Aluminium Metal Matrix Composite Reinforced With Carbon Nanotubes / Graphene – A Review

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Abstract : This paper includes a comprehensive review of composites filed with aluminium metal matrix. The literature study includes all aspects of the preparation methods, mechanical properties, tribological properties, erosion properties and thermal properties of corrosion and cavitation. Recent years, owing to the huge demand in various industrial applications, aluminium graphene/CNT nano-composites was gaining greater momentum. The Fabrication of metal matrix composites, strengthening mechanisms in metal matrix composites, mechanical behavior of all composites and evaluation of mechanical properties were discussed below in detail. In fact these newly developed materials have high strength, high stiffness and high hardness, whereas these materials are difficult to be machined by conventional machining processes.

Keywords: Aluminium, MMC, Carbon Nanotubes, Graphene, Fabrication.

Introduction: Metal Matrix Composites are made by adding the reinforcements materials in metal matrix. These reinforcements are such as metals, ceramics etc. Reinforcements are added into base metal to improve the properties of base metal such as physical, mechanical and electrical. Mechanical properties such as stiffness, strength, flexural rigidity, hardness etc. increases in composites when compared to base metal. Generally, metals such as aluminium, steel, magnesium, nickel, copper are preferred to produce MMC. Aluminum is widely used for its low weight, greater stiffness, high strength and cost effectiveness. Aluminium metal matrix composites are widely in various fields such as in automobile, aircraft, marine, aerospace. Aluminium is known for its light weight and low density making it ideal for aerospace and automotive industries. Reinforcement materials like carbon nanotube, graphene, carbon fibre have high strength and good mechanical and electrical properties which can enhance the strength of aluminium. This paper will provide a detailed study on the review done with CNT, graphene and carbon fibre as reinforcement in aluminium metal matrix composites. Also, it focuses on high energy ball milling and stir casting process as processing technique and its effect on mechanical properties

The composites industry has begun to reveal that the commercial applications of composites assure to offer much greater business opportunities than the aerospace sector due to the sheer size of shipment industry. Thus the shift of composite applications from aircraft to other commercial uses has become flashy in recent years. Because of it enhanced stiffness strength and dimensional durability, increased toughness and bounce strength, increased mechanical blunt, diminished permeability to gases and liquids, regulated electrical properties, reduced cost, decreased heat expansion, enhanced chemical wear and decay resistance, reduced density it is used in many engineering applications.

2. PROCESSING TECHNIQUES OF Metal Matrix Composites

There are various fabrication or manufacturing processes being developed by the researchers for metal matrix nano composites. The major four types of methods are (i) Liquid state process (ii) Solid state process (iii) Vapour deposition techniques (iv) Semi-solid state method. The processing methods are shown in Table.

Table 1: Various fabrication ways for aluminium metal matrix nano- composites

Sr. no.	Liquid state process	Solid state process	Vapour Deposition
1	Stir Casting	Diffusion Bonding	Physical Vapour Deposition
2	Squeeze Casting	Powder Metallurgy	
3	Compo Casting	Spark Plasma Sintering	
4	Ultrasonic Cavitations based Solidification	Laser Deposition	
5	Spray Deposition		

2.1 Reviews On Carbon Nanotubes (CNT) Composites Using Various Process Techniques

C. Suryanarayana –[1] Mechanical alloying (MA) is a solid-state powder processng technique involving repeated welding, fracturing, and rewelding of powder particles in a high-energy ball mill. Recent advances in these areas and also on disordering of ordered intermetallics and mechanochemical synthesis of materials have been critically reviewed after discussing the process and process variables involved in MA. The often vexing problem of powder contamination has been analyzed and methods have been suggested to avoid/minimize it. The present understanding of the modeling of the MA process has also been discussed. The present and potential applications of MA are described. Wherever possible, comparisons have been made on the product phases obtained by MA with those of rapid solidification processing, another non-equilibrium processing technique.

Li et al. [2] has developed a method for achieving uniform dispersion in aluminium powder of a high percentage of carbon nanotubes (CNTs). Al powder has undergone surface modification to add on its surface hydrophilic polyvinyl alcohol (PVA) that has excellent wettability and heavy hydrogen bonding which interact with surface modified CNT. It has been established that the PVA-modified Al–PVA powder, when combined with a CNT aqueous suspension, ensued improved uniformity of adsorption of CNTs than the pristine Al powder. Nanoflake Al powder has a larger surface area and possess greater geometric compatibility with the CNTs compared to spherical powder resulting in significantly improved the adsorption potential of CNTs. Consequently, the nanoflake Al-PVA powders reached an even dispersion of 20 vol. per cent CNTs.

M. K. Esawi et al. [3] dispersed Carbon nanotubes (CNTs) by multi-pass friction stir casting into Al matrix to produce 5 percent CNT- 2009 Aluminium composites. The extreme strength of the composites was attained with three-pass FSC and ascribed to the collective result of reduction of the CNT cluster, grain refining, and shortening of the CNT. A universal strength model that takes into account the microstructural factors – the size ratio of CNTs, grain size and CNT cluster and pore concentration – is suggested to forecast the consolidation of CNT – 2009Aluminium composites. The projections agree well with the experimental findings.

A. M. K. Esawi et.al. [4] in another study manufactured composites with 1 and 5 per cent carbon nanotubes dispersed in 2009 aluminium composites using with powder metallurgy (PM) route complemented by four pass friction stir casting. Tensile properties and the thermal expansion coefficient (CTE) of the composites were measured at temperatures between 20 to 300 oC. It has been suggested that the load transmission mechanism is present even at temperatures up to 300 oC , thus increasing the yield strength of the 2009Aluminium composite with 1.5 percentage CNTs at 260 – 300 oC compared to the base 2009 Aluminium matrix. Yet, due to the faster refining of the ultrafine-grained matrix, the yield strength at 300 oC was even inferior for the 4.5 per cent CNT- 2009 Aluminium composite than that for the matrix. Compared to the base metal matrix, the composites' CTE is substantially decreased which could well be expected by the Schapery model.

Kim et. al. studied semi-solid powder processing (SPP) which has the merits of both semi-solid forming with powder metallurgy. In their research SPP has reinforced carbon nanotube (CNT) in 6061aluminum alloy. Mechanical alloys were used in the matrix process to distribute the CNTs. The influence of the casting temperature on the composition and microstructure of Al6061–CNT composite and its effect hardness was investigated. Overall, during the strengthening of semi-solid system, the Al6061–CNT composite displayed complete with 1000 bar of pre-compaction. Microstructure and the fracture surface analysis revealed that the CNTs were distributed evenly around the matrix

Phuong et.al. prepared CNT reinforced aluminium (CNT / Al) nanocomposites using the innovative method of powder metallurgy and consequently manufactured using the technique of high-pressure torsion (HPT). It examines the impact of CNT percentage and annealing temperature on the nanocomposite hardness. The findings show that annealing materials lead to secondary hardening at temperatures below 150 oC, while annealing softens the nanocomposites at higher temperatures. It is shown that composite produced by HPT with 1.5% of CNTs have the highest hardness compared to composites with CNTs from 0 to 2%.

Zhao et.al. has developed the carbon nanotube (CNT)-reinforced Aluminium composites production process. In a characteristic procedure, the Co-catalyst was uniformly placed on the surface of Aluminium powder by impregnation route, and the CNTs were then produced by chemical vapour deposition in the Al powder to attain CNT - Aluminium powders. Later a short period of ball-milling of the attained powders, CNT – Aluminium composites were produced by compaction, sintering and hot extrusion of the powders. The CNT dispersoid is intensely embedded in the Aluminium powder during this process, creating an active interface bonding with the matrix. Due 21 to this, the CNT – aluminium composite with 2.5 wt. per cent CNTs demonstrate an ultimate tensile strength of 0.35 GPa and strong ductility of 19 per cent elongation to re that is 1.9 times more than that of pristine Aluminium.

2.2. Review on Graphene Composites Using Various Process Techniques

Ömer Güler –[5]In this paper, the studies conducted on metal matrix composites, in which graphene was used as reinforcing material, were investigated. In these studies, the properties of the produced composites were presented and the factors affecting these properties were explained.

Mevlut Gurbuz –[6] Currently, graphene is used in aluminum matrix composite manufacturing due to its superior mechanical properties. However, few detailed studies exist on the effect of the process conditions such as sintering temperature (TS), time (tS), and a number of graphene nanoplatelets. Therefore, the effects of different sintering times (tS ¼ 60, 120, 180, 300 min), sintering temperatures (TS ¼ 550, 600, 630C), and graphene addition (0.1, 0.3, 0.5 wt%) on apparent density and hardness were reported in detail in this study. The crystal structure and microstructure of fabricated

composites by powder metallurgy method were examined with X-ray diffractometer and scanning electron microscopy. Apparent density and mechanical properties were tested by density meter and micro Vickers hardness tester. The results indicated that the best sintering time, sintering
temperature, and graphene addition were determined to be 180 min, 630C, and 0.1 wt%, respectively, for the best hardness of composite. The hardness of composite increased from 38 to 57 HV when compared with pure aluminum under the best process conditions

S.E. Shin –[7] Microstructure and mechanical properties of aluminum alloy 2024 (Al2024)/few-layer graphene (FLG) composites produced by ball milling and hot rolling have been investigated. The presence of dispersed FLGs with high specific surface area significantly increases the strength of the composites. The composite containing 0.7 vol.% FLGs exhibits tensile strength of 700 MPa, two times higher than that of monolithic Al2024, and around 4% elongation to failure. During plastic deformation, restricted dislocation activities and the accumulated dislocation at between FLGs may contribute to strengthening of Al2024/FLG composites

Muhammad Rashad [8], This paper reports an Aluminum–Graphene Nanoplatelets (Al/GNPs) composite using a semi-powder method followed by hot extrusion. The effect of GNP nano-particle integration on tensile, compressive and hardness response of Al is investigated in this paper. It is demonstrated that 0.3 wt% Graphene Nanoplatelets distributed homogeneously in the matrix aluminum act as an effective reinforcing filler to prevent deformation. Compared to monolithic aluminum (in tension), Al–0.3 wt% GNPs composite exhibited higher 0.2% yield strength (þ14.7%), ultimate tensile strength (11.1%) and lower failure strain (40.6%). Surprisingly, compared to monolithic Al (in compression), Al–0.3 wt% GNPs composite exhibited same 0.2% compressive yield strength and lower ultimate compression strength (7.8%), and lower failure strain (20.2%). The Al–0.3 wt% GNPs composite exhibited higher Vickers hardness compared to monolithic aluminum (þ11.8%). Scanning electron microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDS) and X-ray diffraction (XRD) were used to investigate the surface morphology, elemental percentage composition, and phase analysis, respectively

S. Venkatesan – [9] This research article focuses on the development and characterization of Aluminum alloy 7050 matrix composites reinforced with Graphene nano particles. Liquid metallurgy techniques such as stir casting and squeeze casting processes were adopted for fabricating the composites reinforced with Graphene nano particles. Liquid metallurgy techniques such as stir casting and squeeze casting processes were adopted for fabricating the composites. Certain parameters like melting temperature, stirring speed and graphene content with three levels were considered for the fabrication experiments. Taguchi's L27 Orthogonal array is used to evaluate the yield strength, tensile strength and hardness of AA7050-graphene composites fabricated by stir and squeeze casting. Based on the experimental results, analysis of variance (ANOVA) was conducted to determine the level of influence of the parameters on the strength properties such as yield, tensile strengths and hardness of the specimens

Neelima Devi-[10] Aluminium alloy materials found to the best alternative with its unique capacity of designing the materials to give required properties. In this paper tensile strength experiments have been conducted by varying mass fraction of SiC (5%, 10%, 15%, and 20%) with Aluminium. The maximum tensile strength has been obtained at 15% SiC ratio. Mechanical and Corrosion behavior of Aluminium Silicon Carbide alloys are also studied.

Gyanendra Singh –[11] different type of metals like Mg, Zn used in the process of manufacturing of aluminum composite in this research paper we take an sample of aluminum composite material containing Cu-Zn-Mg composite materials generally produces by selecting the matrix and reinforcement. Aluminum composite material has high melting point .in this paper we wake our test sample of aluminum magnesium composite material by stir casting. The purpose of our work is to find out the mechanical properties of Aluminum composite material & find the working capacity with compare to pure Aluminum metal. .pure metals have some limitations like low melting points, low porosity, low elasiticty etc. in technology Sector we used composite material to make an much effective prototype or mechanical structure having very good mechanical properties. Properties of composite materials is completely depends on the method used to produce it.

S.E. Shin –[7] Microstructure and mechanical properties of aluminum alloy 2024 (Al2024)/few-layer graphene (FLG) composites produced by ball milling and hot rolling have been investigated. The presence of dispersed FLGs with high specific surface area significantly increases the strength of the composites. The composite containing 0.7 vol.% FLGs exhibits tensile strength of 700 MPa, two times higher than that of monolithic Al2024, and around 4% elongation to failure. During plastic deformation, restricted dislocation activities and the accumulated dislocation at between FLGs may contribute to strengthening of Al2024/FLG composites

Jayanta Mondal -Graphene oxide (GO) powder was dispersed in an AlMg5 matrix using high energy ball milling. The obtained blend was then completely densified by hot pressing. No further hardening processing step was performed. Nevertheless, only 1 vol% of GO in the Aluminum alloy matrix leads to a significant improvement of the mechanical resistance. The ultimate tensile strength (540 MPa) and the macro hardness (166 HV) are increased by a factor of 2 compared to the same AlMg5 alloy without Nano particulate material and compacted under the same conditions. The bending strength is even increased by a factor of 4 reaching a value over 800 MPa. The GO powder can be applied as a mechanical reinforcement to other scenarios such as polymer and ceramic systems.

Mina Bastwros, A 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. A three point bending test was performed to characterize the mechanical properties of the composite. 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 processed at the same condition.

Sr. No	Year	Author	Title	Base Material	Reinforcement	Fabrication Method
1.	2019	P.Shriram Murthy	Impact on mechanical properties of hybrid aluminium metal matrix composition	Aluminium	Silicon carbide	Stir casting
2	2015	Tanuj Giri	Fabrication of aluminium / magnesium composite. Material and optimization their mechanical properties	aluminium	Cu-ZN-Mg	Stir casting
3.	2008	M.Adamiak	Manufacturing of aluminium based composition material	aluminium	Al2O3	Powder metallurgy

			reinforcement by Al2O3 particle			
4.	2019	Abdul Munaf Shaikh	Hybrid metal matrix composites reinforced with sic and neem leaf ash using stir casting method	Aluminium alloy 6063	Reinforce ment sic and Neem leaf Ash	Stir casting
5.	2018	S. Venkatesan	Characterization of Aluminium alloy 7050 metal matrix composite reinforced with Graphene.	Aluminium alloy 7050	Graphene.	Stir Casting

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