Effect of Sintering Time and Reinforcements on Density, Hardness of Al/CNT-FA Composites.

Udaya, Peter Fernandes

Abstract: *In this work, 0.5 wt.% carbon nanotube (CNT) and varying content of Fly ash (FA) were used to fabricate Al/CNT-FA composites by powder metallurgy which involves powder blending, compaction and sintering technique. This study was mainly focused on to the development of a metal matrix composite (MMC) and to study the effect reinforcements and sintering time on hardness and density properties. It was found that as the FA content were increased; there were significant increase in density, hardness, up to certain limit (8 wt%) beyond which it decreases. The increase in sintering time also had positive effect on density and hardness properties. The surface morphology was studied using scanning electron microscope to analyze the distribution of reinforcements. It was found that reinforcements were well dispersed and also refinement of the grains occurred as the sintering time is increased.*

Index Terms: Aluminium, Fly ash, Multi wall carbon nanotube, Scanning electron microscope.

I. INTRODUCTION

Composite is very important engineering material due to its unique property over pure metal. In recent years, composite materials have received considerable attention as compared with monolithic materials because of the enhanced mechanical properties such as stiffness, toughness and ambient and high temperature strength. Due to their enhanced performance and reduction in weight by 20-50%, composite materials have become common engineering materials and received greater attention in automobile, sports equipment, satellite component, aerospace, home appliances and marine industries [1]. Fly ash particles are potentially used as reinforcements in MMCs, because of their low density low-density and available at low cost and in large quantities as a unused by-product in electricity generating units. It was found that fly ash effectively enhances bonding between the matrix and reinforcement and increases hardness and wears resistance of Al alloy [2]-[3]. Carbon nanotube (CNT) has been attracting great attention for its excellent mechanical and conductive properties. From the literatures it can be concluded that CNTs as reinforcement improves mechanical and thermal properties of metal matrix composites and can be successfully used for many high strength and structural applications [4]-[7]. Using CNTs in the aluminium matrix is a big challenge due to the difficulty associated with the interfacial reaction between CNTs and Al matrices, and insufficient fabrication technique. In this study development of a metal matrix composite (MMC) using fly ash and CNT as a reinforcement and Al as matrix were investigated. Hardness, density micro structural analysis of the composites was investigated. The influence of sintering time and reinforcements was presented and discussed.

Manuscript Details.

Udaya, Mechanical Engineering Department, NMAM Institute of Technology, Nitte,-574110,India.

E-mail: udaya140213@gmail.com

Dr. Peter Fernandes, Principal, Alva's Institute of Engineering & Technology, Moodbidri, India.

E-mail: petfdcm@gmail.com

II. EXPERIMENTAL PROCEDURE

Thirty grams of Al powder (99.7% pure, mean size 50 µm. Density 2.7 g/cm^3) and 0.5 wt% Multi-wall carbon nano tubes (outer diameter-10-15 nm, inner diameter-2-6 nm, length-0.1-10 µm, density 2.1 g/cm^3, supplier-, Chengdu chemicals Co. Ltd China) with varying weight percentages (4, 8 and 16 wt.%) of fly ash(mean size 9.229 µm, density 1.76 g/cm^3)were placed in 250 ml stainless steel mixing jars containing stainless steel balls (8 mm diameter) giving an ball-to-powder weight ratio of 8:1. The jars then agitated using a planetary ball mill at 250 rpm for, 2 hr milling time. 3 wt.% of methanol were added as a process control agent in order to reduce cold welding of the Al particles and also to avoid powders sticking to the balls and jar walls. Fig. 1 shows the ball milling apparatus used for the powder blending. Mixed powders were cold compacted in a die and plunger arrangements (12 mm diameter) at 285 MPa pressure. Compacted billets of 12 mm diameter and 25 mm height were sintered at 500 ºC for 1, 3 and 6 hrs [9]. Figure 2 shows the fabricated composite sample. The theoretical and experimental density properties of Al/ CNT-FA composites were investigated by rule of mixtures and Archimedes principle respectively, refer to (1) and (2).

$$\rho_{ct} = V_{Al}\rho_{Al} + V_{FA}\rho_{FA} + V_{CNT}\rho_{CNT} \quad (1)$$

$$\rho_c = \frac{m}{m-m_1} * \rho_w \quad (2)$$

where, ρ_{ct}= Theoretical density of composite in g/cc.

ρ_{Al} , ρ_{FA} ,ρ_{CNT} = Density of aluminium, fly ash, CNT respectively in g/cc.

V_{Al}, V_{FA},V_{CNT} = Volume fraction of aluminium, fly ash, CNT respectively. Equation (3) was used to calculate Relative density.

$$\text{Relative density} = \left(\frac{\rho_c}{\rho_{ct}}\right) * 100 \quad (3)$$

The specimens were checked for its hardness in Vickers hardness testing machine where diamond indenter was pressed on the specimen surface of specimen using a load of 5 kg and the indentation formed was in diamond shape.

Vickers hardness number (VHN) $= \frac{1.8544L}{d^2}$

Where L=load applied,

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

d^2=avg. length of diamond shaped pyramid.

The surface morphology was investigated by scanning electron microscope (SEM) to analyze the distribution of reinforcements.

Fig. 1 Ball milling apparatus.


Fig. 2 Specimen after sintering

III. RESULTS AND DISCUSSIONS

A. Micro Structure Study:

The powders of FA MWCNT, Al raw materials were individually studied under scanning electron microscope. FA with the spherical shape having mean diameter of 9.29 µm, MWCNTs having thread like structures having tubular shape with average dimensions 10-15 nm outer diameter, 2-6 nm internal diameter, and 0.1-10 µm in length and Al particles with size varies from 7 tof 50 µm respectively was observed.

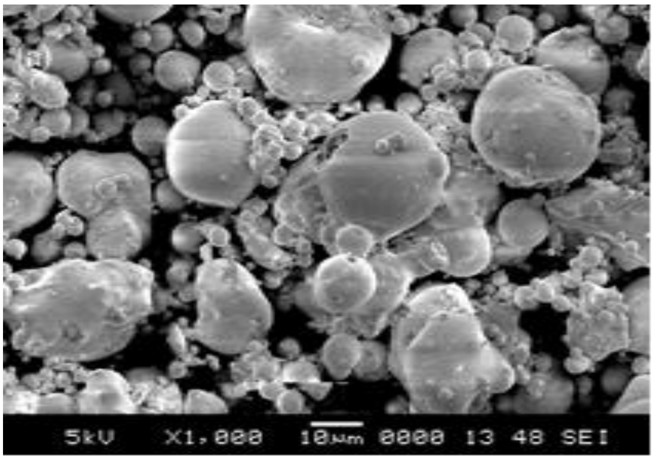

Fig. 3 SEM photos of FA powders.

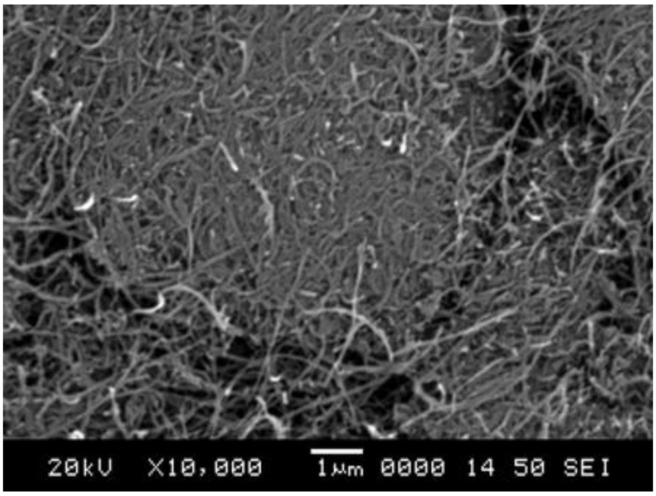

Fig. 4 SEM photos of MWCNTs powders

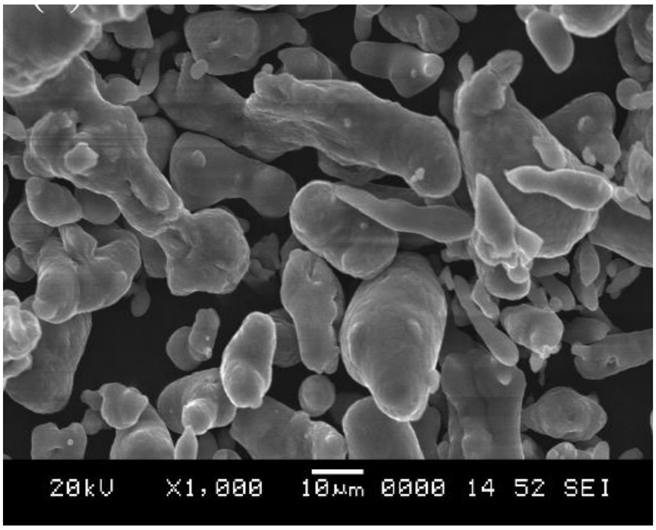

Fig. 5 SEM photos of pure Al powders.

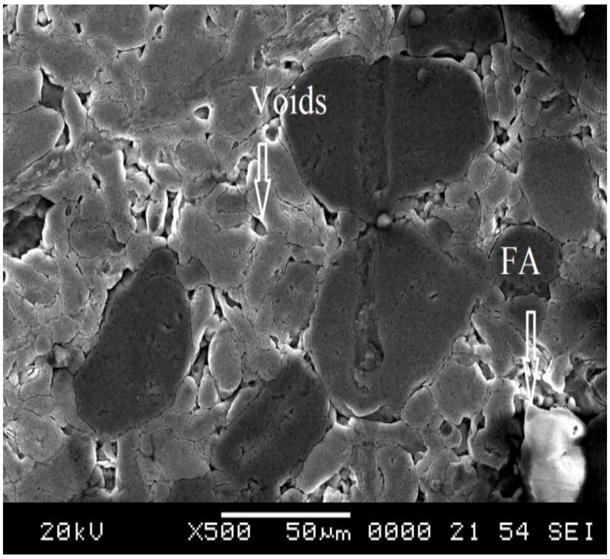

Fig. 6 SEM image of specimen after 1 hr sintering

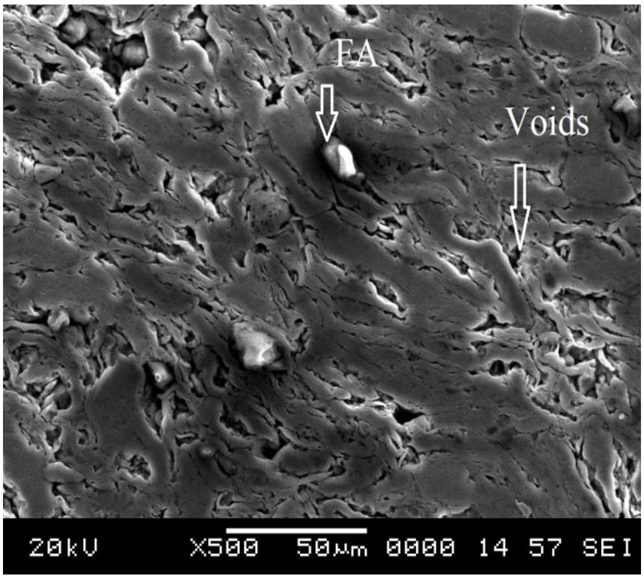

Fig. 7 SEM image of specimen after 3 hr. sintering

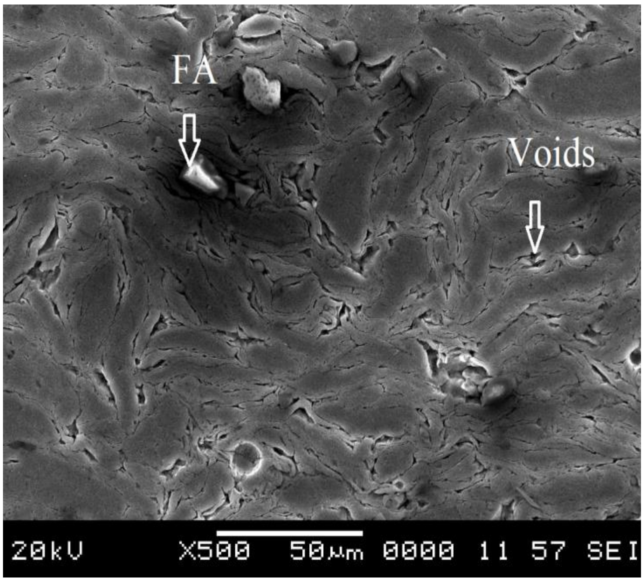

Fig. 8 SEM image of specimen after 6 hr sintering

SEM micrograph of the sintered composite were shown in the Fig. 6 ,7 and 8. The composite clearly reveals that sound sintering with very small porosity as sintering time was increased with indicating a good interfacial bonding between the FA-CNT particles and Al matrix materials. Also it was evident that as sintering time increases porosity level decreases. This was attributed to the grain refinements at longer sintering times.

B. Mechanical properties

Fig. 8 and 9 shows the relative density and hardness of the different combinations of composites sintered for 1, 3 and 6 hours. It was evident that maximum hardness found to be 41.81 HV for 6 hours sintering time for the combination of 0.25 wt.% CNT and 8 wt.% FA. Pure Al hardness was found to be 22 HV. Hence it can be concluded that hardness is improved by addition of fly ash and CNT to the pure aluminum matrix. Increase in the properties was attributed to the harder reinforcing materials which were used in the composites and also good adhesion between matrix and reinforcements.

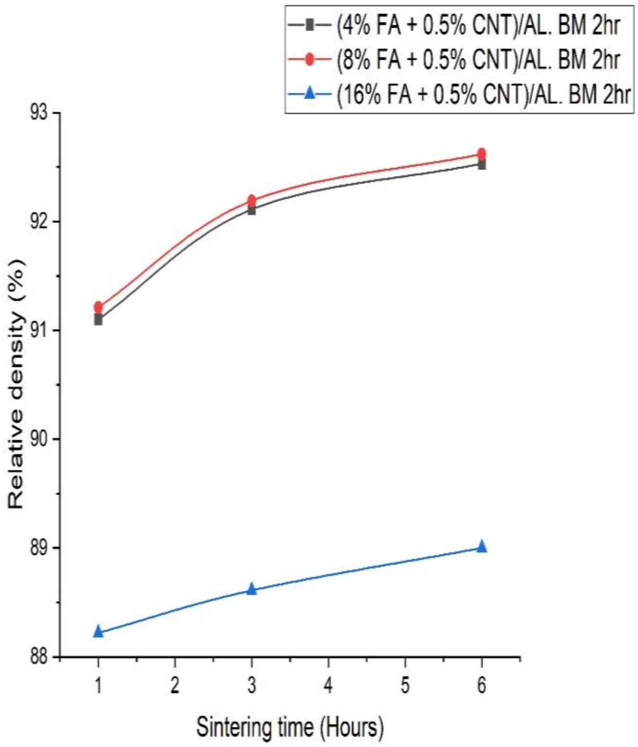

Fig. 9 Effect of Sintering time on Relative density

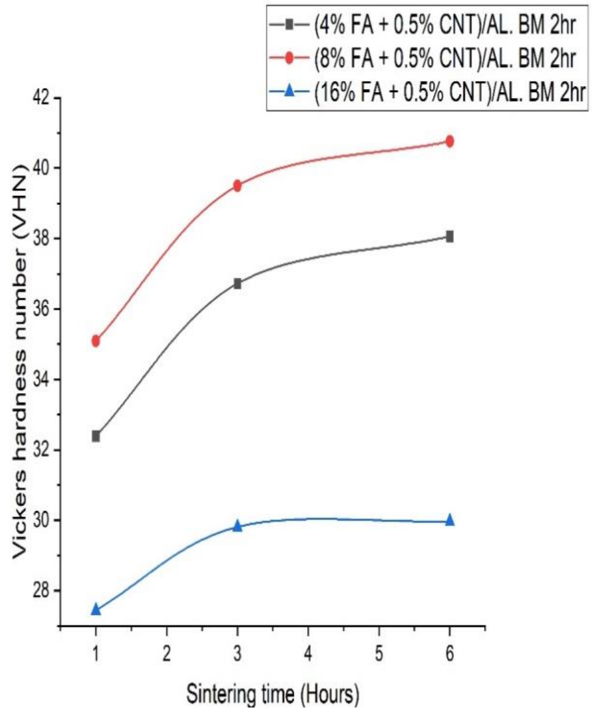

Fig. 10 Effect of Sintering time on hardness

A. Effect of sintering time on relative density

Fig. 9 shows the effect of sintering time on relative density. It is evident that relative density increases with increase in sintering time. A maximum 93.53% relative density is observed for 6 hours of sintering time. This can be attributed to the grain refinement occurs reducing the porosity level [8].

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

B. Effect of sintering time on hardness

Fig. 10 shows the effect of sintering time on hardness of the composite. It is evident that hardness increased with increase in sintering time. Hardness of 41.81 HV is observed for the composite sintered at 6 hours sintering. This incremental effect may be due to the more and more adhesion of Al matrix on reinforcing material as sintering time increases. Thus, strong bond between reinforcement and matrix results increased hardness and less porosity [8]..

C. Effect of reinforcement content on relative density

The effect of Fly ash on the relative density is shown in Fig 9. It can be observed that as weight % of Fly ash increases relative density of the specimen decreases. This can be attributed to the increased formation of sphere packing of FA particle and the inability of Al particles to diffuse into voids [8].

D. Effect of reinforcement content on hardness

Fig. 10 also shows the effect of Fly ash on the hardness. Hardness value appears to be increased up to 8 wt. % of Fly ash and started decreasing above that. This initial increment in VHN may be due to FA being comparatively hard material, addition of this bound to give better hardness in Al composite. The reason behind decrement of hardness above 8 wt. % of FA was due to increased porosity [8].

IV. CONCLUSION

Experimental investigation resulted in the following conclusions

- Powder metallurgy one of the suitable technique to fabricate CNT and FA reinforced aluminum composites.
- The results of the SEM images showed well dispersion of the reinforcements and refinement of grains for longer sintering times for the composites.
- The relative density of 93.53% was observed for the composites for 6 hr sintering time.
- Increase in fly ash content increases hardness up to 8 wt.% beyond that hardness decreases.
- A maximum hardness 41.81 HV was observed for the composites as against 22 HV for pure Al indicating improvement in the properties by the inclusion of CNTs and FA to the pure Al.

REFERENCES

1. Rohatgi P.K,Weiss D, and Gupta Nikhil, Applications of Fly Ash in Synthesizing Low-Cost MMCs for Automotive and Other Applications, Journal of the Minerals, Metals and Materials Society, vol 58,(2006): pp 71-76
2. M. Ramachandra, K. Radhakrishna, Effect of reinforcement of fly ash on sliding wear, slurry erosive wear and corrosive behaviour of aluminium matrix composite" Wear 262 (2007) pp.1450–1462
3. Sudarshan and Surappa, M.K. (2008), "Dry sliding wear of fly ash particle reinforced A356 Al composites", Wear, vol.265, pp.349-360.
4. T. Laha, Y. Chen, D. Lahiri, A. Agarwal, Tensile properties of carbon nanotube reinforced aluminium nanocomposite fabricated by plasma spray forming Composites: Part A 40 (2009) 589–594
5. A.M.K. Esawi, K. Morsi, A. Sayed, A. Abdel Gawad, P. Borah, Fabrication and properties of dispersed carbon nanotube–aluminum composites Materials Science and Engineering New York, 1979, A 508 (2009) 167–173n,
6. S.R.Bakshi,D.Lahiri and A. Agarwal Carbon nano tube reinforced metal matrix composites- a review International Materials Reviews 2010 vol 55 No 1 pp.45-64
7. Rupesh Khare, Suryasarathi Bose "Carbon Nanotube Based Composites- A Review Journal of Minerals & Materials Characterization & Engineering, vol. 4, No.1, pp 31-46, 2005
8. R. Q. Guo, P. K. Rohatgi," Preparation of aluminium–fly ash particulatecomposite by powder metallurgy technique", Journal of Materials science 3 2 (1997) pp.3971–3974
9. Udaya**,** Dr. Peter Fernandes **"**Effect of fly ash and ball milling time on CNT-FA reinforced Aluminium matrix hybrid composites**"**, *Mater. Res. Express* https://doi.org/10.1088/2053-1591/ab1e20

AUTHORS PROFILE

First Author cuurrently doing Ph.D in composite materials. He currently published one paper in Trans Tech Publications, Switzerland, 2 papers in Material research and presented papers in ICETE 2018 proceedings held at NMAMIT Nitte, ICAMPS 2018 held at Trivandrum Life Member of Indian Society for Technical education ,Indian Welding Society, Indian Society of systems for Science & Engineering

Dr. Peter Fernandes, Ph.D, M.B.A, He has co-author of papers published in Trans Tech Publications Switzerland, 2 papers in Material research, ICETE 2018 proceedings held at NMAMIT Nitte , ICAMPS 2018 at Trivandrum. Life Member of Indian Society for Technical education, Life Member of IIM Chapter Trivandrum.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication