FABRICATION AND EVALUATION OF MECHANICAL PROPERTIES OF ALUMNIUM HYBRID NANO METAL MATRIX COMPOSITES

[1]Sachin.S. P, [2]Rajath.S, [3]Sanjay Patil. S, [4]Sangharsh Mudugal,[5]Vijee Kumar
[1,2,3,4] UG Student,[5]Assistant Professor
School of Mechanical Engineering
[1]REVA University, Bengaluru, India

Abstract: In this present work, Al6061 used as base material and Carbon Nano Tubes (CNT's)'s and Graphene were used as reinforcing materials to develop hybrid composites. Al6061 is mixed with CNT's (2% in weight) and Graphene (0.5% and 1% in weight) using ball milling for different time duration for different set of samples to study the properties. The powder samples were prepared by using powder metallurgy technique. The blended powders compacted using hydraulic machine and obtained saples were subjected to sintering process carried out at 580°C with nitrogen atmosphere. The blended powders were characterised using Scanning Electron Microscopy (SEM) and X-Ray Diffraction(XRD). The results shows hardness of the composites was subsequently increases for 2% CNTs and varying graphene.

***Index Terms* – Al6061, CNT's, Graphene, Powder metallurgy, Characterization-SEM & XRD**

1. INTRODUCTION

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small number of dispersed phases in their structures, however they are not considered as composite materials, since their properties are similar to those of their base constituents (physical property of steel is similar to those of pure iron). Favourable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc[1-3].

In 1991 the true first invention of nanotube was finally made. It seems as though there was a race between Russian nanotechnologists and Sumio Iijima. The first observation of the Multiwalled carbon nanotubes was credited to Iijima. In 1859 Benjamin Collins Brodie became aware of the highly lamellar structure of thermally reduced graphite oxide. The structure of graphite was identified in 1916 by the related method of powder diffraction. It was studied in detail by Kohlschütter and Haenni in 1918, who described the properties of graphite oxide paper. Its structure was determined from single-crystal diffraction in 1924[3-5].

Metal Matrix Composites (MMCs) reinforced with ceramic particulates offer significant performance advantages over pure metals and alloys. MMCs tailor the best properties of the two components, such as ductility and toughness of the matrix and high modulus and strength of the reinforcement. These prominent properties of these materials enable them to be potential for numerous applications such as automotive, aerospace and military industries. Carbon nanotubes (CNTs) is regarded as one of the stiffest and strongest materials ever discovered[6-8].

2. MATERIALS AND METHODS

2.1 Material Used

Aluminium6061(Al6061) (fig.1) has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation. Carbon Nanotubes are the strongest materials used in any aspects, it has been used in almost all the stressed parts in automobiles, aircrafts and ship building etc. Graphene is kind of material, which has the strongest binding and stressful conditions to use in heavy weight carrying and wear conditions. Chemical composition of Al6061 shown in Table.1(a) and some of the properties are shown in Table.2&3.

Table.1: Chemical composition of Al6061 alloy

Components	% used	Components	% used
Al	Remaining	Magnesium	0.8-1.2
Silicon	0.4-0.8	Chromium	0.04-0.35
Iron	0-0.7	Zinc	0-0.25
Copper	0.14-0.4	Titanium	0-0.15
Manganese	0-0.15	Others	0.15

Key Properties of this material are like, it is having medium to high strength., good toughness., good surface finish., excellent corrosion resistance to atmospheric conditions., good workability, widely available.

Table 2: Physical and Mechanical properties

Particulars	Density	Young's Modulus	Tensile Strength	Elongation	Poisson's Ratio
Values	2.70g/cm^3	68.9 Gpa	124-290Mpa	12-25%	0.33

Table 3: Thermal properties

Particulars	Melting temperature	Thermal conductivity	Linear thermal expansion co-efficient	Specific heat capacity
Values	605°C	151-202W	2.32×10^{-5} k^{-1}	897 J/kg-k

2.2 Reinforcements

2.2.2Carbon Nanotubes

Multi walled Carbon Nanotubes(MWCNTs) (fig.2) are allotropes of carbon with cylindrical nano structure. This cylindrical carbon molecules have unusual properties, which are valuable for Nano technology, electronics, optics and other fields of material science and technology. Some of the properties are shown in Table 4.

Table 4: Properties of CNT's

Properties	Specific Density (kg/m^3)	Youngs Modulus (Tpa)	Strength (GPa)	Strain of Break (%)	Thermal Conductivity (W)	Electrical Conductivity(seimens/m)
Values	1.3 – 2	1	10 – 60	10	>3000	10^6 - 10^7

2.2.1 Graphene

Graphene (fig.3) is an allotrope form of carbon consisting of a single layer of carbon atoms arranged in a hexagonal lattice. Some of the key properties are, most reactive form of carbon, tensile strength exceeds 1 Tpa and it is stretchable up to 20 of its initial length. Some of the properties are shown in Table.5.

Table 5: Properties of Graphene

Properties	Stiffness	Strength	Toughness
Values	1 Tpa	42 N/m	4 – 4.6 MPa

Fig.1: Al6061 powder

Fig.2: Graphene

Fig.3: CNT's

2.3 Preparation of powder samples

In the case of fabrication of CNTs-MMCs through powder metallurgy process, Al6061 fine powder as matrix and fixed weight percentage (2%) MWCNTs having diameter 30-50nm, graphene 30nm thickness (varying percentage of 0.5% and 1%) were used as reinforcements. Planetary ball milling used to blend the powders by varying ball milling time 0.5hr, 1hr and 1.5hr with 250rpm speed constant for samples. The weight percentage and time variation of each sample is shown in the below Table.6&7.

Table 6: Weight ratio of powder samples

Sample Number	Al6061	CNT	Graphene
S-1	100%	0%	0%
S-2.1	97.5%	2%	0.5%
S-3.1	97%	2%	1%

Table 7: Speed and time of milling sample

Sample number	Speed in rpm	Time in min
S-1	300	60
S-2.1	300	30
S-2.2	300	60
S-2.3	300	90
S-3.1	300	30
S-3.2	300	60
S-3.3	300	90

3. EXPERIMENTATIONS

3.1 Compacting and Sintering

After ball milling the powder samples as shown in fig.4, using Compact Testing Machine (CTM) as shown in fig.5, the powder samples were compacted by the using die as per ASTM standards. After compaction, the green samples are as shown in fig .6. The green samples were processed for sintering carried out with temperature 580°C, constant for all the samples. Sintering is done for 8hours nitrogen atmosphere to prevent oxidation of the specimens.

Fig.4: Powder samples

Fig.5: Compacting

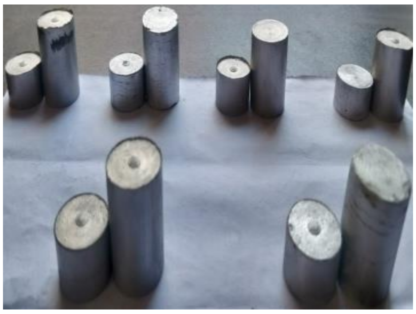

Fig.6:Green samples

3.2 Density Test and Hardness Test

A material's density is defined as its mass per unit volume. In other ways, density is the ratio between mass and volume or mass per unit volume. Density is essentially measurement of how tightly matter is crammed together. The principle of density was discovered by the Greek scientist Archimedes, but it is easy to calculate if u know the formula and understand its related units. By the formula below the Actual density can be calculated to compare the values between reinforced and non-reinforced materials given by Equation -1, Fig.7 shows the density testing apparatus.

$$Density = \frac{W(air)}{[W(air) - W(water)]} \ldots Eq\ (1)$$

Hardness is defined as the ability of a material to resist plastic deformation. Micro Hardness testing machine as shown in fig.8 determines the degree of deformation of a material and it is generally accepted as an important property and a valuable parameter of comparison with the tooth structure. We are using micro hardness testing machine which is more accurate and easier to measure the indentation than Vickers and Brinell. Indenter used is Diamond indenter. It is having a magnification of 100X and 500X.

Fig7: Density testing apparatus

Fig 8: Computerized Micro Hardness Testing Machine

3.4 Scanning Electron Microscope

A Scanning Electron Microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image. In a typical SEM, an electron beam is emitted from an electron gun fitted with a tungsten filament cathode. Tungsten is normally used in thermionic electron guns because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be electrically heated for electron emission, and because of its low cost. Other types of electron emitters include lanthanum hex boride (LaB6) cathodes, which can be used in a standard tungsten filament SEM if the vacuum system is upgraded or field emission guns (FEG), which may be of the cold-cathode type using tungsten single crystal emitters or the thermally assisted Schottky type, that use emitters of zirconium oxide. For study of dispersion of the reinforcements in the matrix.

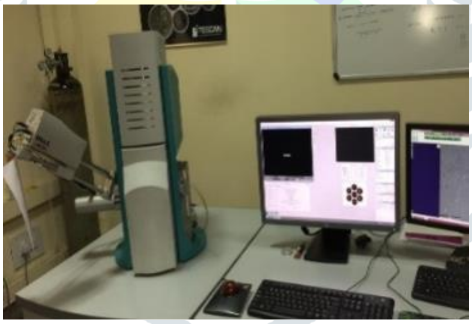

Fig.9: Scanning Electron Microscope

4. RESULTS AND DISCUSSION

4.1 X-Ray Diffraction

XRD for Al6061 powder sample carried to make confirm Al6061 and the below Table 8, Figure 10 shows the XRD graph. The results shows peaks of counts for the preferred angle Al6061 and used in the present work.

Table 8: XRD result of Al6061

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
38.4869	11307.35	0.0900	2.33719	100.00
44.7322	4754.00	0.1076	2.02432	42.04
65.0871	2579.67	0.1201	1.43194	22.81
78.2020	2370.04	0.1402	1.22136	20.96

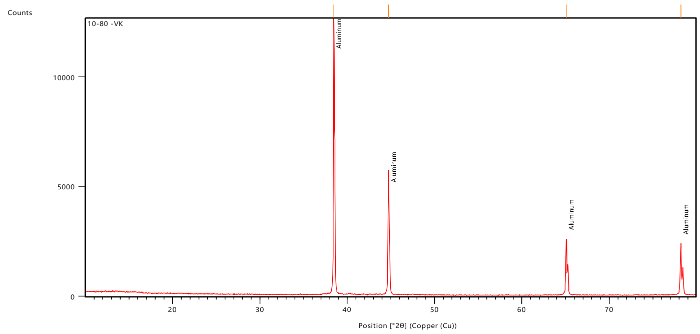

Fig 8: XRD image of Al6061

4.2 Density

Theoretical density test was performed by using rule of mixture, it shows the density is decreasing for increasing the weight percentage of graphene. Actual density was calculated for green samples and also after sintering by Archimedes principle, the results shows that density of the composites increases with increasing ball milling time. The table 9 shows the details results of density of nano composites.

Table 9: Density Results

Sample number	Theoretical density (g/cm^3)	Actual density (g/cm^3)	
		Before sintering	After sintering
S-1	2.7	2.209	2.337
S-2.1	2.685	2.278	2.442
S-2.2	2.685	2.138	2.552
S-2.3	2.685	2.327	2.571
S-3.1	2.683	2.177	2.535
S-3.2	2.683	2.418	2.492
S-3.3	2.683	2.230	2.535

4.3 Hardness

Hardness is defined as the ability of a material to resist plastic deformation .Hardness determines the degree of deformation of a material and it is generally accepted as an important property and a valuable parameter of comparison with the tooth structure. increase in the ball milling increases, since uniform distribution of reinforcement. For 1% wt nano Graphene percentage composites is more difficult to distribute in between matrix. The below fig.9 gives the information about the results obtained from hardness test.

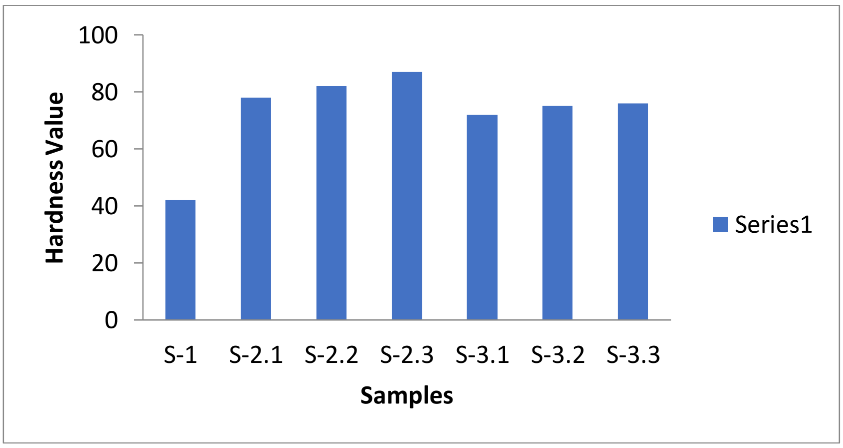

Fig.9: Graphical Representation of Hardness test results.

4.4SEM images of Ball milled powdered samples

The SEM results shows the below and reveals that for 0.5% of graphene samples, uniform distribution takes place by increasing ball milling time but whereas for 1% graphene composites samples from agglomeration due to difficulty in distribution of reinforcement in matrix.SEM images about each sample as shown in fig.10.

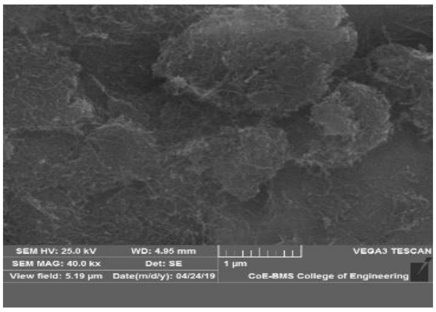

Fig10.1: SEM image of S-5.1.

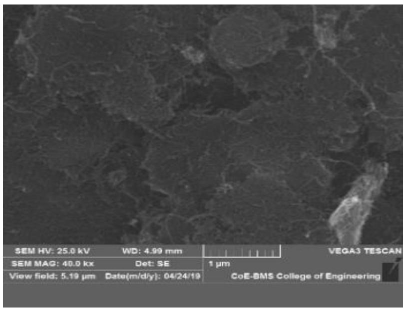

Fig.10.2: SEM image of S-5.2.

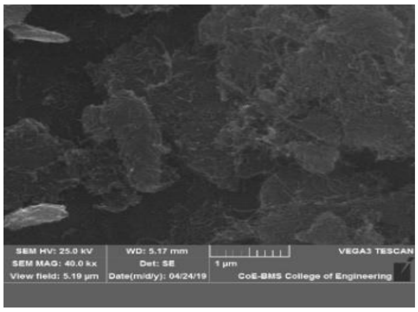

Fig.10.3: SEM image of 5.3.

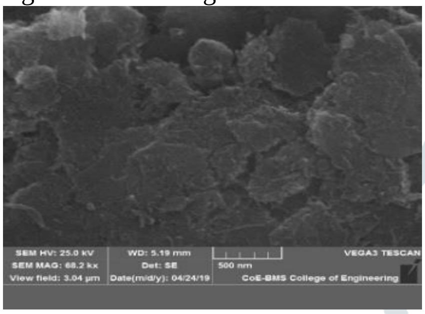

Fig.10.4: SEM image of S-6.1.

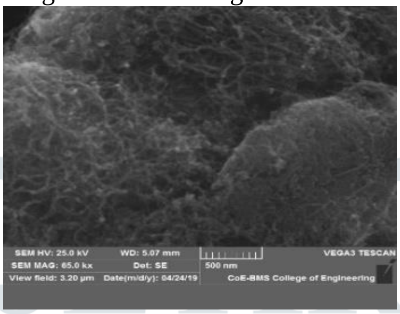

Fig 10.5: SEM image of S-6.2.

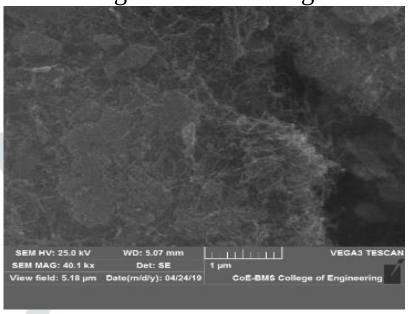

Fig 10.6: SEM image of S-6.3.

Fig.10 SEM images of nano composites samples.

5 Conclusion

From the results, Al6061 as confirmed with no oxide formation, and CNT's and Graphene are used for the preparation of the hybrid matrix prepared by powder metallurgy process. From the results of density, the theoretical density is decreasing whereas the actual density of the samples before sintering is comparatively lesser than density after sintering, so this shows that after the sintering process the binding of the particles is carried out. Hardness result, increase in the ball milling increases the hardness. SEM results shows the distribution of the reinforcements into the matrix which exhibits same results that we can conclude the distribution of the particles are improved on increasing the ball milling time. It is referred that increasing the ball milling time will increase the distribution, but we have not reached the complete uniform distribution as mixing of Graphene with 1% of weight percentage is difficult.

6 Reference

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