SYNTHESIS AND EVALUATION OF PROPERTIES OF GRAPHENE REINFORCED ALUMINIUM METAL MATRIX COMPOSITE – A REVIEW

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ABSTRACT

Aluminium alloys and its composites have been widely used in Aerospace and automobile industries due to its potential properties like low density and good structural rigidity. However, the important criteria in enhancing the mechanical properties without compromising the ductility is always challenging in Aluminium and its alloys based composites. Graphene is considered as an ideal reinforcement for the production of composites due to its outstanding mechanical properties. These characteristics offer an increased opportunity for their study in the production of metal matrix composites (MMCs). This study is based on the reinforcement of graphene in aluminium alloys. The synthesis of Graphene Aluminium metal matrix composite is performed by Powder metallurgy process. The composite mixture with various proportions of graphene is ball milled and is extruded to form pellets. These Graphene Aluminium Composite pellets are further Sintered in Argon atmosphere to improve its yield and tensile strength. The increase in ball milling time and proportion of the graphene increases the hardness of the composite. In some times the sintering temperature improves the homogeneous dispersion of the materials.

Key words: Aluminium, Graphene, Metal Matrix composites, Powder metallurgy, graphene aluminium composite.

1. INTRODUCTION:

The wide application of aluminium in the automotive and aerospace industry, makes aluminium-matrix composites an important option to meet future challenges in the design of structural components. In this concern, the reinforcement material used in the production of composites plays a key role in order to maximize the mechanical performance of the composites. The use of nanometric reinforcement materials for the development of aluminium-matrix composites has demonstrated a positive effect on the mechanical behavior of the final products. This has been the case of aluminium-matrix composites reinforced with carbon nanotubes [1] and most recently reinforced with graphenes [2, 3]. A single layer of graphite is called graphene. It has good electrical, thermal, and physical properties. The nanometric nature and high specific surface area allow a great interaction of reinforcement phase with the matrix even in small concentrations.

The strength of aluminium alloys may not be high enough to be used in the manufacture of automobile and aerospace parts for specific applications. One method to enhance the strength of aluminium alloys while maintaining their light weight is fabricating metal matrix composites (MMC)

using novel and high strength materials as reinforcement. Various processing and manufacturing methods, mostly based on casting or powder metallurgy (PM), are available to synthesize nano size particle reinforced metal composites. However, uniform and homogeneous dispersion of these nano-size particles reinforced in molten metal is not possible. Also, agglomeration, micro-level porosity is observed as a common defect in casting process. Techniques based on powder metallurgy are most suitable and effective for fabrication of MMC. The fabrication process involves combination of material in nano size level particulate homogeneously. But, in general, they are time-consuming and may not be cost-effective for fabrication of mass and bulk composites. Important factors in any composite material reinforced with nano-particles are homogeneous and uniform distribution, nature and strong interfacial bond between the matrix and the nano reinforcement. But due to evolution in the materials and processing methods, it's required to study the new class of materials and its unusual blends without sacrificing the key properties. Carbon based reinforcement such as carbon nanotube (CNT), fullers &graphite were used in base metals like aluminium (Al), copper (Cu), magnesium (Mg) and their alloys. Some of the results found to have significant improvement in the mechanical properties of CNT reinforced MMC's as reported in the literature. Graphene is being one such new class of material in carbon group. It is strong $sp2$ − hybridized 2D- sheet like nanomaterial which is well endowed with extreme strength. Further it got massive attention due to its excellent characteristics in physical and mechanical properties. Graphene possess elastic modulus (0.5 − 1 TPa), Tensile strength 130 (GPa) & Thermal conductivity (5.3 ×103 Wm-1K-1) as reported [4]. Compared to other form of carbon based materials like CNTs and fullerenes, Graphene has been expected to outperform due to its distinctive properties and have potential in developing the nano composites. Graphene is being discovered in many composites structures for its outstanding ballistic transportation and its mechanical and other important properties. Studies are focused mainly on processing methods in polymer matrix and ceramic matrix composites which involves the Graphene as reinforcement.

In this research, the use of GNPs in the production of GNP/Al composites is investigated. The use of several milling times and GNP concentration, as well as the selection of sintering time in the production of composites have been considered and the properties of the GNP/ Al composites were discussed.

2. EXPERIMENTAL PROCEDURE:
2.1 COMPOSITE MATERIAL SELECTION:

In this study on both aluminium-graphene and aluminium alloy- graphene composites were made. This helps in understanding the variations of the properties of the composites and also gives a wide range of processes that can be implemented to overcome the problems faced during the composite preparation.

2.1.1 ALUMINIUM GRAPHENE COMPOSITE:

R. Pérez-Bustamante et al [5] synthesized the aluminium metal matrix composite by using Aluminium powder (99.9% pure, _325 mesh in size) and GNPs produced from graphite exfoliation. Graphene sheets of less than 10 nm in thickness are observed. GNPs and Al powder were placed in a vial made from a hardened steel tool and milling media made from a hardened stainless steel.

J. Wang [3] used graphite oxide (0.1 g, 95% in purity) was added to deionized water (200 ml) and the solution was ultra sonicated until it became brown, which implied that the GO had been exfoliated into several or single-layered nanosheets. The spherical Al powder (about 10 lm in diameter, 99% in purity) were transformed into 2 lm thick Al flakes through ball milling in an attritor at 325 rpm.

In J.L. Li [10], Gas-atomized aluminium powder with a mesh size of ~70 μm was supplied as the starting matrix material. Table 1 shows the chemical compositions of the aluminium powder. Fig. 1 contains the optical microscopy and SEM images of the aluminium powder. It can be seen that the

aluminium powder has an average grain size of ~15-20 μm and a spheric/spherical morphology. GNFs applied in this investigation were chemically synthesized from graphene oxides which were prepared by Hummer's method.

2.1.2 AA 5083 GRAPHENE COMPOSITE:

Haiping Zhang [6] synthesised composite with spherical Al5083 powder with 300 mesh in size and GNP (Nanjing XF Nano Material Tech Co. Ltd, China) with 5–20 nm in thickness were used as the starting materials to produce GNP/ Al 5083 composites. The chemical composition of Al 5083 is shown in table 2.1.1. The raw GNP consists of flake–like agglomerated wrinkled powder and Al 5083 powders with different additions (0, 0.5 and 1.0 wt %) of GNP mixed for preparing the composites.

Table: 1 Composition of AA 5083

Element	Mg	Mn	Si	Fe	Cu	Cr	Zn	Ti	Al
Wt %	4.50	0.37	0.17	0.20	0.03	0.14	0.11	0.07	Bal

2.1.3 AA 6061 GRAPHENE COMPOSITE:

In Prashantha Kumar H.G [7] ,Aluminium alloy powder synthesized by gas atomized commercial grade Al6061 with particle size ranging from 30 to 35 μm (from Ampal Inc.) was taken as a matrix material and the chemical composition of Al 6061is shown in the table 2. Graphene (from Angstron Materials) is used as reinforcement and ultrasonication is used to disperse it in metal matrix, the structure and morphology are shown in fig.1 and fig 2 respectively. Initially Graphene with weight percentage of 0.25, 0.5, 0.75 & 1.0 wt. % are dispersed in acetone as solvent. The dispersion is done using magnetic stirrer assisted probe type ultrasonic liquid processor (Ultrasonic solutions make, INDIA). Ultrasonication is carried out for 1hr keeping in ice bath to avoid evaporation and to maintain the constant dispersion efficiency of acetone. To achieve the smart dispersion, Al 6061 powder is directly added to acetone - Graphene slurry and sonication is continued for further 30 min. After sonication, acetone in slurry was evaporated on hot plate with magnetic stirring (To avoid the sedimentation of nano particles) at 60·c for 3hrs followed by drying the powder mixtures in oven at 90·c for 24hrs.

Table: 2 Composition of AA 6061

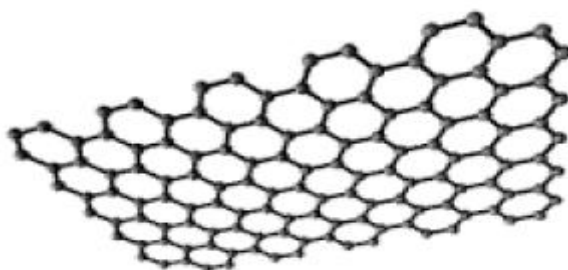| Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al	Others
Wt %	0.81	0.72	0.35	0.15	1.50	0.25	0.15	Bal	0.05

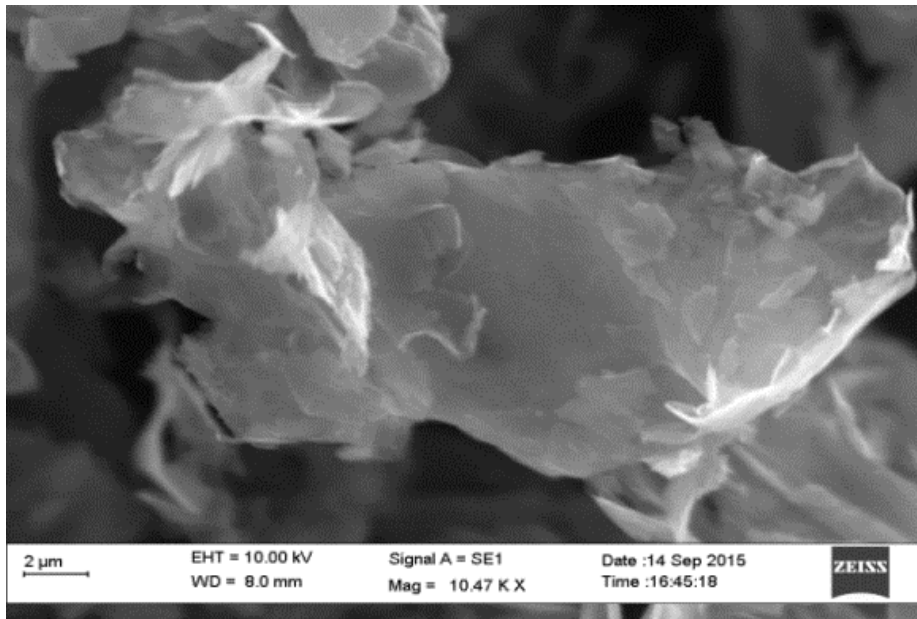Fig: 1 Structure of Graphene

Fig: 2 SEM image of Graphene Morphology

In Mina Bastwros [9], Graphite was expanded to exfoliate graphene according to the modified Brodie's method. First, 10 g of graphite, 160 ml of nitric acid, and 85 g of sodium chlorate were mixed at room temperature. The mixture was kept for 24 h under continuous stirring. Then it was washed with 5% hydrochloric acid and distilled water for four times. The intercalated graphite was achieved through sedimentation and finally was dried at 60 °C. With the aid of ultrasonication, the intercalated graphite was exfoliated to monolayer or ''few-layer'' graphene oxideAluminium alloy 6061 (Al6061) was used as the matrix phase, and its chemical composition is listed in Table 3. Mechanical alloying was performed using a SPEX 8000x ball milling machine to disperse the graphene into the Al6061 particles.

Table: 3 Composition of AA 6061 for GO

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Al
Wt %	0.09	0.28	0.27	1.03	0.03	0.52	0.01	0.06	Bal

2.1.4 AA 2900 GRAPHENE COMPOSITE:

In P. Ashwath [8], the matrix material used in this research work is AA2900 alloy which is alloyed with copper. Reinforcement SiC, Al2O3 and Graphene of particle size 10 microns in case of SiC and Al2O3 and 10 Nano micronsin case of Graphene. It was observed that particle size of Aluminium alloy and reinforcement particles have a substantial effect on the hardness, microstructure and fracture toughness of the composite. Relatively non uniform microstructure was obtained when the reinforcement particle size was smaller than the matrix particle size. Hence in the present work both matrix and SiC of equal size particle size of 10 microns is chosen.

2.1.5 AA 2024 GRAPHENE COMPOSITE:

In S.E. Shin [11], the matrix alloy employed in this study is gas-atomized Al2024 aluminium alloy powder (99.5 % purity and <150µm diameter), with a composition of 4.5% Cu, 1.5% Mg, and 0.6% Mn in an aluminium matrix (weight %). FLG composed of graphenenanoplatelets (6−8 nm thick with a typical specific surface area of 120−150 m2/g) was selected as the reinforcement. Graphene exfoliation was performed by tip ultrasonication in ethyl alcohol (C2H6O) for the manufacture of the Al2024/FLG composites.

2.1.6 AA 7075 GRAPHENE COMPOSITE:

In Wen-mingTian [13], 7055 aluminium alloy powder with a diameter of 50 μm was used as the metal matrix material. The graphene plates were chemically reduced from graphene oxide (GO) suspension by hydrazine, and the GO was prepared via the Hummer's method. The whole reduction process took place in an ultrasonic bath.

2.2 COMPOSITE PREPARATION:

R. Pérez-Bustamante et al [5] produced the composites by mechanical milling (MM) in a high energy ball mill Spex 8000 M. GNPs were added in several compositions (0.0, 0.25, 0.50 and 1.0 wt%). The powder mass was 8.5 g and the ball-to-powder ratio was set to 5:1. All milling runs were performed with methanol as a process control agent (PCA). Argon atmosphere is maintained to avoid excessive agglomeration and oxidation, respectively. The milling times were of 1, 3 and 5 h. Milled powders were cold consolidated to form discs of 6.7 mm of diameter and 1 mm of height, under 950 MPa and then sintered under Ar atmosphere during 0.5, 1, 2, 3, 4, and 5 h at 500 ºC with a heating and cooling rate of 5 °C/min.

In Haiping Zhang [6] Al5083 powders with different additions (0, 0.5 and 1.0 wt.%) of GNP were loaded in a stainless steel jar with stainless steel balls of 3 mm in diameter at ball powder ratio of 20:1, and were ball-milled by planetary ball mill under argon atmosphere at a rotation speed of 350 rpm for 24 h. 1.0 wt.% stearic acid was added as process control agent. The milled GNP/Al5083 composite powders were loaded in a stainless steel mold with an inner diameter of 23 mm, maintained at 673 K (heating rate: 20 K/min) for 1 h to remove the stearic acid, and then sintered at 773 K for 1 h under 300 Mpa uniaxial com- pressive force. The sintered samples were extruded at 773 K at the extrusion rate of 1 mm/min and an extrusion ratio of 10:1. For comparison, the pure Al5083 sample without GNP addition was fabricated under the same procedures.

J. Wang [3] compacted and consolidated of GNS/Al composite powders as The GNS/Al composite powders were first compacted into U40-30 mm billets, which were consolidated by sintering in an Ar atmosphere at 580 °C for 2 h, followed by hot extrusion at 440 ºC with an extrusion ratio of 20:1. For comparison, a pure Al specimen was also prepared by the same process using flaky Al powder.

In Prashantha Kumar H.G [7] Powder metallurgy technique was used to develop the composite and the synthesis process followed in this work is shown in fig.3 Al 6061and Graphene mixture was compacted according to ASTM standard B925–08 (Standard Practices for Production and Preparation of Powder Metallurgy Test Specimens). Carbide die with chromium hot work tool steel (40 to 48 HRC) die case was used to compact the powder mixtures. Powder mixtures are preheated and compacted with compaction pressure at 460 MPa for all the samples to obtain a green billets. Zinc stearate was used as lubricant and thus obtained green compacts are shown in the fig.4.

The green compacts are further preheated at 135˙c to burn zinc stearate and polished with fine emery (Silicon carbide electro coated 1000 to 2000grade) to remove all burn out lubricants and dirt. Subsequently the specimen is subjected to sintering in conventional tubular furnace (Delta power controls make, INDIA) at 450, 500, 550 & 600 ºC for 30 minutes by maintaining ramp up rate of 2.1ºC/min argon atmosphere followed by furnace cooling.
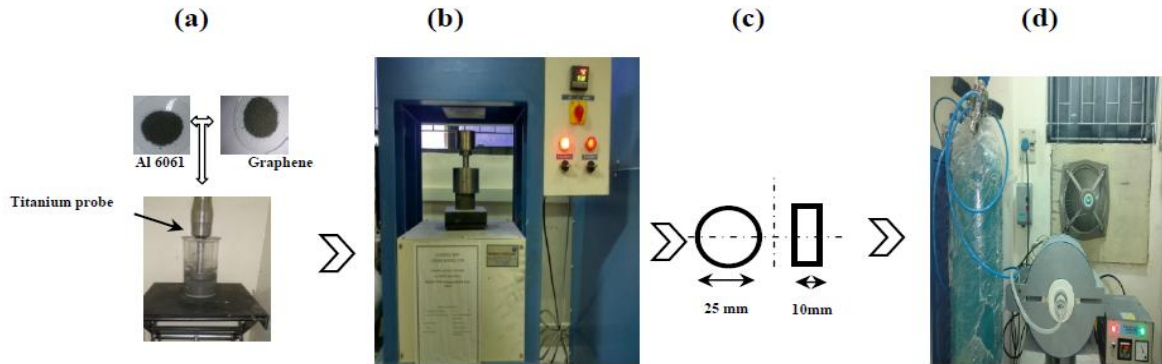
Fig: 3

(a) Powder processing through ultrasonic liquid processor (b) Powder compaction in hydraulic press
(c) Compacts dimensions (d) Sintering with inert gas facility

Fig: 4 Al 6061 + Graphene circular green compacts

In P. Ashwath [8], the weighed powder is mixed in a high energy ball mill from VB Ceramics Inc. Chennai. Since the particle size of matrix and the reinforcements are 10 microns which is sufficient for compaction ball milling was focused only on mixing rather than running it for hours to further break particles to attain fine grains. The ball milling time was 20 min for all the reinforcement composition. Compaction of the powders has been carried out in a standard die-setup. Compaction was carried out in a universal testing machine with a capacity of 100 tons. Uni-axial pressing was carried out at 650 Mpa compacting pressures. Zinc stearate mixed with acetone was used for die wall lubrication and no lubricant was used in the powder mixture since it was noticed that powder with mixed lubricant did not help in gaining preferred green compact density. Die was manufactured from ASTM D2 high carbon steel, hardened, tempered and Carbide inserted. Punch and die were ground to close tolerances. Sintering was carried out for some samples at 550 °C for 15 min in Microwave sintering furnace at a rate of heating up to 10 ºC per minute, the specimens after the sintering time was allowed to cool up to 250 °C inside the furnace to avoid atmospheric contamination and sudden cooling and then to room temperature.

S.F. Bartolucci [2], to prepare the composites, the powders were blended, milled, pressed and extruded. Aluminium–graphene composite powders were fabricated by initially blending the constituent precursory powders of Valimet Al and graphene. Blending was conducted using a ResodynLabRAM acoustic mixer for ~5 min. This blend was then milled in a Zoz high energy attritor under an Argon atmosphere for one hour. After hot isostatic pressing, the ~20 mm diameter billets were preheated to ~550 ∘C for ~4 h and then extruded on a 50-ton aluminium extrusion press. The extrusion ratio was 4:1, ram speed was ~12.5 mm/s, and extrusion pressure reached ~65 ksi. Pure aluminium, Al–graphene, and Al–MWNT samples were all prepared in the same manner.

In Mina Bastwros [9], Al6061–1.0 wt % graphene samples were prepared at various ball milling times: 10, 30, 60, and 90 min. In addition, a reference sample was prepared for each ball

milling time with only Al6061 powder to isolate the strain hardening effect that came from the ball milling. The ball milling was performed in ambient conditions. 0.05 g of graphene was mixed with 4.95 g of Al6061 in a zirconia vial. Two zirconia balls, weighing 7.5 g each, were used in the mixing process, resulting in a ball to powder ratio (BPR) of 2.6. The ball mill was stopped for every 30 min to prevent heating of the powder. The experimental setup used for the composite synthesis is shown in Fig.5. The die was made of H13 tool steel and was lubricated by spraying a thin layer of boron nitride to prevent a potential reaction between the aluminium and the die at elevated temperatures. The consolidation was performed in two stages. First, a pre-compaction pressure of 50 MPa was applied to the alloyed powder at room temperature. Then, the powder compact was hot-pressed at 100 MPa for 10 min in the mushy zone (between the solidus and liquidus temperature of Al6061) at 630 ºC. The liquid phase fraction at this temperature is about 18%. The obtained composites were cut using a low-speed diamond saw and were polished to the final dimension of 0.9 mm in thickness and 1.2 mm in width.
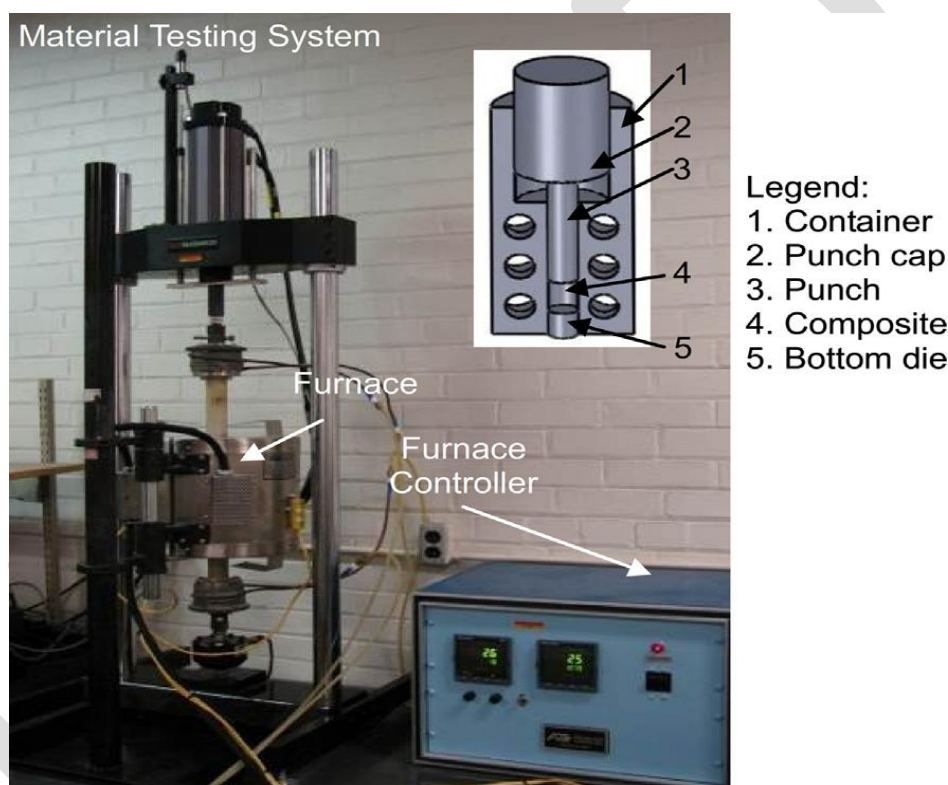

Fig: 5 Experimental setup for semi-solid sintering.

In J.L. Li [10], the combination of several processing routes: blending, cryomilling, degassing and hot extrusion was employed in the current study for preparing the bulk nanostructured Al/Gr composite reinforced with zero, 0.5, 1.0, 1.5 and 2.0 wt. % GNFs, respectively. Take Al/0.5 wt. % Gr composite for example, the detailed fabrication processes are as follows. At the first step, aluminium powder (995 g) and GNFs (5 g) were mechanically mixed with stearic acid (2 g) using a modified V-blender at a speed of 17 rpm for 24 h. Then, the blended powder was cryomilled in an attritor with a stainless steel vial and balls (8mm in diameter, ball-to-powder weight ratio of 40:1) at a rate of 180 rpm for 2 h. Afterwards, the canned composite powder was extruded at 300 °C to form a bar of 15 mm in diameter with an area reduction ratio of 17.6:1. Finally, all specimens were subjected to an anneal heat treatment at 300 ºC for 2 h. Additional details of this procedure can be found in the literature.

In S.E. Shin [11], the exfoliated graphenenanoplatelets were mixed with Al2024 powder using a planetary mill at 100 rpm for 3 h using a process control agent of 1wt.% stearic acid

(CH3(CH2)16CO2H). Milling was paused for 15 min every 30 min (the 4 weight ratio of ball-to-powder was 15:1) in order to prevent powder heating. FLG attached to the aluminium powder surface was gradually embedded and dispersed within the Al2024 powder. For further dispersion of FLG in aluminium powder, the planetary-milled mixture was high-energy ball-milled in an attritor at 500 rpm for 9 h in a purified argon atmosphere. Hot-rolling of ball-milled powders was used to fabricate Al2024/FLG composites. The ball-milled powders were placed in a copper tube (60 mm in diameter, 150 mm in height, and 1.5 mm in thickness), compacted, and then hot-rolled. The sample was heated to a predetermined temperature of 450 °C with a heating rate of 15 ºC /min, and rolling was conducted with a 12% reduction per pass. The final thickness of the samples was 1 mm.

In M. Rashad [12] the solution for the problem of heat generation during ball milling was eliminated. Ball milling is an incompatible technique for handling magnesium as it produces heat which can burn magnesium powder easily. Therefore solution based powder method is adopted here to prepare the composites. Magnesium and Al (Al with 0.5wt%, 1.0wt% and 1.5wt. %) powders were mixed in ethanol using a mechanical agitator. At the same time, Graphenenanoplatelets (GNPs) were separately ultra sonicated in ethanol, for 60 minutes. Graphenenanoplatelets (GNPs) solution (with 0.18 wt %) was added drop wise into the above magnesium and Al powder solution in ethanol. Mixing process was continued for 60 min by using a mechanical agitator to obtain the homogeneity in the mixture. The mechanically agitated mixtures were filtered and vacuum dried overnight at 70o C to obtain the composite powders.

The composite powders were compacted in a stainless steel mold at room temperature under the pressure of 600 MPa to obtain green billets with Φ80×40mm dimensions. After compacting the green billets were buried in graphite powder and sintered in box furnace at 630 ºC for 110 minutes in the argon atmosphere. Sintered billets were preheated to 350 °C for 1 hour and extruded at 350 ° C to obtain the rods of 16 mm diameter. The extrusion ram speed was set at 1m/min. For comparison pure Mg sample was also prepared by compacting, sintering and extrusion process.

In Wen-mingTian [13] 0, 1wt%, 3wt%, and 5wt% graphene plates were wet-blended with 7055 aluminium powders in an acetone solution in an ultrasonic bath for 4 h. The mixed powders were vacuum dried at 50°C for 24 h. Then the dried mixed powders were loaded in a cylindrical graphite die with an inner diameter of 15 mm for SPS processing. The SPS experiments were carried out at 400°C in vacuum with a 1 min dwell time and a heating rate of 50°C/min. A uniaxial pressure of 50 MPa was applied during the whole SPS process. The samples were cooled naturally after the sintering period.

In S.J. Yan [14], Al alloy powder (1 kg) and the GNFs solution (1 L) were mixed and sealed into a roller milling tank. After this, the mixture solution was ball milled for about 12 h (with ball material ratio 10:1, rotating speed 75 r/min). The GNFs/Al mixture slurry was soaked into a water bath and mechanically stirred at 80 °C until became semi-dry state. Then fully dried in an oven at 60 °C. The dosages of GNFs in the mixture were 0.15 wt.% and 0.5 wt.%, respectively. Subsequently, the mixtures were sealed in a cylinder-shaped Al package, and pumped to 1×10-3 Pa. In order to further removing moisture and remaining gas of the mixed powders, the Al package was heated to 300 and 480 °C for 2 h, respectively. The package was heat isostatic pressed (HIP) at 480 °C and 110 MPa for 2 h. Finally, the 40 mm diameter billet was preheated at 450 °C for 1 h in a stainless steel mold, and then hot extruded into 12 mm diameter rods. The ram speed was 2.2 mm/s and extrusion pressure force was about 300 kN. The graphene reinforced Al alloy nanocomposite rods were solution heated at 495 °C for 30 mins, and then quenched in water. The dumb bell shape tensile coupons with size of 5 mm diameter and 25 mm gauge length were machined for the mechanical performance measurements.

2.3 CHARACTERIZATION:

R. Pérez-Bustamante et al [5] investigated that Aluminium coat on graphene delayed the formation of amorphous structures in graphene as a consequence of the increase of milling time. Milling time and GNPs have a positive effect on hardness values. The mechanical behavior of GNP/Al composites evaluated by hardness show that increase in the milling time increases composites at 2 h sintering.

Haiping Zhang [6] examined that with the increasing of GNP content, the GNP / Al 5083 composites show significant improvements on mechanical performances. With 1.0 wt % GNP, both the yield strength and ultimate tensile strength are enhanced by 50% more, from 219 MPa to 332 M Pa and 301 MPa to 470 MPa, respectively. Both the GNP and nano scale Al_4C_3 can act as effective reinforcements in composites. The results indicate that GNP can be a good reinforcement candidate in metal matrix composites.

Prashantha Kumar H.G [4] concluded that it is worth to note that the notable benefit of the GNFs/Metal matrix nanocomposites, comparing with conventional metal matrix composites, and has an immense potential to fabricate the composite reinforce with Graphene having important properties and have high levels of stiffness and strength, this means that the outcome of composite will possess outstanding mechanical properties. Although some positive results have been achieved, there still have a lot of unknown influencing issues need to be explore in graphene reinforced metal matrix nanocomposites and the future research will be focused on the optimization of processing parameters to improve the content and dispersion of GNFs in the metal matrix, also sintering and extrusion parameters.

In J. Wang [3] the composite with only 0.3 wt.% GNSs addition exhibited a tensile strength improvement of 62% over unreinforced matrix, as well as a uniform elongation well beyond the 5% standard for engineering applications.

In the study of Prashantha Kumar H.G [7], the Al6061- Graphene composites were processed by ultrasonic liquid processing of Al6061 particles and Graphene. The precursor are preheated and compacted in the liquid-solid semistate. Finally, the compacts are sintered in conventional tubular furnace successfully with varying the sintering temperatures. XRD analysis has revealed the existence of all major alloying elements of Al6061 including Graphene (peak at 26.50°) in the developed composite and no carbide formation at the surface. The peak micro hardness values is given at 0.5 wt% Graphene sintered at 500 °C. Also addition of Graphene gives rise to tendency of decreasing diametrical expansion during quenching and seen least for the sample sintered at 500 °C. It can be concluded that, addition of Graphene prone to increase in hardness values and affinity in decreasing the diametrical expansion at its optimum Graphene content in the developed composite.

In S.F. Bartolucci [2], Vickers hardness tests were performed on the materials with a 200 g weight. A minimum of 5 data points were averaged for each material. Materials were machined into flat dog-bone tensile coupons and tested with a ~0.5 mm/min crosshead rate on an Instron tensile testing machine. The tensile properties reported were the calculated average of 3 samples. Microstructural observations were also performed by field-emission scanning electron microscopy (FE-SEM) on a JEOL 6330F operating at 5 kV. The structure of the Al, Al–graphene, and Al–MWNT samples were examined using a Scintag 4-circle PTS Diffractomer; using Kalpha radiations from a fine-focus Cu X-ray tube. Differential Scanning Calorimetry (DSC) was performed on a Perkin-Elmer DSC 7 and heated at ~10 °K/min for the steady heating experiments and ~20 °K/min for the isothermal experiments.

In Mina Bastwros [9], the Al6061-1.0 wt.% graphene composites were fabricated by ball milling Al6061 particles and graphene, followed by pre-compaction at room temperature, and finally by hot compaction in the semi-solid regime. The ball milling time varied from 10 min to 90 min. The 10- and 30-min ball milling times were not enough to homogeneously disperse the graphene into the Al6061 matrix, which resulted in degradation of the flexural strength for the 10-min milling time sample and no enhancement for the 30- min milling time sample. The strength increase for the

Al6061- 1.0 wt.%graphene composite was 47% and 34% for the 60-min and 90-min times, compared with the reference Al6061 sample. According to the Raman analysis, further milling did not introduce more damage to the graphene, but instead helped to uniformly disperse the graphene and reduce the number of the stacked layers. It was concluded that the strengthening was significantly affected by the dispersion of the graphene in the matrix phase.

From J.L. Li [10] we come to know that, Bulk nanostructured Al/Gr composites were prepared by cryomilling combined with hot extrusion in the current study. With an introduction of 0.5 wt. % GNFs, the composite exhibited increased strength and unsubdued ductility over monolithic aluminium. By incorporating 1.0 wt. % GNFs into aluminium matrix, another composite with a good combination of strength and ductility (8.3% tensile elongation) was successfully synthesized. As the content of GNFs increased (especially above 1.0 wt. %), however, the extent of the agglomeration of GNFs within aluminium matrix increased, which in turn lowered the strengthening effect. By theoretical calculation, the appropriate content of GNFs added into nanocrystalline aluminium matrix should be less than 4.0 wt. %.

S.E. Shin [11] concluded that with increasing FLG content, the Al2024/FLG composites exhibited an increase in the tensile strength that indicated FLG effectively strengthened the composites. High specific surface area of FLG can lead to efficient load transfer at the interface from the matrix to the FLGs. A maximum tensile strength of 700 MPa was obtained for 0.7 vol % FLG. During plastic deformation, FLG with a high specific surface area blocks the dislocation movement, producing deformation bands in the composite.

3. CONCLUSION:

In this study the Aluminium graphene composites were prepared by Powder metallurgy process. The Aluminium Alloy composition is ball milled with various proportions of graphene that would result in different properties. The ball milling was either carried out either continuously or in intervals for the elimination of heat generated during the ball milling process. In some cases the mechanical agitators are used for the mixing of the composite materials. The solution of ethanol can also be used to eliminate the heat generation.

The ball milled composite powder is either compacted directly to the pellets to form green billets or the composite powders are sintered to required temperature and then the mixture is compacted to the required size. In some cases the compaction process id accompanied with the heating process called the hot isostatic pressing which improves the strength of the bonding between the particles. The compaction pressure with 300 MPa to 450 MPa has a greater impact in the properties like yield strength and tensile strength.

The sintering process is done to improve the hardness and strength of the composite. The sintering temperature ranges from 450 ℃ to 600 °C. The sintering is carries out in the Inert gas atmosphere or in vacuum, but mostly the sintering is carried out in the Argon atmosphere. Both the ball milling time and the proportion of the graphene has an effect in the hardness of the composite. In some times the sintering temperature improves the homogeneous dispersion of the materials.

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