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Analysis of wear rate test for aluminium carbon nanotube graphene

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ABSTRACT
Carbon nanotubes make the ideal reinforcement for metal matrix composites material which enhances the mechanical properties as well as tribological properties of base metal. In this paper wear rate study and analysis is conducted on two different composite materials out of which one is prepared from Carbon nanotubes, Graphene as reinforcement with Aluminum as matrix and another only prepared by only Graphene as reinforcement and Aluminum as matrix. Wear rate is studied for both composites and compared with each other.

Keywords: Carbon nanotubes; Graphene; Metal matrix composite; Wear rate; Reinforcement

Abbreviations: CNT-carbon nanotubes

1. INTRODUCTION
Nanocomposites have become one of the more interesting topics in material science. Nanomaterials are materials that are functionally used at the nanoscale (1-100nm). At that size, classical mechanics are no longer valid, with the result that many favorable properties are possible that are not on a larger scale (Srinivas R Bakshi et al., 2011). This is the primary reason that Nanomaterials have received so much interest and research attention in recent years. Nanomaterials have attracted the interest of many industries, including the aerospace industry, particularly the use of

Nanomaterials to enhance the performance of composite materials (Manjunath L.H et al., 2013). Nanocomposites are multiphase solid materials with nano-scale repeat distances between their phases. A wide variety of synthetic Nanocomposite has been created, but these materials can also be found in nature, as in the structure of the bone. Nanocomposites can be divided into three main groups: Polymer-Matrix Nanocomposites: Also known as nanofilled polymer composites, these consist of nanomaterial filler added to a polymer matrix. Proper dispersion of the filler yields composites with high performance (Threrujirapapongthotsaphon et al., 2008). PMNC materials such as epoxy, vinyl ester, polyolefin, specially polymers. Ceramic-Matrix Nanocomposites: Ceramic Nanocomposites usually consist of metal nanoparticles dispersed through ceramic matrix, in order to enhance the physical and mechanical properties of the material CMNC materials such as Al2O3, Sic &Sin. Metal-Matrix Nanocomposites: Metal matrix Nanocomposites, also known as reinforced metal matrix composites, is divided into non-continuous and continuous reinforced materials (Weiping X U et al.,). Nano particles of other metals, non-metals, or more exotic nanomaterial like carbon nanotubes can used to develop composite materials that have good electrical conductivity and high tensile strength.

1.1. Properties of Carbon Nanotubes

CNTs have about 1 to 5 TPa of Young's ModulusCNTs have excellent electrical properties and are used as reinforcement to metals in order to enhance electrical properties. CNTs have extremely high thermal conductivity that allows metal matrix carbon nanotubes to be used for thermal management. The thermal properties of CNT metal matrix composites can be improved based on the distribution and bonding of CNTs with the matrix.

1.2. Properties of Graphene

In Aluminum metal matrix nanocomposite Graphene reinforcement is also added which also have some distinctive properties

- Modulus, fracture strength ~130 GPa
- Low density ~2 g/cm3
- Thermal conductivity ~3000 W/m-K in plane—but highly anisotropic; ~ 2 W/m-K out of plane
- Electrical conductivity: ballistic electron transfer; high mobility
- High specific surface area (limit: 2630 m2/g)
- Physical properties can be 'chemically tuned
- Barrier material—impermeable if defect-free
- High temperature 'base' (support) material (in reducing or neutral conditions)

1.3. Metal Matrix Nanocomposites

The term "Metal Matrix Nanocomposites (MMNCs)" broadly refers to a composite system which is based on metal or alloy substrate, combined with metallic or non-metallic nano-scale reinforcements. The main advantages of MMNCs include excellent mechanical performance, high working temperature, wear resistance, low creep rate and etc. As with conventional metal matrix composites with micron-scale reinforcements, the mechanical properties of a MMNC are strongly dependent on the properties of reinforcements, distribution, and volume fraction of the reinforcement, as well as the interfacial strength between the reinforcement and the matrix. Due to their high surface area, nanosize powders and nanotubes will naturally tend to agglomerate to reduce their overall surface energy, making it difficult to obtain a uniform dispersion by most conventional processing methods. In addition, due to their high surface area and surface dominant characteristics, these materials may also be highly reactive in metal matrices.

2. EXPERIMENTAL PROCEDURE

The wear rate is calculated on pin on disc wear machine for various wt% combinations of composites. The disc is 150 mm in diameter where job slides on 100 mm diameter. Conventional setup has done for various levels of parameters namely RPM, LOAD and TIME. The experimental levels of parameters are for

Load is 1 kgs, 2 kgs

Time is 3 minutes, 5 minutes

RPM is 100 rpm, 200 rpm

For each specimen one parameter is kept varying and other two kept constant as a sample experiment is as shown in Table 1

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Table 1

Wear experiment table; Load varying, time =5 minutes and rpm=200

Levels of loads	Initial wt of composite	final wt of composite	Loss in weight
1kgs			
2kgs			

Like above experiment load varying and keeping time and rpm constants the experiments was conducted for all specimens. On second time now time is varied for three levels and load, rpm is kept constant experiments was conducted for all specimens. On third set up Rpm is varied and load and time is kept constant experiments was conducted. Wear rate is calculated on mass basis by below formula. Wear rate = (loss of mass/distance travelled) GRAMS/m

3. RESULTS AND DISCUSSIONS

From figure 1 to 6, table 2 to 7 shows the comparison of wear rate for different load, time and speed for AL+CNT+GR and AL+GR composites. It clearly indicates that wear rate increases with increase in load, time and speed, also wear rate is more for AL+GR composites as compared to AL+CNT+GR as shown the figure, this is due to carbide formation occurs on the surface for AL+CNT+GR composites which resist the further wear but in AL+GR composites Graphene is in 2D structure which is not hard and allows to wear the Aluminum matrix rapidly.

4. CONCLUSION

In evaluation of Tribological property the wear rate decreases as reinforcement percentage increases. As compared to (AL+CNT+GR) composites the wear rate is more for (AL+GR) composite Although Carbon Nanotubes and Graphene have nearly same mechanical properties, Composites prepared from only Graphene as reinforcement in aluminum matrix composites and also composites prepared with both Graphene and Carbon Nanotubes in hybrid form as reinforcement in aluminum matrix were compared .Wear resistance is substantially increased in composites where carbon nanotubes and Graphene are used as reinforcement compared with aluminum composites .the combination in hybrid reinforcement form of carbon nanotubes and graphenes in aluminum matrix makes hard layer which resists the further abrasion. Carbon nanotubes in fibrous form and Graphene in whiskers prohibits the wear rate.

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Table 2

wear rates for Load varying, Time and Speed constant

Load=1kg and Time=5 min Speed=200rpm

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	2.71	2.63	2.58	2.5	2.43	2.73	2.63	2.54	2.47	2.42
final wt of composite(gms)	2.65	2.59	2.52	2.45	2.38	2.65	2.57	2.47	2.42	2.38
Loss in wt(gms)	0.06	0.04	0.06	0.05	0.05	0.08	0.06	0.07	0.05	0.04
Wear rate x10-4 (gms/mtr)	1.9	1.27	1.9	1.6	1.6	2.5	1.9	2.2	1.6	1.3

Wear rate =loss in wt/ (πDNT) D=diameter of pin sliding disc

=0.06/3.142*100*200*5 =0.00019 N=RPM, T=time taken for wear

Table 3

wear rates for Load varying, Time and Speed constant

Load=2 kg and Time=5 min Speed=200rpm

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	2.35	2.27	2.2	2.14	2.09	2.37	2.28	2.19	2.12	2.04
final wt of composite(gms)	2.28	2.21	2.14	2.1	2.06	2.28	2.2	2.12	2.05	1.99
Loss in wt(gms)	0.07	0.06	0.06	0.04	0.03	0.09	0.08	0.07	0.07	0.05
Wear rate x10-4 (gms/mtr)	2.2	1.9	1.9	1.3	1.27	2.9	2.5	2.2	2.2	1.6

Table 4

Wear rates for Time varying, Load and Speed constant

Time=3 min and Speed=200rpm Load=2kg

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	2.05	2.01	1.96	1.94	1.91	1.99	1.96	1.92	1.89	1.86
final wt of composite(gms)	2.02	1.98	1.94	1.92	1.9	1.94	1.92	1.89	1.86	1.84
Loss in wt(gms)	0.03	0.03	0.02	0.02	0.01	0.05	0.04	0.03	0.03	0.02
Wear rate x10-4 (gms/mtr)	0.95	0.95	0.64	0.64	0.32	2.6	2.1	1.6	1.6	1.1

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Table 5

Wear rates for Time varying, Load and Speed constant

Time=5 min and Speed=200rpm Load=2kg

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	1.9	1.84	1.79	1.74	1.7	1.86	1.78	1.72	1.67	1.63
final wt of composite(gms)	1.84	1.79	1.75	1.7	1.67	1.78	1.72	1.68	1.63	1.6
Loss in wt(gms)	0.06	0.05	0.04	0.04	0.03	0.08	0.06	0.04	0.04	0.03
Wear rate x10-4 (gms/mtr)	1.9	1.59	1.2	1.3	0.95	2.5	1.9	1.3	1.3	0.95

Table 6

Wear rates for speed varying, Load and Time constant

Speed=100rpmand Load=2kgTime=5min

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	1.67	1.62	1.57	1.52	1.49	1.6	1.54	1.49	1.45	1.4
final wt of composite(gms)	1.62	1.57	1.53	1.49	1.47	1.54	1.49	1.45	1.41	1.37
Loss in wt(gms)	0.05	0.05	0.04	0.03	0.02	0.06	0.05	0.04	0.04	0.03
Wear rate x10-4 (gms/mtr)	1.5	1.5	1.2	0.95	0.64	1.9	1.6	1.3	1.3	0.95

Table 7

Wear rates for speed varying, Load and Time constant

Speed=200rpm and Load=2kgTime=5min

Percentage combination of reinforcements	Al 99.8	Al 99.6	Al 99.4	Al 99.2	Al 99.0	Al 99.98	Al 99.96	Al 99.94	Al 99.92	Al 99.0
	Cnt 0.1	Cnt 0.2	Cnt 0.3	Cnt 0.4	Cnt 0.5	Cnt 0.0	Cnt 0	Cnt 0	Cnt 0	Cnt 0
	Gr 0.1	Gr 0.2	Gr 0.3	Gr 0.4	Gr 0.5	Gr 0.2	Gr 0.4	Gr 0.6	Gr 0.8	Gr 1.0
Initial wt of composite(gms)	1.47	1.4	1.34	1.28	1.2	1.37	1.29	1.22	1.15	1.09
final wt of composite(gms)	1.4	1.34	1.28	1.21	1.15	1.29	1.22	1.15	1.09	1.04
Loss in wt(gms)	0.07	0.06	0.06	0.07	0.05	0.08	0.07	0.07	0.06	0.05
Wear rate x10-4 (gms/mtr)	2.2	1.9	1.9	2.2	1.6	2.5	2.2	2.2	1.9	1.6

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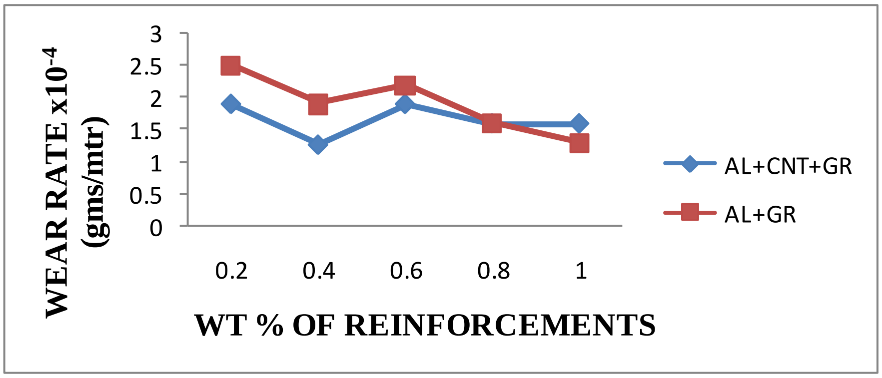

Figure 1

Comparison of Wear rate for 1kg load between (AL+CNT+GR) and (AL+GR) specimens Load=1kg and Time=5 min Speed=200rpm

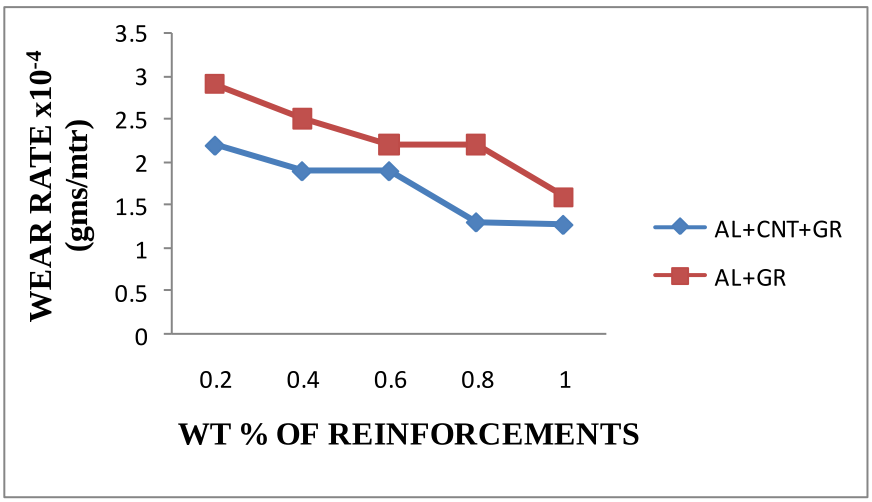

Figure 2

Comparison of Wear rate for 2kg load between (AL+CNT+GR) and (AL+GR) specimens; Time=5min and Speed=200rpm Load=2kg

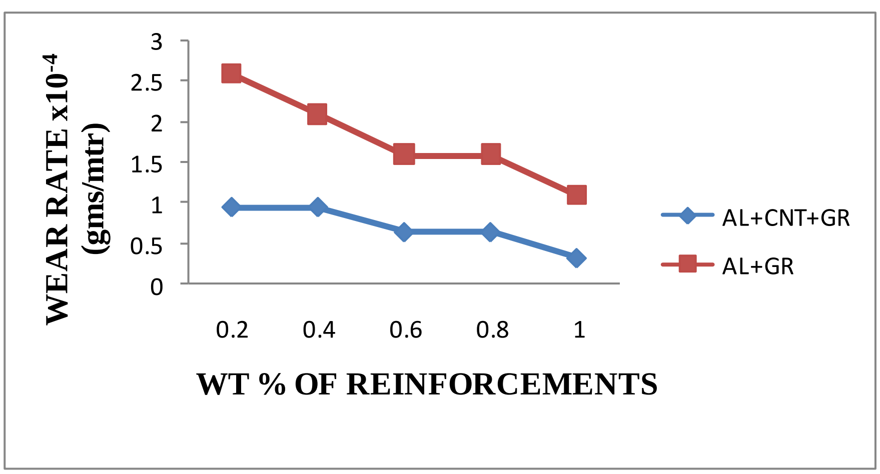

Figure 3

Comparison of Wear rate for 3 min between (AL+CNT+GR) and (AL+GR) specimens; Time=3 min and Speed=200rpm Load=2kg

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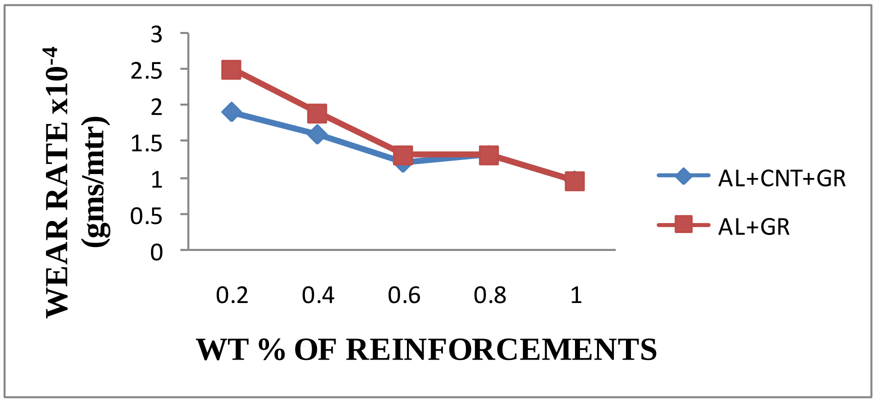

Figure 4

Comparison of Wear rate for 5min between (AL+CNT+GR) and (AL+GR) specimens Speed=200rpmand Load=2kg Time=5min

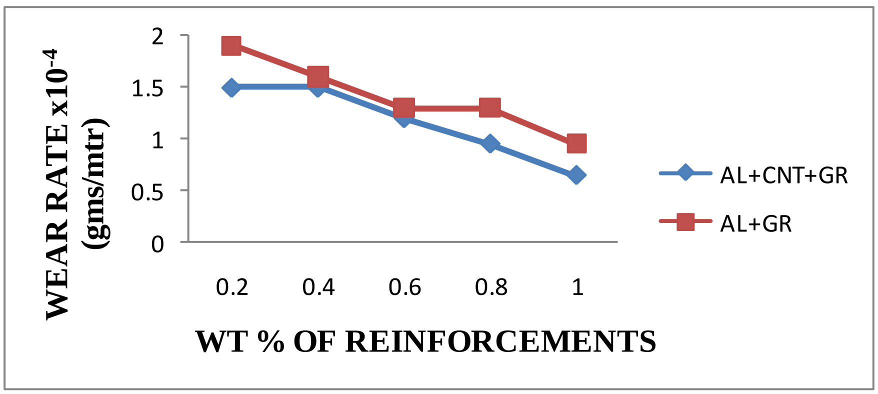

Figure 5

Comparison of Wear rate for 100rpm between (AL+CNT+GR) and (AL+GR) specimens Speed=100rpmand Load=2kgTime=5min

Figure 6

Comparison of Wear rate for 200rpm between (AL+CNT+GR) and (AL+GR) specimens Speed=200rpmand Load=2kgTime=5min