

CARBON NANO TUBES BASED ENGINEERING MATERIALS FOR THERMAL MANAGEMENT APPLICATIONS FOR SYNTHESIZED SILICON CARBON NANOTUBES

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Abstract: The purpose of adding Carbon nanotubes (CNT) to metal is to obtain excellent atomic structure and material properties. The strength, wear and corrosion resistance was improved when the addition of carbon nanotubes to the silicon metal. A uniform mixing of carbon nanotubes were achieved by molecular level mixing through the Spark plasma sintering (SPS) process. The interfacial bonding strength is also improved by this process. The material properties and wear properties were also studied. The most influential factor was found by analysis of variance during wear behavior experiment. The deflection test was also conducted under various load conditions.

Index Terms: Carbon nanotubes, Spark plasma sintering, Wear behavior, Corrosion resistance, Deflection test.

I. INTRODUCTION

In recent days, the demand of carbon nanotubes has been increased due to their exclusive atomic structure and smart properties like as high tensile strength, high aspect ratio thermal and electrical conductivity [1-5]. The high temperature and high pressure were applied to for the processing of carbon nanotube composites and its properties were studied [6]. The interfacial bonding strength was improved due to the addition of carbon nanotubes [7-8]. Silicon composites were used in

manufacturing industries, electronics industries, pipelines, construction and automobile brake systems [9]. The silicon carbide based hybrid metal composites coated with carbon nanotubes were fabricated [10]. One-dimensional nanostructure was analyzed in silicon nitride based nano rods and nano wires [11-14]. The silicon based carbon nanotubes were synthesized and used for template purpose [15-17].

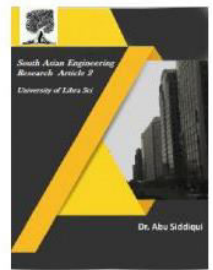


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In the present work describe about a synthesis, characterization analysis of silicon carbon nanotube. The material properties and wear properties were also studied. The most influential factor was found by analysis of variance during wear behavior experiment.

II. MATERIALS AND METHODS

A. Synthesis

The Silicon carbon nanotube was fabricated through the spark plasma sintering process. The uniform mixing of carbon nanotubes and silicon was carried out by ball milling process for 20 hours with 500 rpm. The 6% volume fraction of carbon nanotubes was maintained to the uniform mixture. The carbon nanotubes and silicon powders were compact by mold and the pressure was applied around 10MPa. After that, this mixture was transferred to sintering process. The sintering process temperature and rate of heat were maintained at 1420°C for 10 min. The copper, aluminium based carbon nanotubes were fabricated through the spark plasma sintering process [18-19].

III. RESULTS AND DISCUSSION

The morphological information about the material was confirmed. Si with CNTs provides better refined grain structure. CNTs were uniformly distributed throughout the material structure. The carbon nanotubes were scattered uniformly in titanium alloy which was produced by the spark plasma sintering process [20]. The cluster of silicon particles, inter phase and interlink between silicon and carbon nanotubes. The grain refinement and growth was developed when addition of carbon nanotubes particles. The

stability of the grain structure was also achieved by CNTs. The high extent of grain refinement and mechanical properties were improved due to better interfacial bonding between CNT and Si matrix. The properties of pure silicon and Si/CNT were shown in the Table 1. All material properties were increased due to the addition of carbon nanotube particles.

Table 1: Comparisons of properties

Sample of Material	Grain size (μm)	Hardness (Mohs)	Yield strength (Mpa)	Ductility (%)	Density (g/cm^3)
Pure Silicon	20	6.5	160	50	2.33
Si/CNT	6	7.8	370	30	6.24

IV. ANALYSIS OF CORROSION RESISTANCE

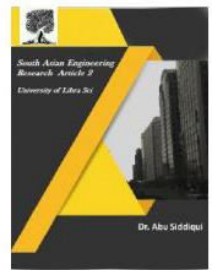
The corrosion experiment was carried out in 2 weight percentage of sodium chloride and hydro chloric acid medium. After preparation of the solution, 25 grams of sodium chloride were mixed with 400ml of water. The temperature was maintained at 30°C. The working metal was submerged in the solution for one hour. The potential range was maintained between -220mv to +220mv. The corrosion behavior has been analyzed using potential E corrosion, current density i_a , and anodic tafel slope β_a . The corrosion potential values are increased and anodic current density has been decreased in the acid medium. A Tafel plot was studied in copper graphite substrate [21]. The corrosion potential values were obtained from sea water and acid medium and recorded in the Table 2.

Table 2: Experimental results for corrosion test

Medium	E_{corr}	i_a	β_a
Sea water	-7.12	1.934×10^{-3}	0.424
Acid	-6.46	1.432×10^{-3}	0.523



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V. ANALYSIS OF WEAR BEHAVIOR

The experiment was conducted by a pin-on-disc wear-testing apparatus. The pin was prepared by 8 mm diameter and 20 mm length. The hardened steel disc was used with HV650 hardness. The constant track diameter of 100 mm was considered for all the tests for 15 min at room temperature. The carbon nanotubes reinforced metal composites reveals admirable tribological properties, like as lower coefficient of friction and high wear resistance [22-24]. The low coefficient of friction was obtained with copper based carbon nanotubes [25]. The Experimental results from frictional wear were shown in Figures 1- 6.

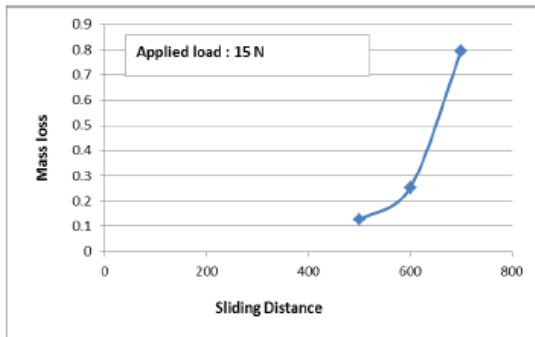


Fig. 1: Sliding distance Versus Mass loss at Applied load 15 N

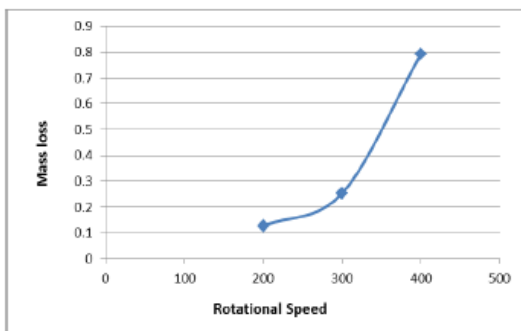


Fig. 2: Rotational speed Versus Mass loss at Applied load 15 N

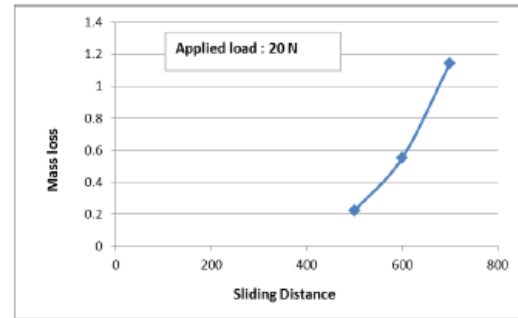


Fig. 3: Sliding distance Versus Mass loss at Applied load 20 N

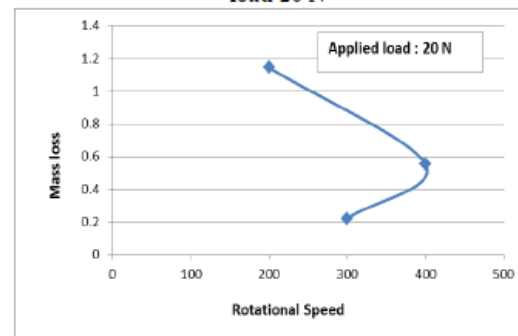


Fig. 4: Rotational speed Versus Mass loss at Applied load 20 N

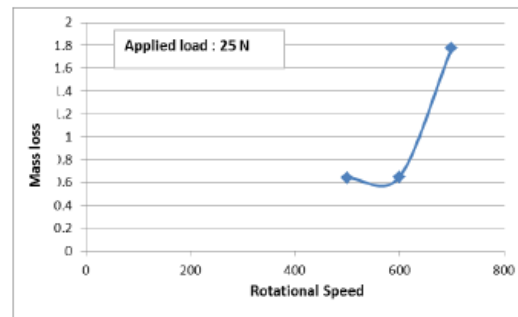


Fig. 5: Sliding distance Versus Mass loss at Applied load 25 N

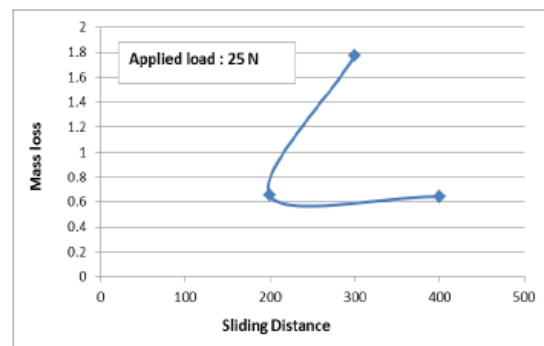
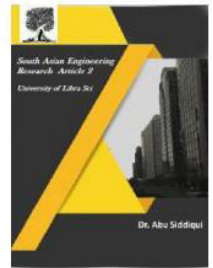


Fig. 6: Rotational speed Versus Mass loss at Applied load 25 N



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By using analysis of variance (ANOVA), sliding distance was the most influential parameter for wear test and shown in Table 3. The applied load was second most influential parameter.

Table 3: Analysis of variance for wear

Source	DF	Adj. SS	Adj. MS	F-Value	P-Value	Percent age %
A: Applied load	2	0.54005	0.27003	6.88	0.127	24.89
B: Sliding distance	2	1.52311	0.76155	19.41	0.049	70.21
C: Disc rotational speed	2	0.02783	0.01391	0.35	0.738	01.28
Error	2	0.07845	0.03923	----	----	03.62
Total	8	2.16945	----	----	----	100

$$\begin{aligned}
 \text{Mass loss} = & 0.6702 - 0.2582 A - 15 - 0.0709 A - 20 \\
 & + 0.3291 A - 25 - 0.3479 B - 500 \\
 & - 0.2299 B - 600 + 0.5778 B - 700 \\
 & - 0.0506 C - 200 + 0.0774 C - 300 \\
 & - 0.0269 C - 400 \quad (1)
 \end{aligned}$$

VI. DEFLECTION TEST

A. Simply Supported Beam

This CNT based alloy is used in various civil engineering applications such as production of survey equipments, trusses, pipes, valves, turbines, nozzles and notches etc. The length, breadth and thickness of the specimen were 1000 x 30 x 5 mm respectively. The deflection was measured by simply supported beam attached with a dial gauge. Due to its high strength and hardness, there was no deflection occurred. The experimental results for deflection test under simply supported beam are presented in Table 4.

Table 4: Experimental results for deflection test under simply supported beam

S.No.	Weight	Distance (mm)	Deflection
1	0	0	0
2	1	250	0
3	3	250	0
4	5	400	0
5	7	400	0
6	9	400	0
7	11	500	0
8	13	500	0
9	15	500	0

B. Cantilever Beam

The deflection was measured under cantilever beam. The same dimension of the specimen was used for this experiment. The experimental results for deflection test under cantilever beam are presented in Table 5.

Table 5: Deflection test under cantilever beam

S.No.	Weight	Distance (mm)	Deflection
1	0	0	0
2	1	200	0
3	3	200	0
4	5	300	0
5	7	300	0
6	9	400	0
7	11	400	0
8	13	600	0
9	15	600	0

The both experiment deflection was measured under different load. Based on the experimental results, this CNT based alloy has withstand more load without any deflection. Hence it can be used in roof, trusses and beams.

VII. CONCLUSION

- Silicon carbon nanotubes were fabricated by molecular level mixing through the spark plasma sintering (SPS) process.
- The corrosion resistance properties of Silicon carbon nanotubes were analyzed. The corrosion potential values were

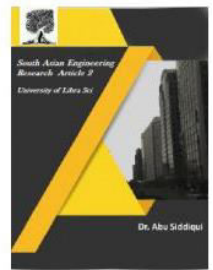


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obtained from sea water and acid medium and recorded.

□ The wear properties of Silicon carbon nanotubes were analyzed and sliding distance was the most influential parameter found by ANOVA.

□ The deflection test was carried out through simply supported and cantilever beam. It has withstands high load without any deflection.

□ Industrial and civil engineering applications were also discussed.

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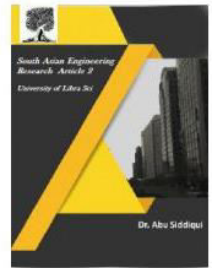


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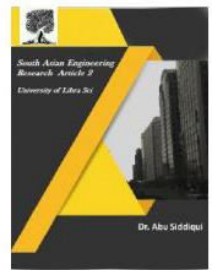


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