Nano World Journal

https://doi.org/10.17756/nwj.2023-s1-095

Research Article

Open Access

Comparative Study of Wear Performance Between High Density Polyethylene and Reinforced High Density Polyethylene

Abhisek Pradhan*, Boddepalli Durga Rao and Trilochan Rout

Department of Mechanical Engineering, Parala Maharaja Engineering College, Berhampur, Odisha, India

***Correspondence to:**
Abhisek Pradhan
Department of Mechanical Engineering,
Parala Maharaja Engineering College,
Berhampur, Odisha, India.
E-mail: abhisekpradhan0001@gmail.com

Received: November 24, 2022
Accepted: April 28, 2023
Published: April 30, 2023

Citation: Pradhan A, Rao BD, Rout T. 2023. Comparative Study of Wear Performance Between High Density Polyethylene and Reinforced High Density Polyethylene. *NanoWorld J* 9(S1): S495-S498.

Copyright: © 2023 Pradhan et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY) (http://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

The HDPE (High density polyethylene) composite can be considered for lightweight applications at low temperatures. The HDPE/CNT (Carbon nanotube) composite is prepared with weight variation of CNT as 0.04 and 0.12 wt.% through sonication (>20 k Hz) and magnetic stirring followed by injection molding. The Cu micro powder is added with HDPE with same composition and injection molded. The pin-on-disc wear tester showed significant improvement in wear resistance and wear amount in both the composites compared to pure HDPE. The hardness test also showed improvements carried out at digital Rockwell hardness tester.

Keywords

Carbon Nanotube, Copper, High density polyethylene, Wear properties, Pin-on-disc

Introduction

In modern days components like gears, cams, and bearings can be made of polymers where applied force is small due to its corrosion resistance and cost effectiveness. HDPE has a wide range of industrial applications like medical devices, interiors of airplanes and automotive parts. Although HDPE is excellent compared to other polymers, it lacks wear resistance, stiffness, and rigidity [1]. The wear performance of polymeric composites generally depends upon their self-lubrication property and low coefficient of friction (COF).

The HDPE is a suitable choice for light weight applications such as ship water lubricated stern bearing [2] and aerospace rover bearing due to their cost economy and chemical stability. These are also capable of better toughness to resist impact load. The discovery of CNT by Iijima [3] provided spark in material science researchers due to its high aspect ratio, excellent mechanical, and structural strength. The HDPE/CNT composite prepared and tested by Rao et al. [4] which gives a clear idea about their properties and characteristics. These include mechanical as well as wear characteristics with theoretical validation. The addition of copper (Cu) with HDPE increases UV ray stability of the composite compared to pure HDPE making it advantageous in UV ray exposed atmospheres like outer space [5].

Materials and Methods

Materials

The HDPE was procured from Haldia Petrochemicals limited, India, having product code M5018L having density 0.95 g/cm^3 at 23 °C, tensile strength 22 MPa and Melting point 132 °C. The multi walled carbon nanotube is procured

from Resinte Nano Venture, India, having density 2.15 g/cm^3 at 95% purity, length between 60 to 100 nanometer and length ranging from 5 to 15 micrometer. The Cu powder is purchased from Aldrich Chemistry, USA, with molecular weight 63.55 g/mol, melting point: 1083.4 °C, density: 8.94 g/ml at 25 °C, grain size: 14 - 25 micrometers, purity >99%.

Functionalization

As CNT is insoluble in many solvents it is essential to functionalize it for uniform dispersion through the composite. For HDPE matrix no complex procedure is required rather it is essential to put the CNT in extreme acidic condition of HNO_3 and H_2SO_4 at elevated temperatures. The steps are as following:

Pure HNO_3 of LR grade and pure H_2SO_4 of LR grade with 99% purity mixed in 1:3 ratio in beaker. This mixture must be surrounded with an ice bath to remove the extra heat from exothermic reaction. Sudden mixing was avoided, and the mixing was done by drop wise addition. Very slowly CNT was added to this mixture. The magnetic stirrer heating machine is used to heat this mixture to 140 °C through constant mixing. Then the mixture was left alone to settle down CNT overnight. Then acid solution was drained out and water addition was done into it. This new solution was centrifuged for 20 minutes at 12000 rpm, and water was drained out. This process was repeated until reaching 6 - 7 pH. The wet CNT was heated overnight to remove traces of moisture particles. The mortar and pestle were used to grind the hardened functionalized CNT [4].

Material preparation

The distribution of CNT across the composite can be achieved uniformly by accurate mixing of HDPE and CNT. Before mixing the HDPE is preheated to 70 °C for 180 minutes to remove moisture in a furnace then gradually cooled to room temperature. Ethanol and CNT solution is prepared separately by 450 ml and 300 ml ethanol with 0.6 g and 0.2 g, respectively. Sonication is provided for 15 minutes with a 5-minute gap. Then 500 gm of HDPE is added with the solution followed by stirring through magnetic stirrer. Magnetic stirring is continued for 3 hours to remove ethanol. Then this mixture is put in an oven for 1 hour to remove any trace of ethanol.

Composite preparation

The HDPE/CNT composite is prepared through melting, pressurized feeding into a die in an injection molding machine. Before feeding the pellets were preheated at 85 °C for 3 hours to remove moisture particles. The pellets were fed through hopper according to sequence of composites to be manufactured. These further go through the heating coils and heated above its melting point (140 °C). Further it is heated up to 205 °C for homogenized distribution of the CNT. Various samples were prepared after cooling it for 1 minute and these were ejected through ejector pin.

The HDPE/Cu composite is prepared through direct mixing of the Cu powder and HDPE powder through the mixer. The HDPE pellets were ball milled to form into powder shape before feeding. The mix then passed through the heating coil, melted and pressure fed into the die. The prepared samples were then obtained after cooling and ejection.

Wear test

The wear testing is carried out on DUCOM TR -201 pin-on-disc machine. This set up consists of two units; one is a field unit and the other is a control unit. The field unit consists of the rotating disc (165 mm diameter and 8 mm thick) which have rotational speed range 200 to 2000 rpm having proximity sensor and 0.1% accuracy. This disc is mounted on a base containing a motor connected to the disc. There is an arm connected through lever and spring, one end of which is placed above disc containing gripping section (3, 6, 10 and 12-mm diameter holder) to hold the specimen. The other end is connected through a wire to free hanging base for attaching load (0.5 kg to 20 kg). Various sensors like temperature sensor, wear measurement sensor and friction force measurement sensors are provided to measure these quantities. Provision is provided to move and adjust the arm from zero to 100 mm so as to change the track diameter as per requirements. The control unit consists of various regulators and switches alongside PLC known as controller. This is connected to a desktop to collect the data while doing experiments.

First of all, the parameters are fixed according to research requirements. Here the specifications were: length of the specimen - 55 mm, surface area - 36 mm^2, travel distance - 1000 m, rpm - 500, track diameter - 80mm.

For experimentation, first the specimens as shown in figure 1 are prepared to have the same surface area to get uniform and accurate results. The machine disc must be cleaned properly before starting the experimentation. For getting considerable wear amount emery paper of 320 grade is used which can be chosen according to the application. After fixing emery paper the right size of job holder is attached to the lever arm. Then the job is attached to it. The all parameters are recorded before starting the test and set to zero wear by operating switch. The load is attached to the load set up. Also, the adjusting screw is adjusted to set friction force to zero. Then the machine is set for the number of revolutions through switch or computer and experiment started. After the prerequisite time the experiment stops, and the data were collected. This process is repeated for various samples.

Hardness test

The hardness test is carried out as per ASTM 785 by plac-

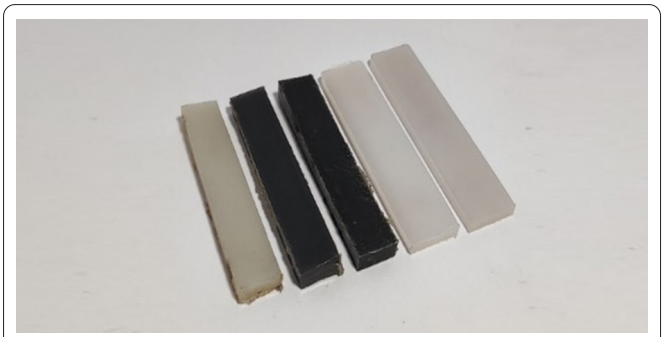

Figure 1: Wear test specimen.

ing the specimen on the anvil. The specimen must be finished properly to get accurate results before conducting the test. The type of scale and indenter is selected first. The load is also selected manually by the rotary switch provided at the right side and digitally by the selector switch. After placing the specimen on the anvil, it is moved up by rotating the handle to make contact with the indenter. After making first contact the rotary handle rotated a few revolutions till the digital screen reading shows complete contact with a ratchet noise. The reading can be seen on the screen with the green light blink after the preset dwell period if the reading is correct, else there will be error indication. This reading directly indicates the Rockwell hardness number of the specimen. The test specifications were as follows: Scale - M scale [6], Manual load - 10 to 100 kg, Digital load - 20 to 100 kg, Indenter type - ball.

Results and Discussion

The wear test results showed three parameters FF (Friction force), COF, wear and mass loss. The FF graph as indicated below shows highest at pure HDPE as 5.98 N peak value followed by 0.04% CNT as 5.79 N, 0.12% CNT as 5.64 N, 0.04% Cu as 5.12 N, and 0.12% Cu as 4.86 N as shown in figure 2.

The COF value also got proportional to the FF as the load applied is constant. The peak COF is obtained for pure HDPE as 0.472 followed by 0.04% CNT as 0.457, 0.12% CNT as 0.44, 0.04% Cu as 0.372 and 0.12% Cu as 0.356 as shown in figure 3.

The wear value is lowest for 0.12% CNT with 1506.31 µm and increases gradually as 0.04% CNT with 1843.53 µm, 0.12% Cu with 2064.59 µm, 0.04% Cu with 2066.55 µm and pure HDPE with 2070.32 µm, respectively as shown in figure 4.

The mass loss is obtained as 0.1792 gm for 0.12% Cu, 0.1313 gm for 0.04% Cu, 0.104 gm for pure HDPE, 0.0795 gm for 0.04% CNT and 0.0589 gm for 0.12% CNT as shown in figure 5.

The hardness values obtained are as follows which indicates 0.12% Cu as hardest, followed by 0.04% Cu, pure HDPE 0.04% CNT and 0.12% CNT (Table 1).

The scanning electron microscope (SEM) images as shown in figure 6 indicate the distribution of reinforcement in the composite which indicates the distribution of Cu is more uniform compared to CNT across HDPE matrix.

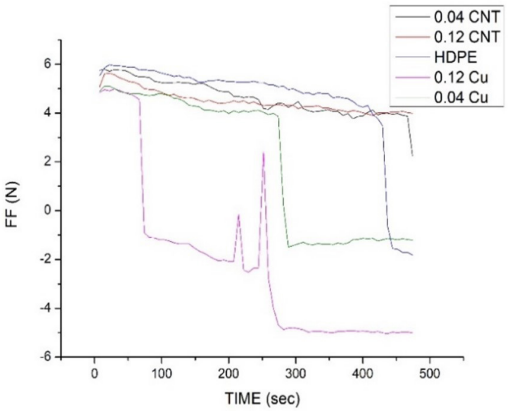

Figure 2: Friction force vs time graph.

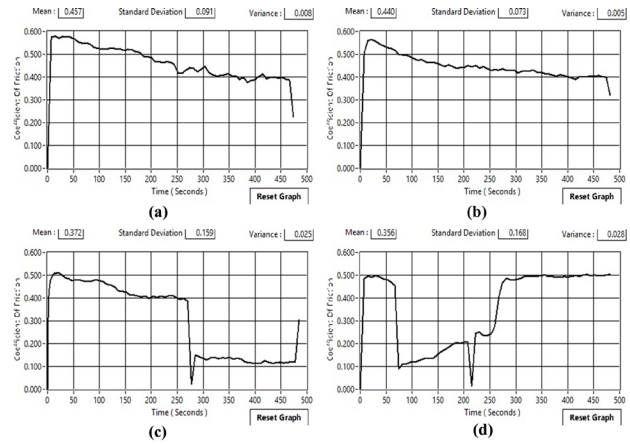

Figure 3: The COF graph of **(a)** 0.04% CNT, **(b)** 0.12% CNT, **(c)** 0.04% Cu, and **(d)** 0.12% Cu.

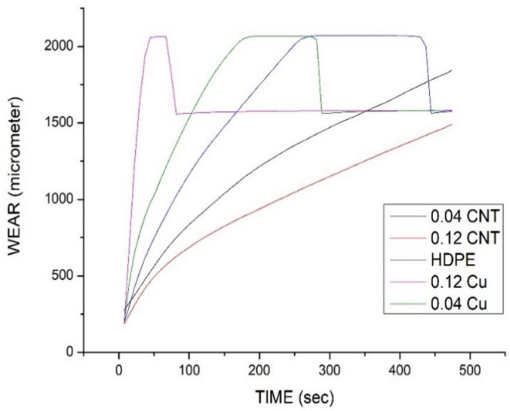

Figure 4: Wear vs time graph.

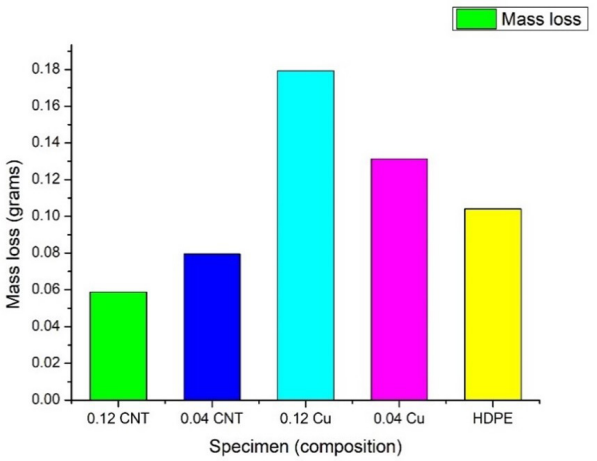

Figure 5: Mass loss vs composition graph.

Conclusions

From the experimental data we can see that the CNT reinforced composite poses more resistance to wear as compared to Cu reinforced composite. This is due to fibrous

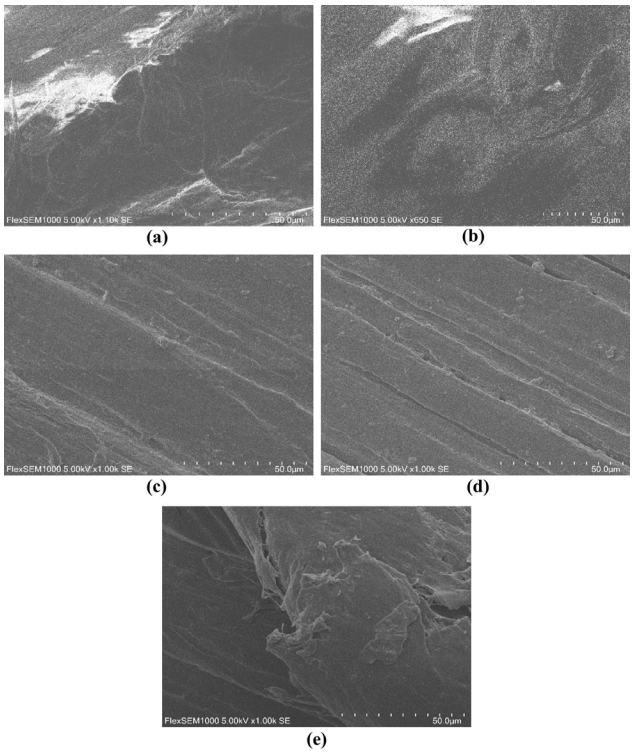

Figure 6: SEM images of **(a)** 0.04% CNT, **(b)** 0.12% CNT, **(c)** 0.04% Cu, **(d)** 0.12% Cu, and **(e)** pure HDPE composites.

Table 1: Rockwell hardness table for various composites.

Composition	Hardness
0.12 CNT	54.25
0.04 CNT	49.75
HDPE	43.8
0.04 Cu	61.23
0.12 Cu	65.4

nature CNT, which comes between the rotating abrasive paper and the HDPE matrix interface causing more resistance to wear whereas Cu is in powder form causing rapid wear in the in the abrasive paper and the HDPE matrix interface. The SEM image supports this reason as we can see the white fibrous flakes appear on the surface upon wear in HDPE-CNT composites whereas in HDPE-Cu there is no such phenomena. Also, the hardness of Cu composites became more than CNT composites due to homogeneous and regular distribution of Cu along the matrix compared to CNT. So, from these we can conclude that CNT composites are better wear resistant than Cu composites.

Acknowledgments

We are grateful to the technicians of PMEC, Berhampur, Berhampur University and CIPET, Bhubaneswar for their sincere help and cooperation during experimentations.

Conflict of Interest

The authors declare that they have no conflict of interest that could have appeared to influence the work reported in this paper.

Credit Author Statement

Abhisek Pradhan: Conceptualization, Methodology, Experimentation, Writing - original draft preparation, Writing - review and editing; Boddepalli Durga Rao: Conceptualization, Writing - original draft preparation, Writing - review and editing; Trilochan Rout: Conceptualization, Writing - review and editing, Supervision. All the authors read and approved the manuscript.

References

1. Badgayan ND, Samanta S, Sahu SK, Siva SV, Sadasivuni KK, et al. 2017. Tribological behaviour of 1D and 2D nanofiller based high density poly-ethylene hybrid nanocomposites: a run-in and steady state phase analysis. *Wear* 376: 1379-1390. https://doi.org/10.1016/j.wear.2016.12.037
2. Wu Y, Dong C, Yuan C, Bai X, Zhang L, et al. 2021. MWCNTs filled high-density polyethylene composites to improve tribological performance. *Wear* 477: 203776. https://doi.org/10.1016/j.wear.2021.203776
3. Iijima S. 1991. Helical microtubules of graphitic carbon. *Nature* 354(6348): 56-58. https://doi.org/10.1038/354056a0
4. Rao BD, Pradhan A, Sethi KK. 2022. Study of wear performance and mechanical properties of HDPE on addition of CNT fillers. *Mater Today Proc* 62: 7501-7508. https://doi.org/10.1016/j.matpr.2022.03.705
5. Grigoriadou I, Paraskevopoulos KM, Karavasili M, Karagiannis G, Vasileiou A, et al. 2013. HDPE/Cu-nanofiber nanocomposites with enhanced mechanical and UV stability properties. *Compos B Eng* 55: 407-420. https://doi.org/10.1016/j.compositesb.2013.07.002
6. Dabees S, Tirth V, Mohamed A, Kamel BM. 2021. Wear performance and mechanical properties of MWCNT/HDPE nanocomposites for gearing applications. *J Mater Res Technol* 12: 2476-2488. https://doi.org/10.1016/j.jmrt.2020.09.129