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REVIEW ON CHARACTERIZATION OF ALUMINIUM MATRIX COMPOSITE REINFORCED WITH NANO FILLER BY STIR CASTING METHOD

B.Parameswararao*1
A.Manimaran[2]
K.Logesh[3]
M.Venkatasudhahar[4]
[1] Department of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India
parameshp99619@gmail.com
mullaimaran@rediffmail.com
klogesh7@gmail.com
kmrflowers@gmail.com

ABSTRACT

In this paper in depth review of aluminium matrix material with different particle size reinforcement is explored. Metal matrix composites are important class of novel engineering materials used in different applications because of their lower density, higher specific strength and better physical and mechanical properties. Aluminium alloy based metal matrix composites (AMMC) are widely used for sliding wear applications because of their excellent wear resistant properties. They are widely used in Aerospace, Defense, Automobile, Marine industries, etc. due to their excellent mechanical properties. Engine Pistons are commonly made of a cast aluminum alloy for excellent thermal conductivity and light in weight. The continuous development of modern fuels leads to specific objectives for further piston development in the field of reduction of piston weight, increase of mechanical and thermal load capacity and lower friction etc. New compositions of aluminium materials have to be studied so that to meet the development of new kind of fuels. [1-5]The Aluminium matrix is strengthened when it is reinforced with hard particles like SiC, Al_2O_3, B_4C, CNT, Graphene etc. resulting in enhanced wear resistance and improved strength to weight ratio. Based on the type of reinforcement, size and morphology, The AMCs are fabricated by different methods like powder metallurgy, stir casting, squeeze casting etc. In this paper an attempt is made to review micro and nano particle reinforced aluminium matrix composite.

Keywords: Aluminium Matrix Composites, wear resistant properties, Nano scale, stir casting.

INTRODUCTION

Aluminium matrix composites are the class of metal matrix composites. Aluminium based composites are findings increased use in military, automotives and aerospace industries. In general these composites can be fabricated through various methods such as powder metallurgy, Melting and squeeze casting. Pistons are commonly made of a cast aluminum alloy for excellent and lightweight thermal conductivity. Engine pistons are mostly made with Aluminum alloy or aluminium material composites as they have low density and high thermal conductivity. The continuous development of modern fuels leads to specific objectives for further piston development like reduction of piston weight, increase of mechanical and thermal load capacity and lower friction etc. These goals are achieved by high performance aluminium piston materials, novel piston designs and the application of innovative coating technologies. New compositions of aluminium materials have to be studied so that to meet the development of new kind of fuels.

[7]Powder metallurgy is a remarkable method due to its ability to give a more homogeneous dispersion. Samples fabricated by this method require minimal finishing and economic/technical advantages which made them very attractive for various applications in industry. The Powder metallurgy method is applicable for the production of large-scale and complex-shaped engine parts. Also, it provides final near net shape without secondary process.

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[8]Stir Casting is yet another method of making producing aluminium matrix composites. It is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Stir casting is the simplest and the most cost effective method of liquid state fabrication. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies**.**

ALUMINIUM MATRIX COMPOSITE REINFORCED BY GRAPHENE NANOPLATELETS

Graphene nanoplatelets (GNPs) have drawn the attention of researchers due to their superior properties such as superior electrical, thermal, mechanical and tribological properties. The elastic modulus and tensile strength of graphene were determined as 1.0 Tpa and 130 GPa, respectively. Graphene has been used as reinforcement element in metal matrices such as aluminum, magnesium, titanium, and copper to enhance the properties of metal matrix nanocomposites. Mechanical or tribological properties of Al–GNPs composites demonstrate the positive effects of graphene addition where it suppresses the friction, wear and enhances the density, hardness, and strength up to certain graphene content. GNPs have the superior tribological properties and the self-lubricating ability during wear tests

Materials used to make the Al-GNPs composite

- Atomized aluminium powder with 99% purity and the average size of 10µm was used as a matrix material. The theoretical density of Al powder is approximately 2.7 g cm^{-3}.
- GNPs with 99% purity and 5–8 nm thickness were used as a reinforcement material. The theoretical density of GNPs is nearly 2.25 g cm^{-3}.

Al-GNPs composite fabrication with the PM method

Powder metallurgy method was used to produce Al–GNPs composites as given in Figure 1. GNPs (0.1, 0.3, 0.5 wt-%) were dispersed in ethanol for 1h. Aluminium powder was mixed in ethanol by using the mechanical mixer, simultaneously. Then, GNPs slurry was added drop by drop to the aluminium powder slurry. The solution was ultrasonicated for 30 min to obtain a homogeneous mixture. After ultrasonication, the prepared solution was filtered and it was dried at 50°C overnight in order to obtain a dried mixture. The dried powders were pressed in a die at 600MPa. Afterwards, the composite green samples were sintered in a tube furnace under vacuum. The sintering conditions of sintering temperature (T_S = 630°C) and sintering time (t_S = 180 min).

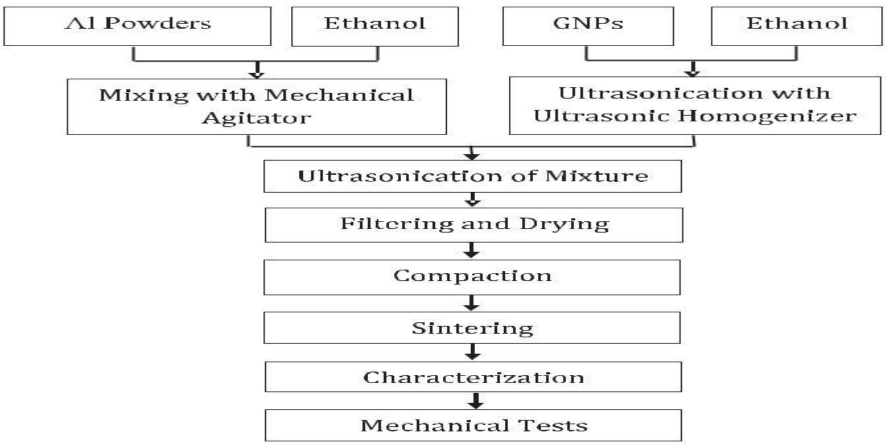

Figure 1. Schematic diagram of Al-GNPs composite fabrication with the PM method [7]

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Characterization of Al-GNPs composite

The morphology and microstructure analysis of composites were determined by using SEM (Scanning Electron Microscopy). Also, EDX mapping and line analyses were carried out to detect the distribution of GNPs in Al structures. X-ray diffraction (XRD) analysis was performed to investigate the phase analysis of powders and fabricated composites. Raman spectroscopy was used to confirm the existence of graphene in Al composite.

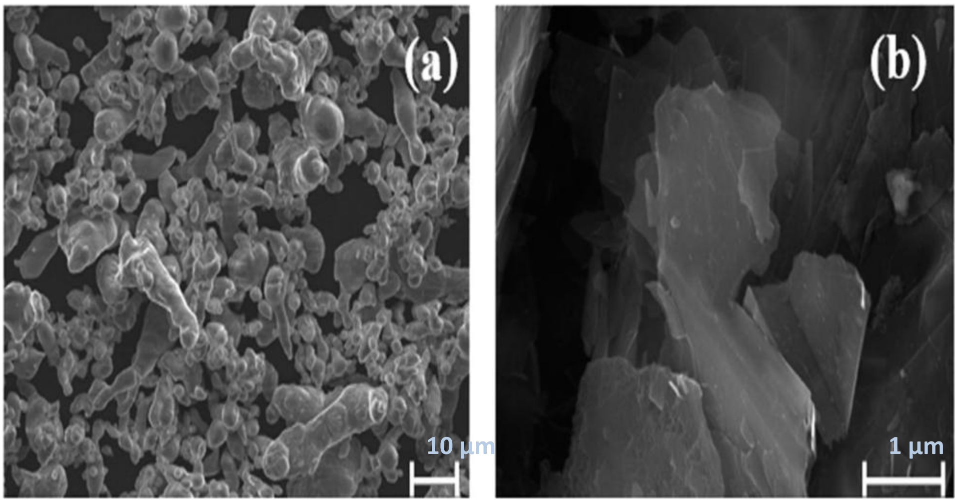

Figure 2. SEM micrographs of Al (a) and GNPs powders (b) [7]

The morphology of Al is generally an irregular form (Fig. a). GNPs include few layers of two-dimensionally arranged graphene nano sheets (Fig. b) shown in figure 2. Figure 3 shows the SEM image and elemental distribution of Al and C from GNPs for Al–0.1 GNPs mixed powders after ultrasonication. From this analysis, the uniform carbon distributions from GNPs in Al matrix can be clearly seen. This process is important to detect the agglomeration tendency of GNPs in Al–0.1% GNPs composite.

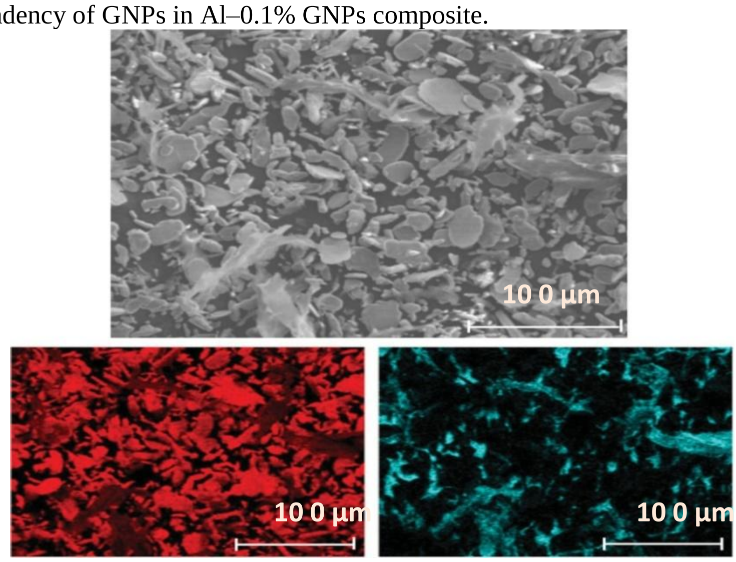

Figure 3. SEM image (a) and elemental distribution of Al (b) and C from GNPs (c) for Al–0.1GNPs mixed powders after ultrasonication [7]

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Mechanical properties of Al-GNPs composite

The Vickers hardness measurements of samples were carried out via a Vickers hardness test machine by using 200 g load and 15 s of indentation time on polished surfaces. The hardness measurement was carried out five times from cross-sections randomly and they were averaged. The compressive strength was determined by a Universal test machine. Five measurements were averaged for each composition with the compression rate of 10mm min−1. The highest apparent density (2.58 g cm−3), relative density (95.5%), and Vickers hardness (57HV) have been obtained at Al–0.1 wt-% GNPs. After 0.1 wt-% GNPs content, both apparent density and Vickers hardness decreased due to the agglomeration of GNPs.

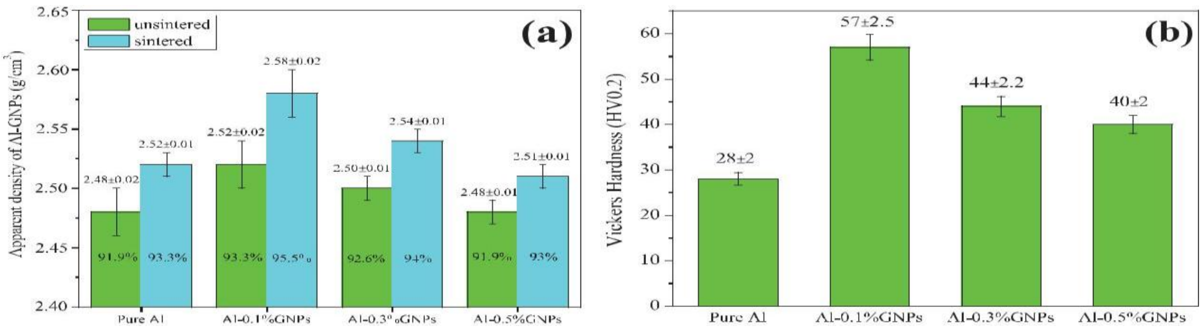

Figure 4. The variation of apparent/relative density (a) and Vickers hardness (b) in Al–GNPs composites. [7]

Aluminium metal matrix nano composite by the hybridization technique

Clustering of the reinforcement particles is identified as a major cause of reducing the strength of cast metal matrix nanocomposites (MMnC). Pre-distribution of nano reinforcement as a technique is revealed to circumvent the clustering of nano reinforcements in the matrix. However, pre-distribution of the nano reinforcements by ball milling involves metal particles called launching vehicles that carry the nano reinforcement into the molten matrix. Ball milled Al and Cu particles with Al_2O_3 nanoparticles (1:1 weight ratio) independently and introduced the components into the metal melt by stir casting to achieve a uniform distribution**.** Reducing the size of nanoparticles to ultra-fine nanoparticles promotes clustering in the matrix, which necessitates a better pre-distribution methodology unlike the regular use of a single launching vehicle (which is termed the primary vehicle in the investigation). In the present investigation, an attempt was made to distribute ultra-fine nanoparticles (13 nm in size) in the cast sample by a stir casting route. In this study it is used two types of launching vehicles that were prepared by ball milling to launch the nanoparticles into the Al-Cu matrix. With an increase in the launching vehicle to a constant reinforcement (1.5 wt. % Al_2O_3) ratio, this is termed as the launching vehicle to reinforcement ratio (LVRR, by weight).

Materials used to make hybrid aluminium composite

- Matrix material: Al-Cu alloy (3.9% Cu, 1.2% Mg, 0.3% Mn, 0.2% Fe and balance Al).
- Primary launching vehicle: aluminum powder (75 µm)
- Secondary launching vehicles: CNTs (9nm in diameter and 5µm in length) .
- Reinforcement: Ultra-fine nanoparticles of Al_2O_3 (13 nm).

Fabrication method for making hybrid aluminium composite

The reinforcement mixture involving launching vehicles and nanoreinforcements, were individually placed in a stainless steel jar containing 138g of tungsten carbide balls (20 in number). Each mixture was milled in a planetary mill at 300 rpm for 2 hours. The ball-milled mixtures were examined in terms of the reinforcement distribution among launching particles by transmission electron microscopy (TEM). These mixtures were then preheated to 200˚C before their addition in to the matrix material. Heated mixtures are added into the Al-Cu metal melt maintained at 700˚C, i.e., above the liquidus temperature of the matrix alloy (584˚C) and primary launching vehicle (660˚C), followed by soaking for 30 min. After adding the reinforcement, the mixtures were stirred for 4 min at 200 rpm in a two-stage stirrer. The entire setup was maintained under an argon gas environment. A boron nitrate coating was applied to all of the surfaces exposed to the casting environment to

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isolate the castings from iron contamination because this could show an adverse effect on composite strength. The composite samples are made as per the launch vehicle reinforcement ratios in the table 1. The cast samples were prepared as per ASTM E8 standards.

Table 1: LVRRs for making composite sample

Sample no	Ingredients(grams)	Sample name
1	15 g Al, 14 g nano Al_2O_3, 1 g CNTs	H1
2	45 g Al, 14 g nano Al_2O_3, 1 g CNTs	H3
3	75 g Al, 14 g nano Al_2O_3, 1 g CNTs	H5

Characterization of Al -Hybrid composite

Pre-distribution is clearly revealed by means of dark field transmission electron microscope (TEM) images. Selected area diffraction (SAD) patterns obtained for the samples illustrate the good distribution of the nano reinforcement. Among the different ball milled samples H-3 is noted to attain the best Pre-distribution of Al_2O_3 among the rest of the samples. A notable improvement is observed in the distribution of nanoparticles and CNTs, with an increase in LVRR. H-5 is noted to attain the best distribution of CNTs as well as nanoparticles, unlike H-1, which possesses a poor distribution. This suggests that the H-5 cast sample would attain the best tensile strength as a result of the best distribution of nanoreinforcements in the matrix and due to absence of surrounded voids.

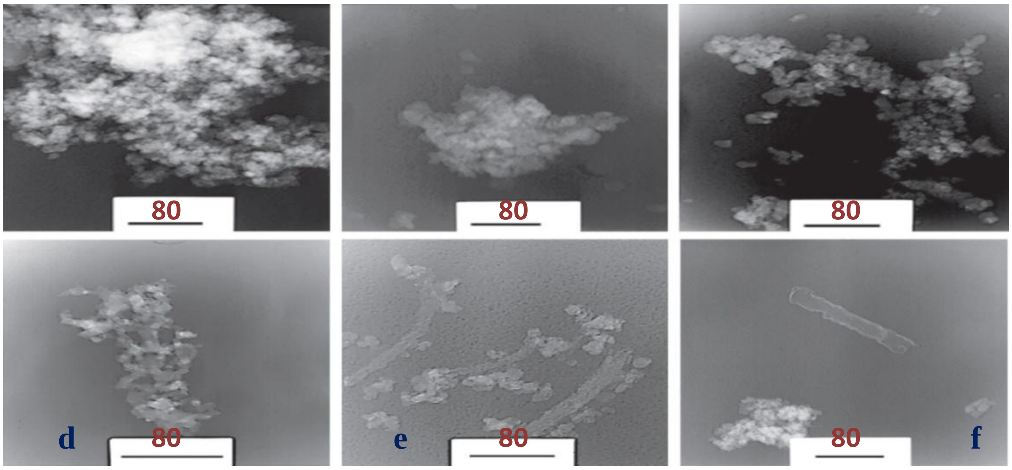

Figure 5. TEM images of the ball milled mixture showing a pre-distribution of (d) H-1, (e) H-3, and (f) H-5 *[8]*

Mechanical properties of Al hybrid composite

CNTs are revealed to play a dual role, i.e., as a launching vehicle and as a secondary nanoreinforcement, which transforms the composite to a hybrid composite. CNTs destroyed during ball milling are illustrated to assist in improving the strength of the composite by anchoring to the matrix via a splat surface. The H-3 sample is identified to be an optimal ratio for attaining enhanced strength and hardness with minimal loss in ductility compared to other nanocomposite samples. H-3 sample: 45 g Al, 14 g nano Al2O3, 1 g CNTs is the opimal sample, which shows UTS is 197 Mpa, % Elongation 3.9, Hardness 93 BHN.

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CONCLUSION

With the use of GNPs as reinforcement in aluminium matrix it is found the density got reduced, Vickers hardness, compressive strength, and wear behavior of the Al composites were improved. The highest Vickers hardness (57 HV) was observed at the Al–0.1 wt-% GNPs composite compared with pure Al (28±2 HV). Above 0.1 wt-% GNPs content, the hardness decreased due to the agglomeration tendency of GNPs. Ultra-fine nanoparticles possess a high tendency to cluster compared to nanoparticles, resulting in the fading of the composite strength. In the case of Hybrid composite ultra-fine nanoparticles are successfully distributed in the Al matrix using a stir casting route with CNTs as secondary launching vehicles. The launching vehicle methodology is noted to be significantly enhancing the distribution of reinforcements. The use of a secondary launching vehicle (CNTs) is observed maximum Hardness 93 BHN. This technique is and also that ductility is also improved by using secondary vehicles.

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