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Research paper

Wear and compression behavior study of carbon nanotube in aluminium Nano composites

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Abstract

In this study, carbon nanotube (CNT) reinforced in aluminium (Al) matrix for different weight percentages were fabricated by powder metallurgy (PM). A mechanical mixing process i.e. ball milling which employs mechanical alloying technique and results in effective dispersion of CNTs in aluminium powder was employed and two different ball materials namely tungsten ball and aluminium oxide ball was used for same composition of CNT/Al composites in order to understand different mill ball material effects on mechanical properties of CNT/Al composites. The powder mixtures were consolidated by microwave sintering. The microstructural analysis of both ball milled powder and sintered specimen were carried out where in case of powder samples effective dispersion of CNTs in aluminium powder was observed and in case of solid sintered samples the grain boundaries and bonding between the particles was observed. The wear test, the compression test of CNT and Al composites was carried out. The considered weight percentages varied from 0.5% to 1.3% for both alumina ball milled and tungsten ball milled specimens. The alumina ball milled specimens was observed to have high compressive strength and improved wear behaviour compared to tungsten ball milled specimens but in both cases 1.3 wt. % CNT reinforced samples showed best results. With CNT reinforcement Al, grains were refined under the pinning effect of CNTs at grain boundaries. The results proved that the alumina ball milled samples with 1.3 wt. percentage CNT reinforced composites had improved compression and wear behavior.

Keywords: *MMC'S; Aluminium, CNT; Microwave Technology; Tribology Etc...*

1. Introduction

A composite material is one which is obtained by the combination or mixture of two or more materials which will have different physical and chemical properties [1] but when mixed or combined at appropriate proportions results in enhanced properties than those of the individual material used solitarily. In disparity to metallic alloys, each material preserves its separate chemical, physical, and also the mechanical properties. The two basic constituents of composite material are reinforcement and a matrix [2]. Obtaining best results as compared to a regular material is understood by calculating the weight to strength ratio where in case of the composite materials high strength and stiffness combined with low density when compared with bulk materials is commonly obtained results, which allows for weight reduction in the finished part [2]
The Metal matrix nanocomposites or reinforced metal matrix composites can be classified into two type's namely continuous reinforced materials and non-continuous reinforced materials. The one of the most important and newly developed nanocomposites is carbon nanotube metal matrix composites, which is developed to yield the advantage of high tensile strength and also the high electrical conductivity of carbon nanotube materials [4]. The carbon nanotube may be of single walled or multi walled which is produced using chemical vapour deposition technique.
The aluminium and carbon nano tube metal matrix nanocomposites is a type of Nano composites in which the carbon nanotube is reinforced into the aluminium matrix in powder form. The carbon nanotube might be a single walled or a multiwalled based on the requirement and aluminium can also be either pure or any series both being in the powder form the powder metallurgy fabrication method is utilized.
Prior to fabrication to ensure a uniform dispersion of the carbon nanotube powder in the aluminium matrix powder, the mixture might have to be subjected to mechanical mixing process such as ball milling which ensures to avoid the agglomeration of CNT in aluminum powder. The results of ball milling being dependent on important parameters such as Mill time, Mill ball material, Milling speed and Number of ball used for milling.
The microwave sintering is a type of sintering process which has been proved to high precision compared to all sintering methods except spark plasma sintering. This process involves a volumetric heating where the conversion of electromagnetic energy into thermal energy takes place. This method proves to be very different compared to conventional heating where here instead of thermal conductivity the heating of the specimen occurs instantaneously where both heating is rapid and high temperatures such as up to 2500 degree Celsius can be achieved at very short time. The volumetric heating results in uniform heating of the material.

2. Materials and methodology

The carbon nanotube (CNT)/ aluminium (Al) nano composites was to be fabricated and tested. The aluminium being available in various alloys namely Al-1000 series to Al-7000 series, the aluminium chosen for the following study was AA1050A and temper

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value zero which means it's not heat treated and it contains 99+% of pure aluminium.

Table 1: Aluminium AA1050A (Pure 99+ %) Mechanical Properties

Alloy		AA1050A
Temper		0
Proof Stress 0.20% (Mpa)		35
Tensile Strength (Mpa)		80
Tensile Strength (Mpa)		50
Elongation A5 (%)		42
Elongation A50 (%)		38
Hardness	HB	21
	HV	20
Fatigue Endurance Limit (Mpa)		50

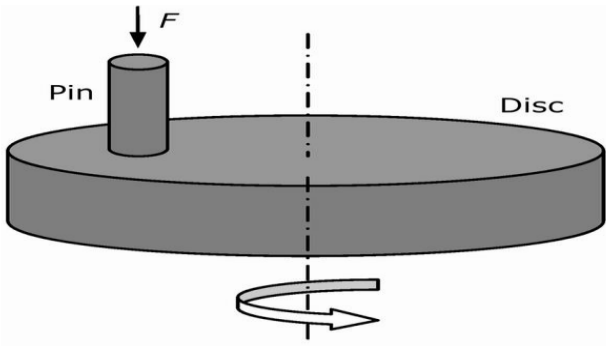
Table 2: MWCNT Characterization

Sl.No	MWCNT standards	Description	Characterization Method
1	Production	Chemical Vapor	Proprietary method
2	Available form	Black powder	visual
3	Diameter	Outer diameter: 10-30nm	TEM,SEM
4	Length	10 micron	SEM,TEM
5	Nanotubes purity	98+% & above pure carbon	TGA,RAMAN
6	Bulk density	0.04-0.06 g/cm3	Pycnometer

Synthesizing of Al-CNT Metal Matrix Composites

- Initially, aluminium powder is mixed with CNT by using planetary ball milling at 400 rpm for 40 min.
- In one container 10 alumina mill balls and in another container 10 tungsten mill balls were added. Since density of alumina was less the ball to powder weight ratio maintained was 1:1 and in case of tungsten the ball to powder weight ratio maintained was 5:1.
- Blended powders are compacted inside the compaction die with a pressure of 5 ton.
- The moulding capacity is 15 mm for length and 20mm for diameter was chosen and the steel mold were filled with ball milled CNT reinforced aluminium matrix powder of weight 25 grams weighed and later pressure was applied for compacting.
- The compacted aluminium - CNT is placed above the susceptor box, which is used to absorb the electromagnetic energy and convert it into heat energy such that initial coupling of susceptors with microwaves allows heating of MMC billet.
- The billets were prepared using steel mold in hydraulic press, and these billets will be further processed in microwave sintering.
- The MMC sample is heated at 550 for 15 minutes. Tribological Characterization

In this study, Pin-on-Disc testing method was used for investigating the wear behavior for minor loads since the specimen was powder metallurgy specimen. Hence minor loads were applied and the pin on disc wear testing was carried out for varying load conditions. The speed was constant 500 rpm for all specimens and time was 10 minutes per specimen means 2.5 minutes per load. Figure 1 shows schematic diagram of Pin-on-Disc setup.



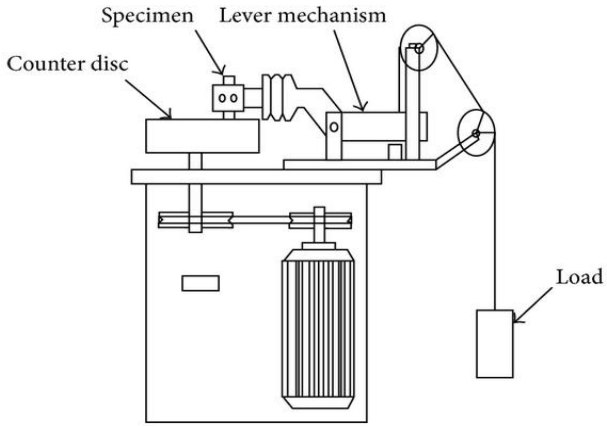


Fig. 1: Schematic Diagram of Pin-on-Disc Setup.

The pin on disc wear test was carried out on the CNT/ Al composites, since the specimen was powder metallurgy specimen with a curiosity to understand the basic tribological behaviour the specimen was wear tested for 2.5 minutes per load means a total of 10 minutes per sample and the results were obtained without damaging the specimen.

The compression test was carried out for all the specimens and hence the stress strain curves were obtained with maximum compressive strength and young's modulus.



Fig. 2: Specimen Placed In UTM for Compression Testing.

3. Results and discussions

Wear v/s Normal Load

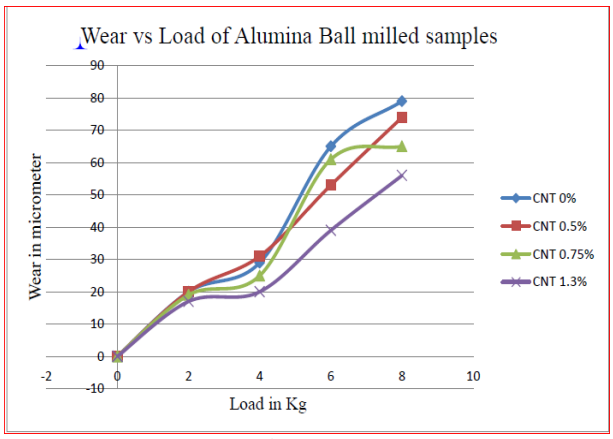


Fig. 3: Wear vs Load Graphs of Alumina Ball Milled CNT/Al Samples.

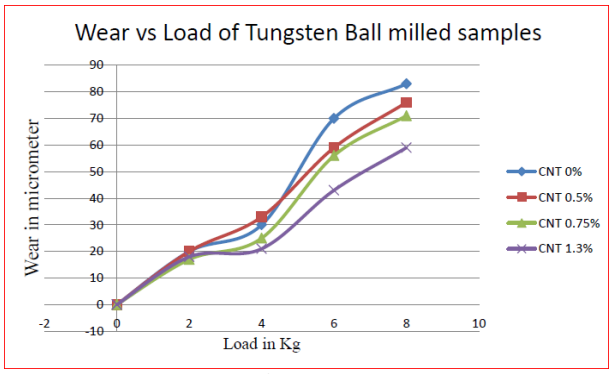


Fig. 4: Wear vs Load Graphs of Tungsten Ball Milled CNT/Al Samples.

From above figure it can be observed that the CNT wt% 1.3 reinforced into the aluminium matrix samples have shown less wear when compared to remaining samples the major reason being the CNT presence in the matrix.
Stress v/s strain curve

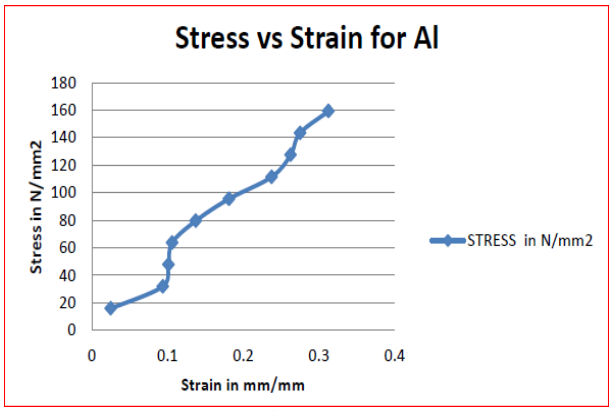


Fig. 5: Stress Strain Curve for Alumina Ball Milled Al Sample.

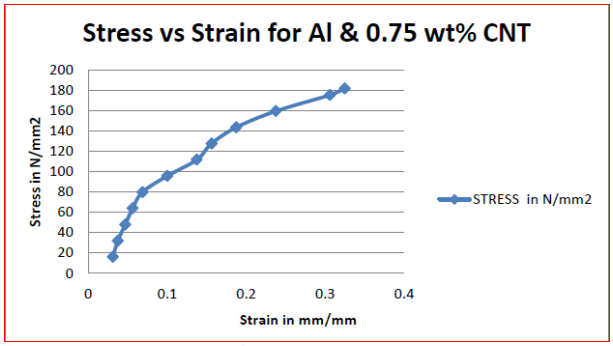


Fig. 6: Stress Strain Curve for CNT 0.75% & Al Alumina Ball Milled Sample.

From graphs it can be observed that the CNT 0.75% and Al tungsten ball milled nanocomposites have highest youngs modulus.
The results from Wear test and the Compression test it can be understood that the alumina ball milled CNT/Al nanocomposites have higher ductility with wear behavior and the ultimate compressive strength when compared to pure aluminium, where the tungsten ball milled CNT/Al nanocomposites have proved to have enhanced results when compared to pure aluminium, but when the same obtained results is compared with alumina ball milled samples the alumina ball milled samples tend to have higher results with no compromise in ductility.

4. Conclusions

Following conclusions are drawn from the investigations of present work:

- The CNT/Al nanocomposites was successfully fabricated by using microwave processing technique and tested.
- The microwave sintering method was successful in producing the powder metallurgy CNT/Al nanocomposites which was capable to undergo Wear test and the Compression test.
- The wear behavior of the CNT/Al nanocomposites was successfully tested and the obtained results proved the efficient reinforcement of CNT in the aluminium matrix and enhanced behavior was observed in highest CNT reinforced composites.
- The compression test was successfully carried out, the young's modulus proved that alumina ball milled CNT/Al nanocomposites have higher compressive strength compared to tungsten ball milled composites but when compared with pure aluminium both ball milled samples had shown enhancement successfully.

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