Dry sliding wear behavior of MWCNT reinforced commercial purity aluminum composites

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Abstract: The purpose of the present work is to investigate the hardness and dry sliding wear behavior of As cast and heat treated composite samples of multiwalled carbon nanotubes reinforced commercial purity aluminum composites fabricated by stir casting technique. Results indicate that, the hardness is increasing significantly in increasing the reinforcement and the heat treated composites shows much higher hardness compare to as cast samples. Wear test were conducted under dry sliding conditions on as cast and heat treated samples for varying loads from 10N to 40N with varying speeds of 100RPM, 200 RPM and 300 RPM and the sliding time of 5 mins, 10 mins, 15 mins and 20 mins. Wear rate is also shows improvement in heat treated samples compared to as casted samples.

Keywords: wear, composite, cast, hardness, heat treated,

1. Introduction

Carbon nanotubes were discovered from carbon by the classical investigations of Ijima in the year 1991 [1], then worldwide many researcher were started studying by giving emphasis on synthesis of carbon nanotubes [2]. It was reported that the carbon nanotubes posses the good mechanical and electrical properties. Carbon nanotubes exhibit almost about 1TPa of elastic modulus and tensile strength of about 150 GPa [3, 4]. Hence carbon nanotube can be used as defect free and light weight potential fiber material for composites. Alternate materials have been gaining many more popularity in many engineering field applications [5, 6]. Aluminum has become one of the most popular materials in major industrial applications. Powder metallurgy technique [7, 8, 9] was adopted by many researchers for synthesizing the composites. Very least attention is given to the casting technique for synthesizing the carbon nanotube reinforced metal matrix composites. In the present work the casting method was used for manufacturing the multiwalled carbon nanotube reinforced aluminum composites.

Wear of metals is probably the most important yet at least understood aspect of tribology. Wear is an intrinsic material characteristic of the engineering system which depends on load, speed, temperature, hardness, presence of foreign material and the environmental condition. Many parameters that needs for proper prediction of the wear behavior of any material [10, 11, 12].

Most of the work has been done on improving on the strength properties and design of carbon nanotube reinforced aluminum composites. Considering this, an attempt was made to access the wear behavior of carbon nanotube reinforced aluminum composites. Thus in this study, multiwalled carbon nanotube reinforced commercial purity aluminum composites were fabricated by stir casting method. The effect of CNT contents on the hardness and wear behavior of the composites under dry sliding condition were investigated.

2. Experimental Method

2.1 Materials

The carbon nanotubes were synthesized by arc evaporation method [7], and it is used as reinforcement. Carbon nanotubes were dispersed in ethanol and sonicated for about 20 min and solution was evaporated by heating. The residue was wet as the reinforcement, with carbon >95%, outer diameter of 10-30nm, internal diameter of 2-6nm, length of 15-30µm, and density about 1~2 gm/cc.

Commercial purity aluminum was used as the matrix material. Properties of Aluminum are given in the table 1.

Table 1: Properties of Aluminum (commercial purity)

Density (gm/cc)	Young's modulus (GPa)	Yield strength (MPa)	Ultimate tensile strength (MPa)	% of elongation
2.70	70	80	125	18

2.2 Preparation of composite specimens

Commercial purity aluminum as a matrix and multiwalled carbon nanotubes as reinforcements, the composite samples were prepared by stir casting method. Aluminum was melted in the furnace at about 660^0C and then multiwalled carbon nanotubes was poured and stirred at a speed of 400rpm for 5 minutes[13]. Finally the molten metal was poured in mould and solidified. The composites were fabricated with 0.5, 1, 1.5 and 2 wt % of reinforcement. The weight of ingot was approximately 1kg.

2.3 Heat Treatment

The casted specimens were heat treated with solution treatment at 450^0 C for 1hr, followed by quenching in water and finally ageing was done at 120^0C for 24hr [14]. This process was done for all the casting samples.

2.4 Hardness and wear tests

Hardness measurements were carried out on Brinell hardness testing machine for both casted and heat treated samples. The wear behavior experiments have been conducted on pin-on-disc type friction and wear testing machine, which was used to evaluate the wear behavior of the casted samples against hardened ground steel (En32) disc having hardness 65HRC and surface roughness 0.5µm. this equipment used to study wear under sliding condition only. The disc rotates with the help of a DC motor, having speed range 1-1500rev/min with wear track diameter 50mm -160mm, which could yield sliding speed range 0 to 10m/sec. load is to be applied as pin (specimen) by dead weight through pulley of 100N. The wear testing machine is shown in fig 1. The wear test specimens were prepared with specimen diameter 8mm and length 22mm.

Fig.1 Wear testing machine

3. Results and discussions

3.1 Hardness

Brinell hardness testing machine was used to test the hardness of the as casted and heat treated samples for various wt % of reinforcements like 0.5%, 1%, 1.5% and 2%. The results were tabulated in table 2.

The figure 2 shows the graph of hardness v/s wt% of MWCNTs of as casted and heat treated composite samples and the observation made here is an increase in the hardness in heat treated samples as compared to as casted samples.

3.2 Wear of Composites

Pin-on- Disc machine has been used to evaluate the wear characteristics of cast and heat treated composite samples. The wear samples, diameter is 8mm and length is 22mm and operated with loads of 10N, 20N, 30N and 40N. The tests were conducted for MWCNT wt% of 0, 0.5, 1, 1.5 and 2. Wear resistance of aluminum based nanocomposites were expressed through wear rate as a function applied load for as casted and heat treated composite samples. The samples were tested for 100, 200 & 300 RPM with a sliding time of 5, 10, 15 & 20 min.

Table 2: Hardness of as cast and heat treated samples

Wt% of MWCNTs	Hardness (BHN)	
	As-casted samples	Heat treated samples
Aluminum + 0 wt% of MWCNTs	40	44
Aluminum + 0.5 wt% of MWCNTs	57	62
Aluminum + 1 wt% of MWCNTs	61	65
Aluminum + 1.5 wt% of MWCNTs	67	71
Aluminum + 2 wt% of MWCNTs	69	77

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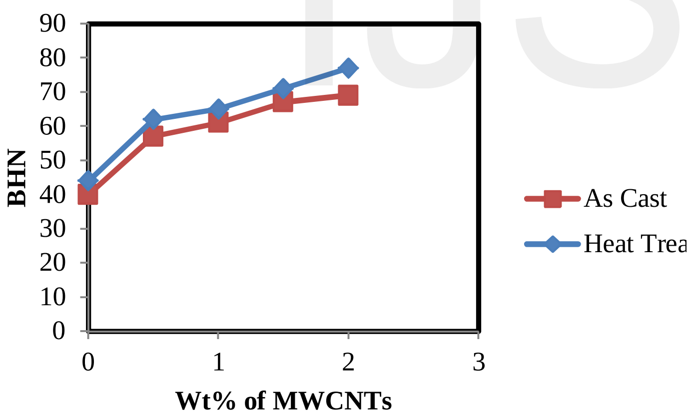

Fig. 2: Hardness (BHN) of as cast and heat treated composite samples

The wear rate is calculated by the equation1 [15]

$$\text{Wear rate (WR)} = \frac{\Delta w}{2\pi rnt} \quad ..(1)$$

The tests on adhesion wear as been carried on groups of specimens given in table 3.

Table 3. Classification of the specimens

Sl. No.	State of Samples
1.	Fabricated Samples of As-casted Al+ MWCNTs composites
2.	Fabricated Samples of heat treated Al+ MWCNTs composites

The wear test conducted according to variable time, variable load and variable sliding speed. Wear rate of fabricated samples of As-cast composites at 100RPM with sliding time of 5mins were tabulated in table4.

The graph of wear rate to wt% of MWCNT of as-cast composites at 100RPM with a sliding time of 5mins plotted in fig.3 and indicates the amount of wear rate decreased with increase in MWCNT weight percentage. Further increase in load the wear rate decreased weight percentage of reinforcement MWCNT.

The heat treated composite samples wear rate for a speed of 100RPM and sliding time 5mins for various loads tabulated in table5 and wear rate vs. MWCNT wt% of heat treated composite shown in fig4, which shows the better wear properties as compare to as-casted composite samples.

Table 4: Wear Rate (g/mm) for as cast composites at 100RPM with a sliding time of 5min

	Wear Rate (g/mm)			
MWCNT Wt%	10 N	20 N	30 N	40 N
Aluminum + 0 wt% of MWCNTs	1.88E-08	2.86752E-08	3.08372E-08	3.60787E-08
Aluminum + 0.5 wt% of MWCNTs	1.79E-08	2.86752E-08	2.96779E-08	3.46933E-08
Aluminum + 1 wt% of MWCNTs	1.60E-08	2.47702E-08	2.89823E-08	3.27884E-08
Aluminum + 1.5 wt% of MWCNTs	1.27E-08	2.308E-08	2.70695E-08	2.94402E-08
Aluminum + 2 wt% of MWCNTs	9.75E-09	1.48791E-08	2.30699E-08	2.6958E-08

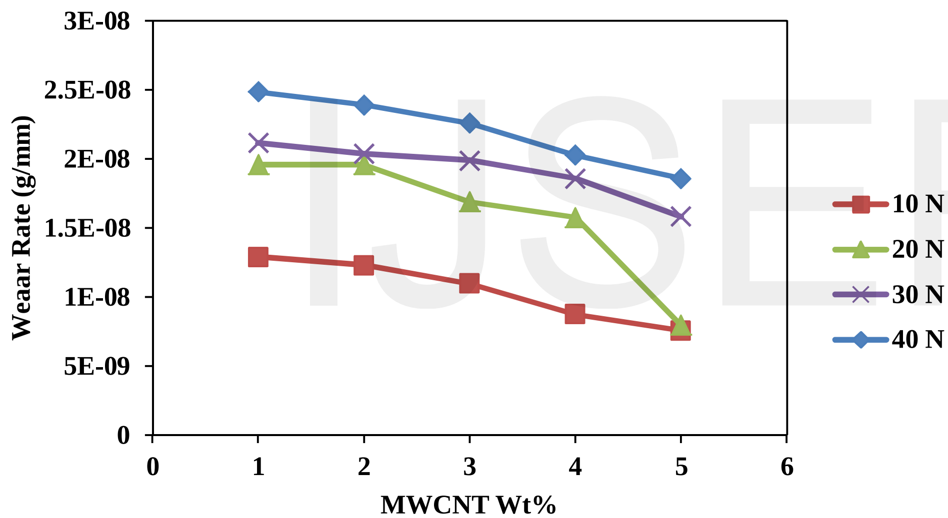

Fig 3. Wear rate vs. MWCNT Wt% of as-cast composites at 100RPM with sliding time of 5mins.

Table 5: Wear Rate (g/mm) for heat treated cast composites at 100RPM with a sliding time of 5min

	Wear Rate (g/mm)			
MWCNT Wt%	10 N	20 N	30 N	40 N
Aluminum + 0 wt% of MWCNTs	1.28899E-08	1.95735E-08	2.11649E-08	2.48647E-08
Aluminum + 0.5 wt% of MWCNTs	1.22931E-08	1.95735E-08	2.03692E-08	2.39099E-08
Aluminum + 1 wt% of MWCNTs	1.09803E-08	1.6908E-08	1.98918E-08	2.25971E-08
Aluminum + 1.5 wt% of MWCNTs	8.75239E-09	1.57543E-08	1.85789E-08	2.02896E-08
Aluminum + 2 wt% of MWCNTs	7.55888E-09	7.95672E-09	1.58339E-08	1.85789E-08

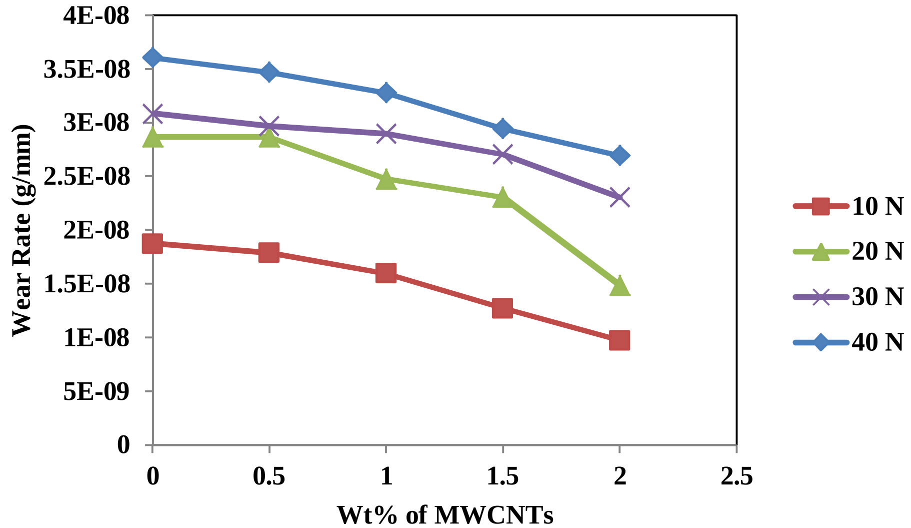

Fig 4. Wear rate vs. MWCNT Wt% of heat treated composites at 100RPM with sliding time of 5mins.

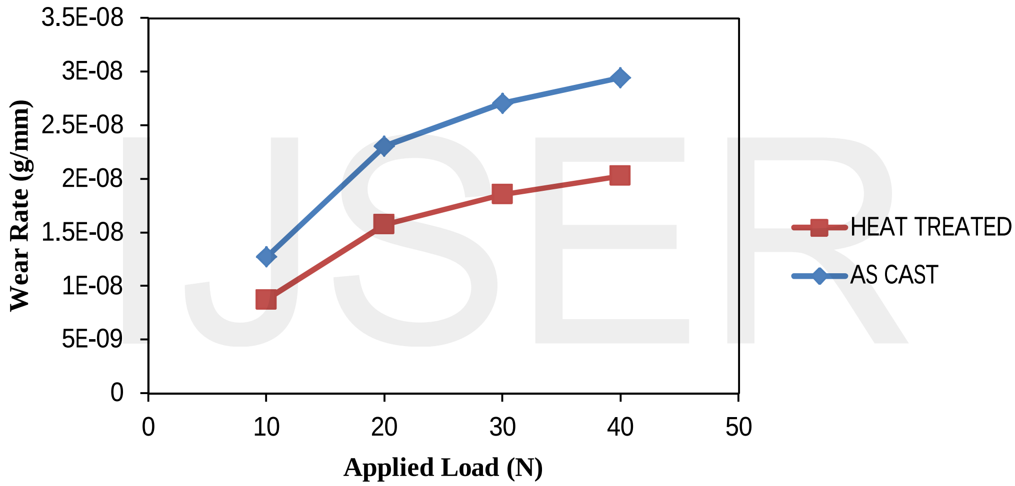

Fig 5. Wear rate vs. Applied Load for as-cast and heat treated composites at 100RPM with sliding time of 5mins.

Comparison between as-cast and heat treated composites is shown in fig5, it is cleared the addition of MWCNT has reduced the wear rate. Simultaneously, wear rate increases as applied load increases.

4. Conclusion

The stir casting technique adopted for fabrication of MWCNT reinforced commercial purity aluminum composites samples. The hardness and the wear behavior during dry sliding condition have been studied for as-cast and heat treated composites samples. The results reveals that heat treated composite samples hardness is relatively large increased compared to as-cast and aluminum samples. The wear rate increases with applied load under dry sliding conditions. The best wear resistance was observed in heat treated samples.

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