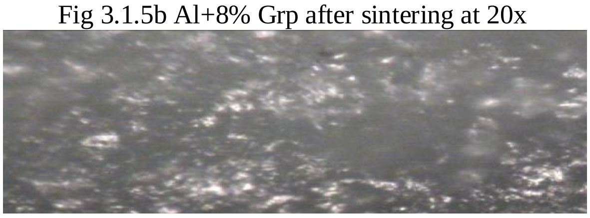

Fig 3.1.6a Pure Grp before sintering at 20x

Fig 3.1.6b Pure Grp after sintering at 20x

3.2 SEM Micrographs of the MMCs

A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity. As shown in fig 3.2.1 to 3.2.4

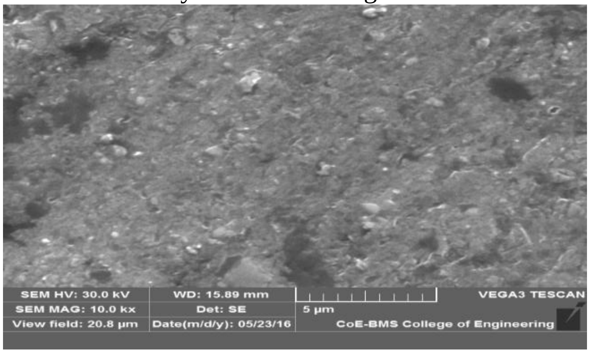

Fig 3.2.1 Al+1%Wt of Graphene after sintering at 10000x

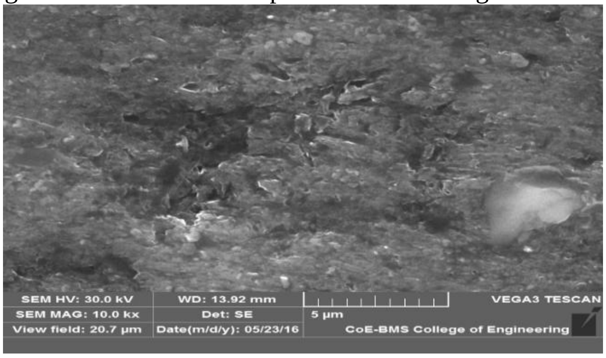

Fig 3.2.2 Al+3%Wt of Graphene after sintering at 10000x

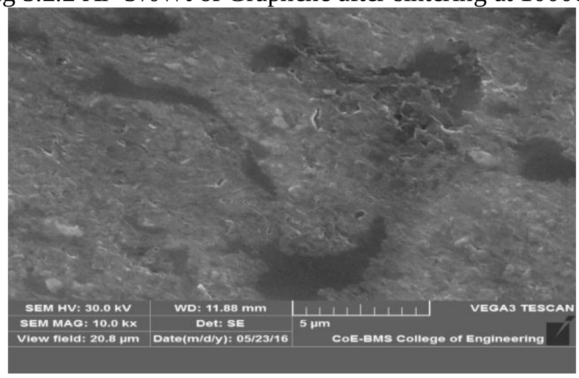

Fig 3.2.3 Al+6%Wt of Graphene after sintering at 10000x

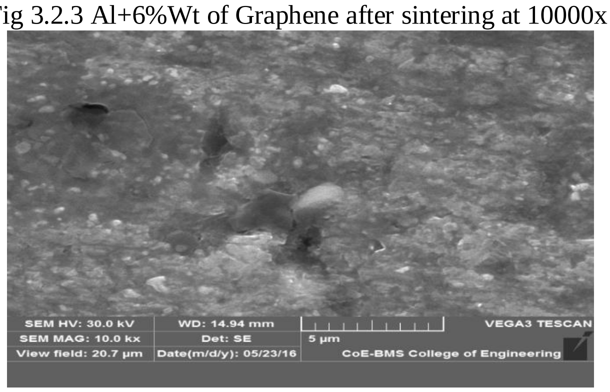

Fig 3.2.4 Al+8%Wt of Graphene after sintering at 10000x

3.3 XRD Analysis

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. The analysed material is finely ground, homogenized, and average bulk composition is determined.

Table 3.3 XRD analysis

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
26.8931	83.67	0.3632	3.31257	1.57
38.8365	5323.68	0.1962	2.31696	100.00
45.0653	3101.41	0.1835	2.01012	58.26
65.4137	1863.30	0.1915	1.42558	35.00
78.5079	1835.44	0.2132	1.21737	34.48

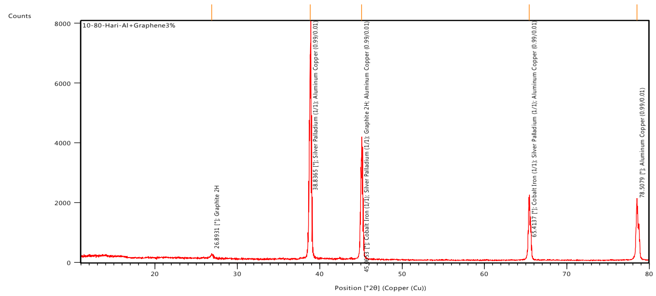

Fig 3.3 XRD analysis in Pc graph

3.4Density

Table 3.4.1 Density results Before Sintering

Material	$\rho_{theoritical}$	$\rho_{experimental}$
Pure Al	$2.515*10^{-3}$	$2.748*10^{-3}$
Al+1% Grap	$2.522*10^{-3}$	$2.758*10^{-3}$
Al+3% Grap	$2.512*10^{-3}$	$2.472*10^{-3}$
Al+6% Grap	$2.482*10^{-3}$	$2.701*10^{-3}$
Al+8% Grap	$2.481*10^{-3}$	$2.700*10^{-3}$

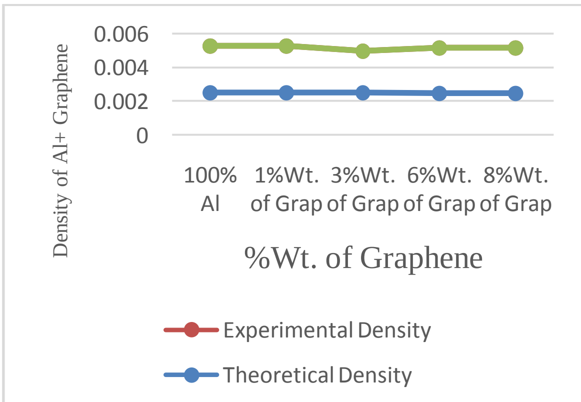

Fig 3.4.1 Shows Density of Al+ Graphene Vs Wt.% of Graphene

Table 3.4.2 Density results After Sintering

Material	$\rho_{theoritical}$	$\rho_{experimental}$
Pure Al	$2.515*10^{-3}$	$2.743*10^{-3}$
Al+1% Grap	$2.505*10^{-3}$	$2.733*10^{-3}$
Al+3% Grap	$2.505*10^{-3}$	$2.459*10^{-3}$
Al+6% Grap	$2.451*10^{-3}$	$2.188*10^{-3}$
Al+8% Grap	$2.456*10^{-3}$	$1.855*10^{-3}$

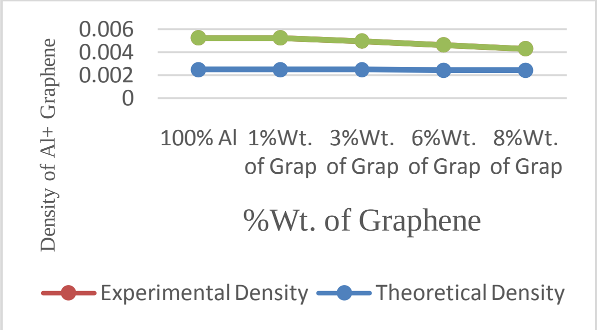

Fig 3.4.1 Shows Density of Al+ Graphene Vs Wt.% of Graphene

IV. CONCLUSION

Aluminum metal matrix composites reinforced with Graphene were successfully fabricated by powder metallurgy and material characterization were carried out successfully. Microstructure study reveal a uniform distribution of Graphene in the Aluminum alloy. Microstructure, Scanning Electronic Microscope (SEM), X-ray Diffraction (XRD) there is an excellent bond between Graphene and Aluminum. Microstructure, Scanning Electronic Microscope (SEM), X-ray Diffraction (XRD) there is an excellent bond between Graphene and Aluminum. Graphene content and Aluminum play significant role in decreasing Density of the material. Aluminum with 8% of Graphene has low density.

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