Dispersion Analysis of Carbon Nano Tubes on AL/CNTs Metal Matrix Composites Produced by Ball Milling Process

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Abstract— In the current research work, is aimed to analyse the Dispersion effect of carbon nano tubes (CNTs) in Aluminium/CNTs metal matrix composites prepared by powder metallurgy (PM) method. To achieve the good dispersion effect of CNTs in aluminium powder ball milling procedure is adopted. Carbon nano tubes (CNTs), has incited overwhelming responses in the field of research due to its extraordinary potential in the form of reinforced composites. CNTs stand-out properties are its inherent strength and low density compare to graphene. But various challenges are faced when CNTs is used as reinforcement, namely the clusters formation, crack initiation and propagation which is mainly depend on arrangement or unpredictability of the added reinforcements. Consequence of carbon nano tubes reinforcement related to discrete on mechanical properties of Aluminium 6061 nanocomposites have been planned to be evaluated. Microstructure analysis are to be analysed for the developed composite.

Key words: Carbon Nanotubes; Aluminium 6061; Microstructure; XRD, Nano-Composites; Powder Metallurgy (PM)

I. INTRODUCTION

In recent years, one of the most dynamic areas of research in materials is Metal Matrix Composites (MMC's). Composite materials are suitable for various applications like in aerospace sector, defence and many industries. MMC's are specially gauged with Aluminium (AI) and its alloys as a matrix in the aspect of light high strength and weight. Commercialization of MMC's is still a challenging stage due to inadequate in correlating the mechanical properties to the theoretical properties. However, nano sized particles of SiC, Zirconia, $Al_2 0_3$, and B_4C are often incorporated in the Al based nano composite as reinforcing materials to attain high strength and density. Powder metallurgy (PM) is the common method used to synthesize these composites due to its easiness of dispersion in matrix phase and good control over processing parameters. The key to achieve enhanced properties in MMC's is inhibited by excessive reactions between the reinforcement and the matrix. It is critical for a composite material to possess a reinforcement in a second phase to be indiscriminately mixed with the matrix via strong interfacial bonds. Carbon based reinforcement such as graphite and fullerenes were used in base metals like Aluminium, Copper, Magnesium and their alloys. They have shown promising results with respect to their mechanical characteristics yet they are faced with multiple concerns regarding their mix-ability and other factors like low surface contact.

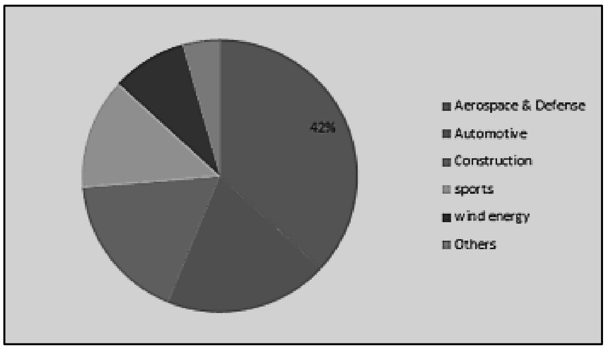

Fig. 1: Applications of carbon nanotube in different fields

II. LITERATURE REVIEW

They confirmed that rutile possesses superior physical and engineering properties. Comprehensive survey on various literatures revealed that no detailed findings are available for powder metallurgy (P/M) processed Al−SiC− TiO2 (rutile) hybrid composites. P/M is widely adapted for achieving uniform distribution of reinforcing phase within the matrix and to produce near net shaped components (Tromans et al, (2002 – 2004)).

With the numerous improved fabrication facility now a days MMCs has great characteristics as well strength, specific modulus of elasticity, damping properties and wear resistance as compared to the unreinforced alloys. Aluminium alloys are used in many engineering applications due to their light weight and high strength characteristics (Saheb et al, (2001)).

They fabricated AMCC's reinforced with CNTs through pressure less infiltration of aluminium into CNTs–Mg–Al preformed in N2 atmosphere at 800˚C. They discover that CNTs were well dispersed and embedded in the Al matrix, the friction coefficient of the composite decreased with increasing the volume fraction of CNTs, and the wear rate of the composite decreased steadily with the increase of CNTs content (from 0 to 20 vol. %) (Zhou et al, 2007)).

Kuzumaki et al said CNTs were synthesized using arc discharge. The pureness of CNTs was found to be about 60% by vol. which is as compared to CNTs are produced nowadays, is measured low. By employing 5 and 10% vol. of CNTs with parent Al and stirred the formed mixture in ethanol for 0.5 h in order to achieve better dispersion of CNTs and Then mixture was held in dry atmosphere and crammed in an Al case which is preheated and steel die compressed then hot extrusion was performed at 773 K. Several characterization techniques were performed, but the significant results came from the tensile strength and elongation percentage tests versus annealing time (Kuzumaki et al, (1998)).

Hansang Kwon et al discussed functionally graded carbon nanotubes (CNT) and nano Silicon carbide (nSiC) reinforced aluminium (Al) matrix composite materials were fully densified by a simple ball milling and hot-pressing processes. The nSiC was used as a physical mixing agent to increase dispersity of the CNT in the Al particles. It was observed that the CNT was better dispersed in the Al particles with an nSiC mixing agent compared to without it used (Kwon et al, (2009)).

They found density of crack and wear characteristics of SiCp reinforced Al-MMC fabricated by DMLS process have been studied. Mainly, size and volume fraction of SiCp have been varied to analyse the crack and wear behavior of the composite. The study has suggested that crack density increases significantly after 15 volume percentage (vol. %) of SiCp (Ghosh et al, (2011)).

Deuis R.L et al. explored that that the Al-Si alloys and AMMCs have found application in the fabrication of numerous automotive engine components where adhesive wear is a predominant process. For adhesive wear, the influence of applied load, sliding speed, wearing surface hardness, reinforcement fracture toughness and morphology are critical parameters in relation to the wear regime encountered by the material. In this review contemporary wear theories, issues related to counter face wear, and wear mechanisms are discussed (Deuis et al, (1997)).

Hybrid composites are those composites which have a combination of two or more reinforcements. Performance of hybrid composites is a weighed sum of the individual components in which there is a more favourable balance between the inherent advantages and disadvantages (Qutub et al, (2013)).

When metal matrices are reinforced with CNTs it reduces their density and meanwhile the tensile strength increases dramatically. We can see in the case of pure Al and Al-CNT composite, the densities are 2.700g/cm3 and 2.655g/cm3 respectively while tensile strength are 52M Pa and 198.8 MPa respectively at 600-degree Celsius temperature (Kwon et al, (2010)).

Out of many methods stir casting is known for its simplicity and cost effectiveness. Aluminium composite made by different powder metallurgy processes like HSBM, SSBM and LSBM gave the tensile strength of 408MPa, 376MPa and 367MPa respectively with 31%, 33% and 41% enhancement on aluminium (Xu et al, (2017)).

With the increase in the content of CNTs in the metal matrix the density, grain size, Electrical conductivity, thermal conductivity and elongation percentage decreases whereas young modulus increase being maximum at 0.75 CNT (% by volume) which was 114.1MPa (Chen et al., (2015)).

Besides the manufacturing processes and quantity of reinforcement the rate of solidification also affects the properties of composites. For example, the magnesium metal matrix with CNT reinforcement are prepared and it is found that the slowly solidified model has greater strength (50% increase in YS) as compared to quickly solidified model (18% increase in YS) (Li et al., (2014)).

Flake powder metallurgy via Shift-speed ball milling is used to get advantage of both LSBM and HSBM as it combines the mechanism of both and by doing so the ductility of Al-CNT composite is doubled and tripled as compared to pure LSBM and HSBM (Xu et al., (2017)).

In another experiment MWCNTs are used as reinforcement in titanium matrix and the use of 0.35 % (by weight) CNTs reinforcement causes increase in tensile strength and yield stress of 157MPa and 169MPa respectively as compared to pure titanium metal. Similarly, aluminium composite made by singly dispersed CNTs have 23.9% and 45.0% high yield strength respectively for 1%wt and 3%wt of CNTs reinforcement as compared to unreinforced aluminium (Kondoh et al., (2009)).

It is also seen that the mechanical properties are affected by dispersion of reinforcement. Proper dispersion can be achieved by reducing the viscosity of molten metal matrix. For example, in this experiment Al has proper dispersion of SiC at 8000 C as compared to 7500 C (Liu et. al., (2012)).

There are various factors affecting properties of composites made by stir casting methods. Some of the factors are clustering of reinforcement particles, wettability of reinforcement (SiC), fabrication method, volume fraction, shape and size of reinforcement particles and distribution of them (Sijo et. al., (2016)).

Gradual increase in YS with increase in reinforcement. The compressive strength of AZ91 is 310Mpa and that of SiC is 3900MPa. So using it as reinforcement results in increased compressive strength (Viswanath et al., (2015)).

It is also noted that the distribution of CNT is more uniform when ball milling is done for more time. Wear rate decreases linearly with increase in Tic reinforcement. It happens due to the presence of hard TiC particles (Zeng et al., (2010)).

Finally, in casting process, particle agglomeration and porosity cause decreased strength and ductility. In extruding process, the strength and ductility increase due to lower porosity content, uniform distribution of alumina and grain size (Gopalakrishnan et. al., (2012)).

In another case where Nano TiO2 was taken instead of rutile TiO2, it again shows the same fashion but different values in change of properties. Further, on adding 0.5% wt% results in increasing UTS whereas for 1%, 1.5% and 2% weight, the UTS starts decreasing (Mirzaee et. al. (2014)).

Using TiO2 and graphite help in improving hardness and tensile strength which can be observed in the research where three different sample having same graphite composition (3% by weight) and different TiO2 composition (5%, 10% and 15%) were used, the testing shows a steady increase in both hardness and UTS (Papagiannakis, (2014)).

It is also observed that adding CNT as reinforcement increases ductile nature of the material which results in more elongation before fracture. So, the Young Modulus and TS increase with increase in CNT content, but it also results in significant decrease in compressive strength (Narayanan et. al., (2015)).

III. GAPS IN THE LITERATURE

After coming across various research papers in this field, it can be seen that a lot of research work has been done in areas like reinforcing Carbon Nanotubes in polymers or fibres using various methods such as Vapour Deposition

Technique, Powder Metallurgy (PM), Centrifugal Method. In powder metallurgy technique, the CNT is mixed with base material by different processes like manual-mixing method, ultra sonication technique, ball milling methods. In all these methods, an increasing trend in mechanical and structural properties were observed by increasing the wt. % of CNT in mixture up to 5%wt. after that agglomeration takes place which reduces the efficiency. So, less focus has been made over the method which is best suitable at 5%wt. of CNT.

IV. Experiment Procedure & Testing

The overall objective of the work is to explore the microstructure analysis of Aluminium 6061 metal matrix reinforced with carbon nano tubes by using SEM, Optical images and XRD patterns. The main objectives are as follows exploring compatibility of Aluminium 6061 and CNTs Testing the real time samples under laboratory test conditions studying about the potential failures of such material systems.

It was seen that Aluminium alloys were a fit component among all the available materials which suited our needs appropriately. Our search ended up in to specific aluminium alloys which were easily available to us and had the best use in the concentrations as specified above.

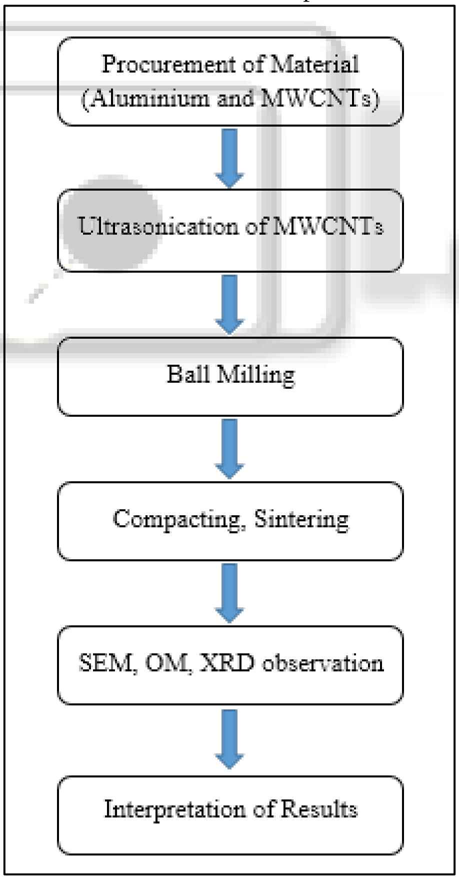

Figure 2 Flowchart depicting the methodology

All the experiments are carried out using Aluminium powders and fine particles of MWCNTs. In case of ultra-sonication of carbon nano tubes, waves (>20 kHz) is used which leads to agitation. High and low pressure cycles are formed due to propagation of sound waves through the liquid medium which is known as compression and rarefaction respectively. During the time of rarefaction, small vacuum bubbles get created due to sonic waves of high intensity in the liquid, which collapses during the time of compression resulting in very high local temperature. Ball milling is a type of grinding used for blending the materials for use in various applications like paints, ceramics and selective laser sintering. The basic working principle followed by it is impact and attrition: which means as the balls drop from the top, the size gets reduced inside the shell.

A. *Experimental Procedure*

The experimental procedure has been planned to focus more on the observable surface properties of the composites. We aim to provide first provide the optical microscope images, XRD and the SEM images of the nanocomposites used so as to standardise the materials.

V. Result

The morphology of aluminium 6061/CNT metal matrix are examined by SEM Carl Zeiss EVO. XRD analysis is carried out on sintered Aluminium 6061 CNT composites to verify the carbide formation during processing due to interfacial reactions microstructural analysis has been carried out for fine polished and etched samples.

In case of ball milling technique, the MWCNT along with aluminium powder were crushed together with stainless steel balls and in due course, large CNT clusters and aluminium particles were fractured into smaller ones and leads to proper dispersion of MWCNTs. We can see that more than 80% of the particles are below 100 psd and only around 5% of the total particles are reaching above the particle size of 800 psd.

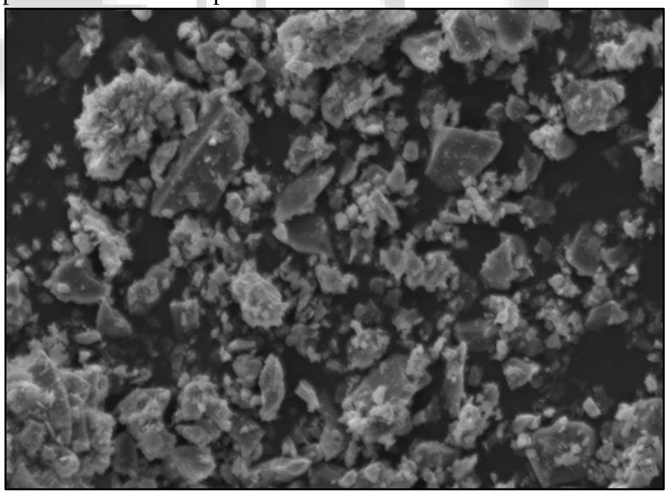

Fig. 5.4: SEM image (Particle distribution)

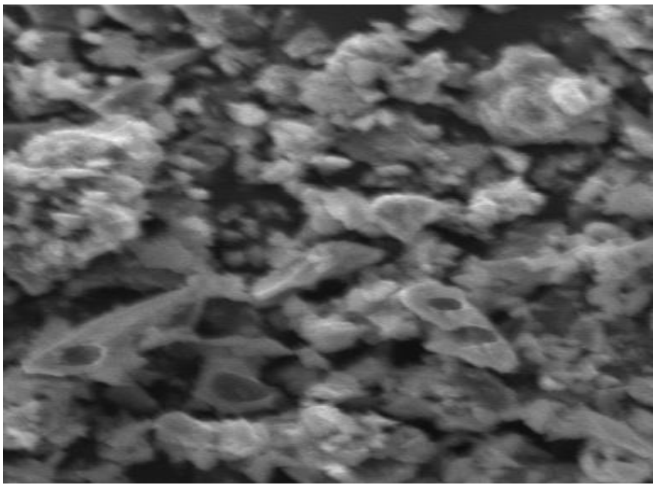

Fig. 5.5: SEM image (Clusters formation and uniform distribution)

The characterization images (Figure 5.2 to 5.5) shows that the materials are proper and provide the required compositions. The results of the XRD and the SEM are in accordance with the previous researches and map the components of the materials adequately. This further proves the integrity of the prepared samples and composites. This determines all samples possess minimum acceptable porosity and well consolidated.

VI. Conclusion

– In the present work, Aluminium 6061 CNT composites of 5 wt. % reinforcement were synthesized by mixing Aluminium 6061 alloy particles and CNTs using ultrasonic liquid processor.
– X-Ray diffraction analysis shows the presence of the very few clusters peaks which is very less and no resilient for carbide formation.
– From the comparative SEM images and microscopes images, found that upon using ultrasonic liquid processor and ball milling process homogeneous and uniform dispersion of CNTs at lower content were achieved.
– Ar inert gas sintering technique can effectively increases the diffusion of ions and thus speed up the sintering process, causing in the grain growth and the densification of matrix.

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