International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Effect of Base Oil on the Anti-Wear Performance of Multi-Walled Carbon Nano-tubes (MWCNT)

S. M. Muzakkir†*, K. P. Lijesh† and Harish Hirani†

†Department of Mechanical Engineering, Indian Institute of Technology Delhi, India

Accepted 10 March 2015, Available online 15 March 2015, **Vol.5, No.2 (April 2015)**

Abstract

The Multi-Walled Carbon Nano-tubes (MWCNT) are employed as anti-wear additives in mineral oil. The high specific surface area of MWCNT causes agglomeration and suitable surfactant is required to maintain MWCNT in the de-agglomerated state. However, the addition of surfactant in the base oil may cause variations in its tribological performance. The effectiveness of MWCNT as anti-wear additive may be dependent on the properties of the base oil. The present experimental work aims to study these effects. The experiments have been conducted to determine the optimum quantity of MWCNT that is able to minimize the wear of the tribo pairs. The nano lubricants containing varying quantities of MWCNT were prepared in two different base oils using the same surfactant to study these effects. The wear tests were conducted on block on disk test setup to determine the anti-wear performance of the nano lubricants. The wear of the block is measured in terms of its weight loss. The results of the wear tests are reported.

Keywords: *MWCNT, Surfactant, Nano-tubes, Wear, base oil*

1. Introduction

The contact between the two surfaces during relative motion is generally avoided so as to eliminate friction and wear, however in several applications the load and speed conditions are not favorable and the tribo pair operates in mixed lubrication regime (S M Muzakkir *et al*. 2011; S M Muzakkir *et al*. 2010). Many alternative technologies have been employed to separate the contacting surfaces (S.M. Muzakkir, Lijesh, and Hirani 2014; Samanta and Hirani 2008; Samanta, P Hirani 2007; Hirani, Athre, and Biswas 2001; Lijesh and Hirani 2015a; Shankar, Sandeep, and Hirani 2006; Chittlangia *et al*. 2014; Lijesh and Hirani 2015b), however the use of Multi-Walled Carbon Nano-tubes (MWCNT) (Popov 2004; Lijesh, Muzakkir, and Hirani 2015), that has recently emerged as an anti-wear additive, is being accepted as one of the most effective solution. Other anti-wear additives like Zinc (S. M. Muzakkir, Hirani, and Thakre 2013), molybdenum disulphide nano-particles (S M Muzakkir and Hirani 2014; S M Muzakkir and Hirani 2015a; S M Muzakkir and Hirani 2015b; S M Muzakkir and Hirani 2015c) Tungsten Disulphide etc are also being used in lubricants for minimizing wear. The properties of carbon nano-tubes are due to the 1D quantum behavior and symmetry. The use of MWCNT as lubricant additive (Li *et al*. 2006) have resulted in reduced wear and increased load carrying capacity of the base oil. However, its high specific surface area (Mahbubul, Saidur, and Amalina 2012; Hu, Hu, and Tribology 2005; Chhowalla and Amaratunga 2000) causes agglomeration (Chu, Chu, and Barigou 2009; Liu *et al*. 2011) and if not de-agglomerated may instead increase the wear. The most common mechanical method of de-agglomeration is by ultrasonic homogenization. After de-agglomeration, a suitable surfactant is required for proper dispersion of the nano-particles in the mineral oil for stable suspension. But the addition of surfactant in the mineral oil may affect its tribological properties.

The effectiveness of MWCNT as anti-wear additive may also be dependent on the base oil properties. Based on the review of the literature it is observed that very few studies have focused on these aspects. Therefore, there is a need to conduct experimental investigations to study these effects and to identify an optimum quantity of the MWCNT that can minimize the wear of the tribo pair corresponding to different base oils. In the present work nano lubricants containing varying quantities of MWCNT were prepared in two different base oils using the same surfactant (TX-100) to study these effects. The wear tests were conducted on block on disk test setup to determine the anti-wear performance of these nano lubricants. The block and disc test setup is used in conducting wear tests. The load and speed conditions are selected so as to cause the operation in mixed lubrication regime. The experimental results are reported.

*Corresponding author: **S. M. Muzakkir**

2. Experimental details

The wear tests have been conducted on block and disk test setup as shown in Fig. 1and Fig. 2.

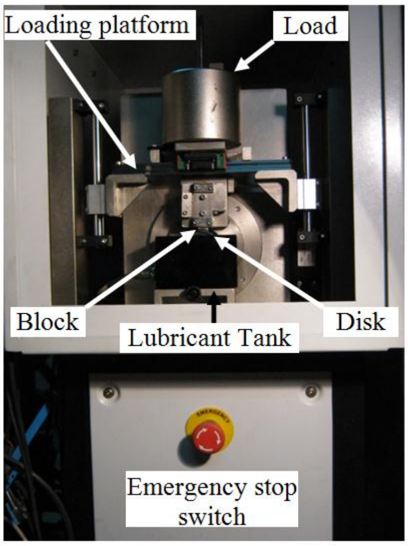

Fig.1 Photograph of block and disk test setup (S. M. Muzakkir *et al*. 2014)

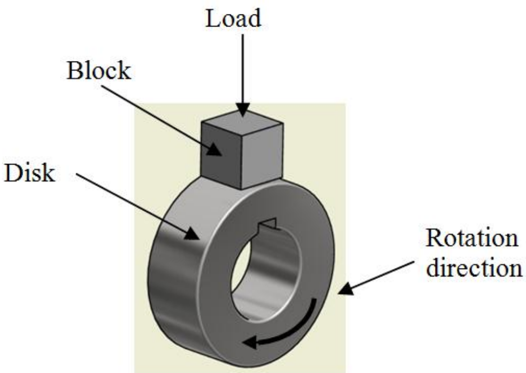

Fig.2 Schematic diagram of block and disk test setup (Lijesh *et al*. 2015)

The block (made of phosphorus bronze material) slides over the disk (made of hardened steel) having 40 mm diameter and 15mm width. The disk is driven by an induction motor. The block is fixed in a holder that is attached to the loading platform. The static load is applied on the loading platform that causes the contact between the flat face of the block with the disk. The block slides against the disk. The disk is partially immersed in the lubricant which is maintained at a temperature of 70°C by the help of heaters and a thermal cut-off switch. The tests were carried out at a load of 70 N. The disk was rotated at a speed of 25 rpm corresponding to a sliding speed of 5.23 x10^{-2}m/sec. A combination above load and sliding speed were considered for the test operating conditions so as to causes the operation in the mixed lubrication regime.

In the present work –COOH functionalized MWCNT was used in the preparation of the nano-lubricants. The weight percentage of MWCNT considered for preparing the nano-lubricant in the present work was taken to be 0.01, 0.05, 0.1 and 0.15% of the lubricant weight. The surfactant quantity is taken to be 350 times the quantity of MWCNT by weight. The ultrasonic homogenization, with a power of 250 W, was carried out for one hour to de-agglomerate and disperse the surfactant and MWCNT in the base oil. The photograph of ultrasonic homogenizer is shown in Fig. 3.

Fig.3 Ultrasonic homogenizer

The dynamic viscosity of the two base oils were determined using Anton Paar™ MCR Rheometer as per ASTM D4440.

Fig.4 Rheometer (Anton Paar™)

3. Experimental results and discussion

The experiments were conducted with different quantities of MWCNT in the two base oils. The experiments were conducted using MWCNT quantity in the ascending order so as to identify the trend of the wear values. The Fig. 5 shows the result of the wear tests conducted on block and disk test setup at the operating conditions mentioned in the previous section for the base oil 1. The dynamic viscosity of base oil 1 and 2 are 0.00196 Pa.s and 0.07280 Pa.s respectively.

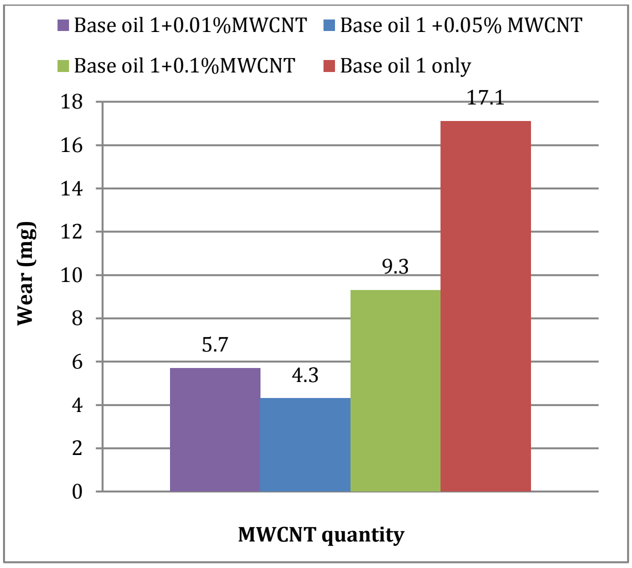

Fig.5 Experimental results for Base oil 1

It is observed from Fig. 5 that a wear of 5.7mg was obtained for 0.01% quantity of the MWCNT. Therefore in the next wear test the quantity of the MWCNT was increased to 0.05% and the wear obtained was found to be lesser than the previous wear test. Based on this trend the quantity of MWCNT was further increased to 0.01% but the wear increased to 9.3mg as compared to 4.3 mg for 0.05% MWCNT quantity. The tests were then stopped. It is thus observed from the Fig. 5 that there is substantial decrease in the wear of the block as compared to the base oil 1 when the quantity of the MWCNT is 0.05%.

The photograph of the worn out flat face of the block depicting the wear scar is shown in Fig. 6.

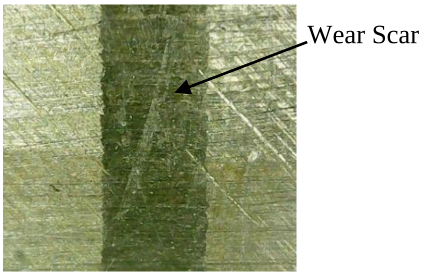

Fig.6 Worn out block after the wear test

The second set of wear tests were conducted using base oil 2. The Fig. 7 shows the result of the wear tests conducted on block and disk test setup at the operating conditions mentioned in the previous section for the base oil 2. The same methodology is applied for conducting wear tests using base oil 2.

It is observed from comparison of base oil 1 and 2 that the wear in case of base oil 2 is comparatively lesser than that of base oil 1. The minimum wear obtained was for 0.1% quantity of MWCNT. Three quantities of MWCNT were taken for testing, namely 0.05, 0.1 and 0.15% by weight as shown in Fig. 7. The minimum wear of the block for base oil 2 is also lesser as compared to that of the base oil 2 and similar trend is observed with the maximum wear when only base oil without any additive is considered. Since the base oil 1 is less viscous, therefore a stable dispersion of MWCNT is difficult to obtain and agglomeration will occur. The increased wear observed with the increase in the MWCNT quantity for the base oil 1 is due to the agglomeration of MWCNT. However an opposite trend is observed for base oil 2 where the viscosity is high and stable dispersion is easy to obtain. Therefore a reduced wear is obtained for base oil 2 with 0.1% quantity of MWCNT as compared to 0.05% quantity of MWCNT foe base oil 2.

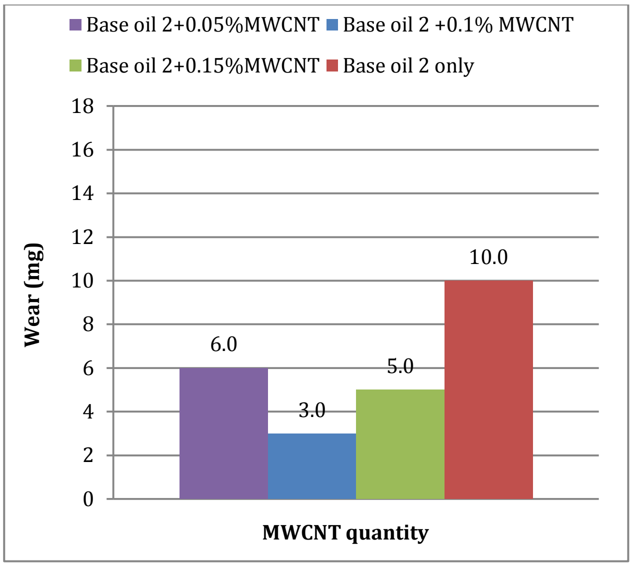

Fig.7 Experimental results for Base oil 2

Conclusions

Based on the observations of the experimental studies, following conclusions are drawn:

1) The wear of the conformal block sliding against the steel disk is significantly reduced by the use of MWCNT as additive in the mineral oil.
2) The performance of the MWCNT was found to depend on the type of base oil.
3) The quantity of MWCNT for base oil 1 that was able to minimize the wear was found to be 0.05% by weight.
4) The quantity of MWCNT for base oil 2 that was able to minimize the wear was found to be 0.1% by weight.
5) Further experimental and theoretical studies are required to determine the optimum quantity of MWCNT that will be able to minimize the wear for particular base oil.

References

Chhowalla, M, and G A Amaratunga. 2000. Thin Films of Fullerene-like MoS2 Nanoparticles with Ultra-Low Friction and Wear. *Nature* 407 (6801) (September 14): 164–7.

Chittlangia, Vedant, K P Lijesh, Kumar Akash, and Harish Hirani. 2014. Optimum Design of an Active Magnetic Bearing Considering the Geometric Programming. *Technology Letters* 1 (3): 23–30.

Chu, Dominique, Shih-Chi Chu, and Mostafa Barigou. 2009. Qualitative Models of Particle de-Agglomeration. *Powder Technology* 195 (2) (October): 171–176.

Hirani, H., K. Athre, and S. Biswas. 2001. A Simplified Mass Conserving Algorithm for Journal Bearing under Large Dynamic Loads. *International Journal of Rotating Machinery* 7 (1): 41–51.

Hu, X G, S L Hu, and Y S Zhao Tribology. 2005. Synthesis of Nanometric Molybdenum Disulphide Particles and Evaluation of Friction and Wear Properties 00 (May): 295–308.

Li, B., X. Wang, W. Liu, and Q. Xue. 2006. Tribochemistry and Antiwear Mechanism of Organic–inorganic Nanoparticles as Lubricant Additives. *Tribology Letters* 22 (1) (May 6): 79–84.

Lijesh, K P, and Harish Hirani. 2015a. Development of Analytical Equations for Design and Optimization of Axially Polarized Radial Passive Magnetic Bearing. *Journal of Tribology* 137 (January): 1–9.

Lijesh, K P, and Harish Hirani. 2015b. Optimization of Eight Pole Radial Active Magnetic Bearing. *Journal of Tribology* 137: 0245021–7.

Lijesh, K P, S M Muzakkir, and Harish Hirani. 2015. Experimental Tribological Performance Evaluation of Nano Lubricant Using Multi-Walled Carbon Nano-Tubes (MWCNT). *International Journal of Advanced Engineering Research*: 1–8.

Liu, Haoyang Haven, Sirikarn Surawanvijit, Robert Rallo, Gerassimos Orkoulas, Yoram Cohen, A Abstract, and Carlo Dsmc. 2011. Analysis of Nanoparticle Agglomeration in Aqueous Suspensions via Constant-Number Monte Carlo Simulation: 9284–9292.

Mahbubul, I.M., R. Saidur, and M. A. Amalina. 2012. Latest Developments on the Viscosity of Nanofluids. *International Journal of Heat and Mass Transfer* 55 (4) (January): 874–885.

Muzakkir, S M, and Harish Hirani. 2014. Experimental Investigation on Effect of Particle Sizes of Molybdenum Disulphide on Wear Under Heavy Load and Slow Speed Conditions. *International Journal of Modern Engineering Research* 4 (12): 46–49.

Muzakkir, S M, and Harish Hirani. 2015b. Experimental Investigation on Effect of Grinding Direction on Wear Under Heavy Load and Slow Speed Conditions with Molybdenum Disulphide (MoS_2) as Additive in Commercial Lubricant. *International of Engineering Research* 5013 (4): 102–104.

Muzakkir, S M, and Harish Hirani. 2015c. Effect of Molybdenum Disulfide Particle Sizes on Wear Performance of Commercial Lubricant 164 (4): 162–164.

Muzakkir, S M, Harish Hirani, G D Thakre, and M R Tyagi. 2010. Study of Lubrication Aspects of Journal Bearing Failure in a Sugar Mill. In *International Conference on Industrial Tribology ICIT 2010*, December 2–4, 2010 RDCIS, SAIL, Ranchi, India.

Muzakkir, S M, Harish Hirani, G D Thakre, and M R Tyagi. 2011. Tribological Failure Analysis of Journal Bearings Used in Sugar Mills. *Engineering Failure Analysis* 18 (8): 2093–2103.

Muzakkir, S. M., Harish Hirani, and G. D. Thakre. 2013. Lubricant for Heavily Loaded Slow-Speed Journal Bearing. *Tribology Transactions* 56 (6) (November): 1060–1068.

Muzakkir, S. M., K.P. Lijesh, Harish Hirani, and G. D. Thakre. 2014. Effect of Cylindricity on the Tribological Performance of the Heavily Loaded Slow Speed Journal Bearing. *Journal of Engineering Tribology* 229 (2): 178–195.

Muzakkir, S.M., K.P. Lijesh, and Harish Hirani. 2014. Tribological Failure Analysis of a Heavily-Loaded Slow Speed Hybrid Journal Bearing. *Engineering Failure Analysis* (February).

Popov, V. 2004. Carbon Nanotubes: Properties and Application. *Materials Science and Engineering: R: Reports* 43 (3) (January 15): 61–102.\Samanta, P., and H. Hirani. 2008. Magnetic Bearing Configurations: Theoretical and Experimental Studies. *IEEE Transactions on Magnetics* 44 (2) (February): 292–300.

Samanta, P Hirani, Harish. 2007. A Simplified Optimization Approach for Permanent Magnetic Bearing. *Indian Journal of Tribology* 2 (2): 23–34.

Shankar, S, Sandeep, and Harish Hirani. 2006. Active Magnetic Bearing: A Theoretical and Experimental Study. *Indian Journal of Tribology* 1 (July-December): 15–25.