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Optimized Characterization of Aluminum - Graphene Metal Matrix Composites Using Powder Metallurgy Technique

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ABSTRACT

Composite materials are combination of different constituent materials which can lead to the desired combination of low weight, High stiffness and strength. The composite material thus obtained has superior properties, than their parental ones. This includes increased strength, service temperature, improved wear resistance, and high toughness etc. Thus these materials become very attractive search for better reinforcement material among the scientific and engineering community. The work 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 Aluminum Metal Matrix Composites significantly.

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 compression, hardness, wear, scanning electron microscope (SEM).

In recent years, powder metallurgical components are increasingly being utilized for automotive and structural applications. As compared to conventional casting techniques, Powder Metallurgy processing offers advantages such as lower processing temperature, near-net shaping, final density, greater material utilization and a more reinforced microstructure that provides superior material properties. In addition, Powder metallurgy products have greater micro structural homogeneity. The project focuses to study of mechanical, tribological and characterization studies of graphene reinforced aluminum composites.

Key words : Powder Metallurgy, Aluminum, Graphene, Wear, Hardness, Compression, SEM.

I. INTRODUCTION

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 (MMC) have evoked a keen interst in recent times for potential applications in aerospace and automotive industries owing to their superior to weight ratio and high temperature resistance. Reinforcement to the aluminum resistance metal by carbon nanotubes along with graphene enhances the mechanical properties like strength of the aluminum composite material. It is important to understand the variation in hardness before and after reinforcement to the aluminum. In this paper hardness test is analyzed along with experimental procedure foraluminum[2].

The term hardness, as it is used in industry may be defined as the ability of a material to resist permanent indentation or deformation when in contact with an indenter under load. Compression strength is the capacity of material to withstand axially directed pushing force. When the limit of the compression strength is reached, materials are crushed.

Aluminum metal matrix composites are widely used in engineering applications, specially automobile, aerospace, marine and mineral processing industries owing to their improved wear properties compared to conventional monolithic aluminum alloys. Presently hybrid composites plays vital role in engineering application. The researchers who developed composites, were subjected to many characterizations, specifically wear behavior of these composites were explored to a maximum extent by number of research for the past 25 years. In the review an attempt has been made to consolidate some of the aspects of mechanical and wear behavior of Al-MMCs and the prediction of the Mechanical and Tribological properties of Aluminum MMCs fabricated using Powder Metallurgy Technique[3].

Al powder of 200 mesh size 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 coveringComposite/Structural materials, Paint &Coating, Energy, Biomedical, Electronics etc.

2. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Materials Used

Table.1 Chemical composition of Al6061 powder by weight percentage

Component	Al	Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	others
Amount (Wt. %)	Balance	0.92	0.76	0.28	0.22	0.06	0.10	0.04	0.07	0.05

Table .2 Details of Graphene

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

2.2 Hardness

Fig 1.Brinell Hardness Test

The hardness of the specimen is calculated by using Brinell Hardness Testing Machine. The load is selected by use of the given test table. The ball indented is chosen for testing the specimens. Major load of 10 kg was applied for ten seconds. The diameter of impression was measured by using Brinell microscope and the BHN of the specimens was calculated by using the formula.

Fig 2. Microscope

BHN = $\frac{2F}{\pi D\left(D-\sqrt{D^2-d^2}\right)}$ …………..E.q 1.1

Where ,BHN =Brinell hardness number, F = Load (kgf),D = Ball indenter dia in mm

D =Dia of identification impression in mm.

2.3Wear

Wear is the loss of material from the surface during relative movement in contact with a counter face and it leads to decreased dimension by which the components cease to be useful. All the mechanical components that undergo sliding or rolling contact are subject to some degree of wear. Typical examples are bearing, gears, seals, guides, piston rings, splines, brakes and clutches.

Fig.3 Wear testing machine

2.4Compression strength

Compression strength is the capacity of material to withstand axially directed pushing force. When the limit of the compression strength is reached, materials are crushed.

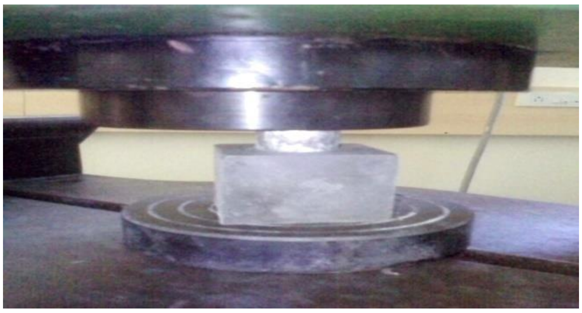

Fig 4. Compression Test

2.5 Scanning Electron Microscope (SEM)

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.

Fig.5 Scanning Electron Microscope apparatus (SEM)

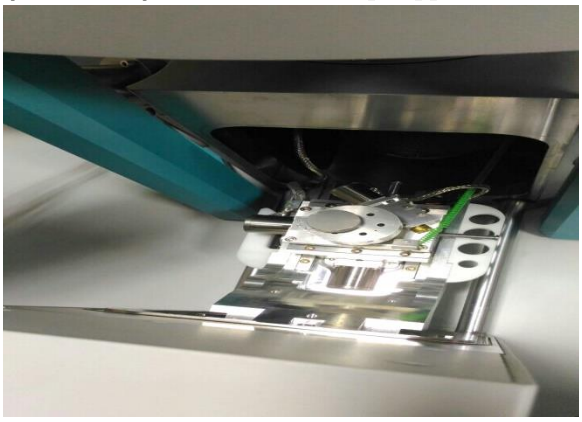

Fig.6 Scanning Electron Microscope with Specimen (in side SEM)

2.6 Experimental Details

The 0, 1, 3,6 and 8 wt. % of grapheneas reinforcement weight percentage was mixed with AluminiumPowder. Use ballmill, the process of mixing is continued for duration of 10 min. at 200 rpm in order to get uniform mixing using ball milling.The mixture of a particular weight percentage of Graphene and Aluminium was compacted in the die assembly using a 40 Ton capacity hydraulic Press and standardized load (200 KN) was applied gradually. In the present study the addition of graphene has been limited to 8% by weight as beyond this value the specimen showed cracked surfaces.

Specimens were prepared for various compositions and the samples were investigated for microstructure, using optical microscope and SEM apparatus. Sintered billets were tested for hardness,wear,compression and SEM analysis.

3.RESULTS & DISCUSSION

3.1 Hardness Test

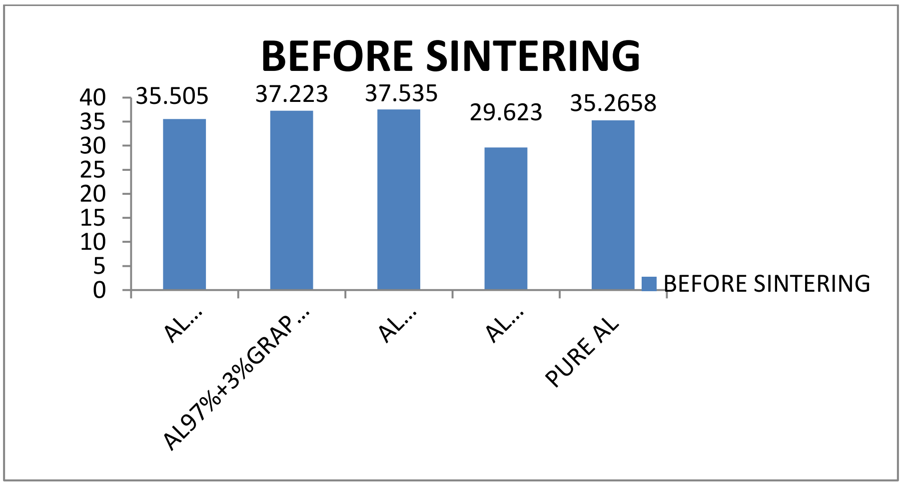

Fig.7 BHN value v/s wt.% of Graphene (Before Sintering)

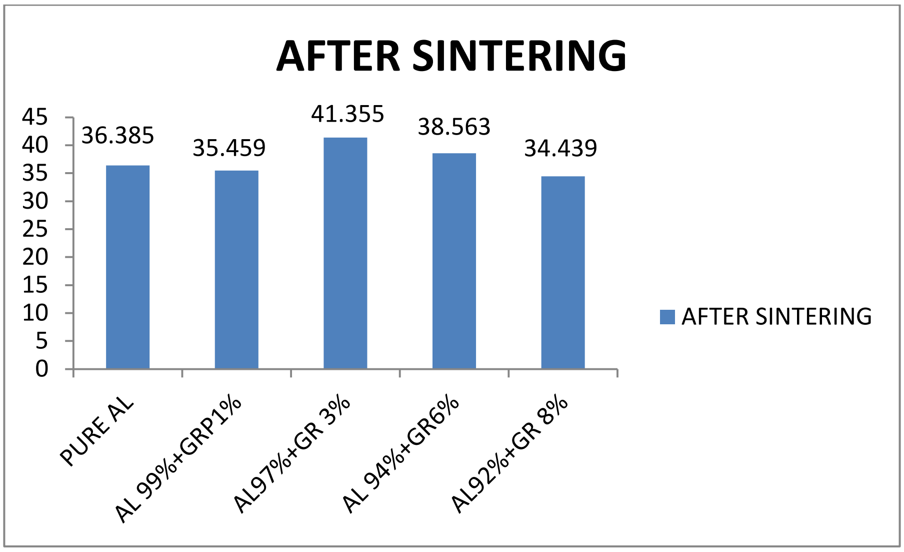

Fig.7 BHN value v/s wt.% of Graphene (After Sintering)

The fig.7 shows the hardness value of the composites after sintering. The composite is found be harder than the matrix alloy due to higher hardness of dispersoid particles after sintering. Increase in hardness of the specimens after sintering with increase in percentage of Graphene is evident.Aluminium 3% wtgraphene has higher BHN no 41.355 as compared to Aluminium.

3.2 Wear Test

The specimen is glued to holder. The surface are polished up to 1000 grit emery paper to obtain flat faces on all the sides. The tribometer has been calibrated to read zero value. The speed is adjusted to 250 rpm using a knob and 0.5kg load is applied on the pan and the time is set in steps of 2 minutes till 10 minutes for 0.5kg. Once the desired time is reached, motor will stop automatically and displayed reading of the wear indicator reading is tabulated. The frictional force was monitored continuously throughout the test. The wear test was conducted for the total period 10 minutes. For every 2 minutes, readings were noted down. Experiment is repeated for all the specimens with constant load and speed.

Operating Conditions: Load – 0.5kg, 1kg, 1.5kg,Speed (N) – 250 rpm,Track Radius – 60 mm,Time – 10 min

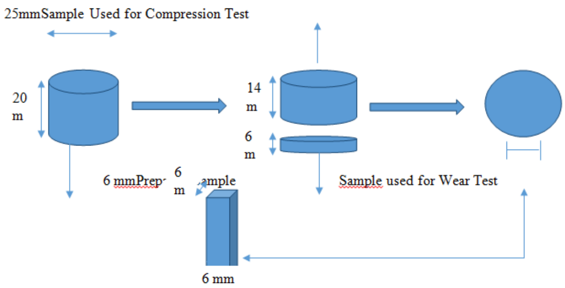

Fig. 8 Flow diagram of Preparation of Samples for Wear Test

Calculations: Sliding Distance = $\frac{2\ \pi r N}{60}$*(t) in mm ………….Eq. no 6.10

Where N is speed of the disc in rev/min ,t' is time in seconds

Specific Wear Rate = $\frac{\text{wear indicator reading}*\text{Density}*\text{Area of specime}}{\text{Sliding density}}$ in mm^3/N-mm.

Cumulative volume loss = Area*Wear indicator reading (mm^3)

Co-efficient of Friction, μ=F/N,Where F is frictional force and N is normal load.

3.2.1 Frictional force results:Table 3.Shows the frictional force and wear results

97% Al Fine Powder + 3% Graphene (0.5 kg), 250rpm

Time	2	4	6	8	10
Frictional Force (N)	0.28	0.30	0.28	0.32	0.28
Wear (mm)	0.00000022	0.0000011	0.0000014	0.00000055	0

97% Al Fine Powder + 3% Graphene (1 kg), 250rpm

Time	2	4	6	8	10
Frictional Force (N)	0.14	0.15	0.16	0.15	0.14
Wear (mm)	0.00000022	0.0000011	0.00000073	0.0000011	0

97% Al Fine Powder + 3% Graphene (1.5 kg), 250rpm

Time	2	4	6	8	10
Frictional Force (N)	0.08	0.09	0.11	0.10	0.12
Wear (mm)	0.00000022	0	0.00000073	0.0000011	0

The Table 3. show Frictional force (N) and wear values with Time.

3.3 Compression Strength

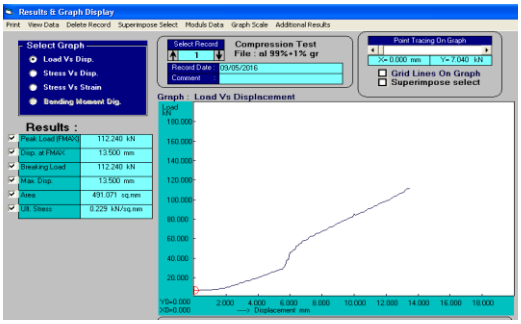

Fig 8a Load Vs Displacement for 1%.Wt of Graphene

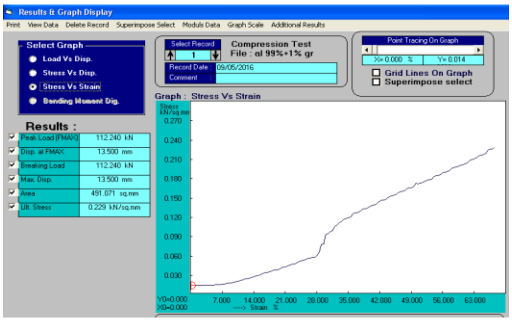

Fig 8b Stress Vs Strain for 1%.Wt of Graphe

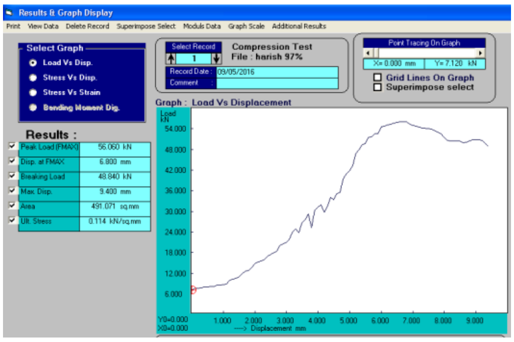

Fig 8c Load Vs Displacement for 3%.Wt of Graphen

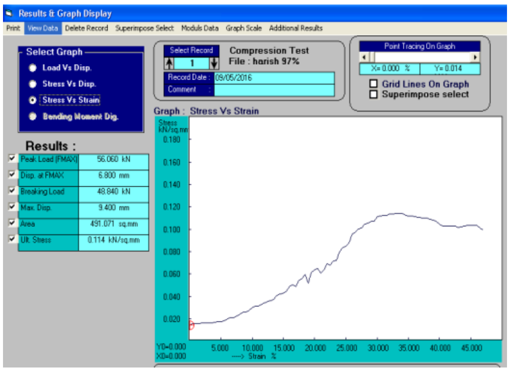

Fig 8d Stress Vs Strain for 3%.Wt of Graphene

The above fig 8a -8d show the stress strain plot obtained due to isostatic compression test. The composite shows lower values of compression strength as compared the matrix composite. Graphs of Specimen taken from UTM during compressive strength test.

3.4 Scanning Electronic Microscope (SEM)

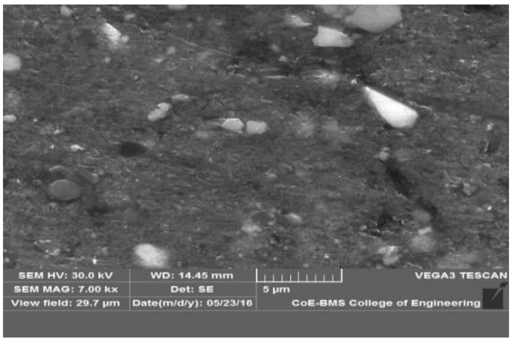

Fig 9.a 100% Aluminum after sintering at 7000x

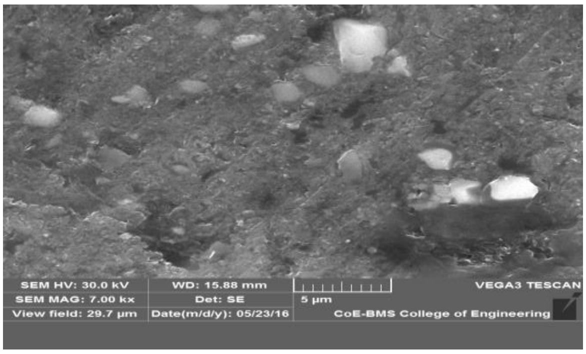

Fig 9.b Al+1%Wt of Graphene after sintering at 7000x

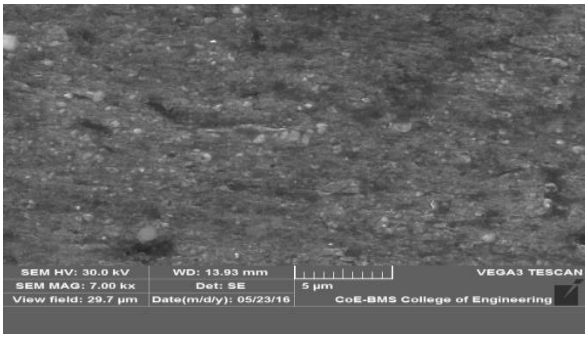

Fig 9.c Al+3%Wt of Graphene after sintering at 7000x

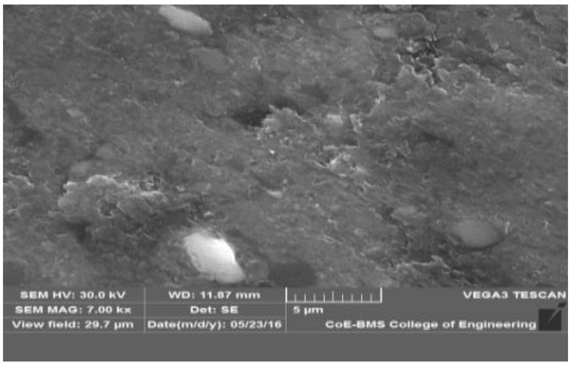

Fig 9.d Al+6%Wt of Graphene after sintering at 7000x

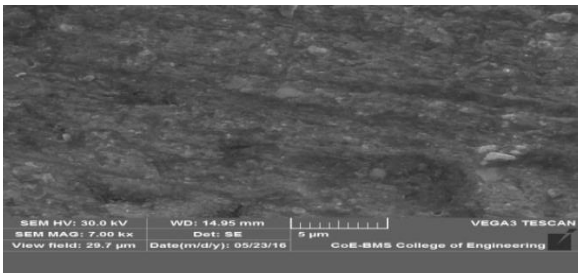

Fig 9.e Al+8%Wt of Graphene after sintering at 7000x

The above fig 8a -8d show SEM study reveal a uniform distribution of Graphene in the Aluminum. There is an excellent bond between Graphene and Aluminum. There is a good interfacial bonding between Aluminum and Graphene metal matrix composites which improve hardness of composites. Graphene content and Aluminum play significant role in increasing wear resistance of the material.

4. CONCLUSION

Powder metallurgy method were successfully adopted in the preparation of Aluminium-Graphene metal matrix composites. Aluminum and Graphene metal matrix composites which improve hardness of composites.Wear of Aluminium strongly depend on Graphenecomposition and decreases with increasing Graphenecontent.The wear properties are considerably improved by the addition of grapheneand the wear resistance of these reinforce graphe also increases with decrease in the grain size. There is a good interfacial bonding between Graphene content and Aluminum play significant role in increasing wear resistance of the material. SEM study reveal a uniform distribution of Graphene in the Aluminum alloy. There is an excellent bond between Graphene and Aluminum. Finally it can be concluded that Aluminium metal matrix composites exhibits superior wear and mechanical properties. Aluminum with 3% of Graphene has high resistance as indicated by lowest wear.

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