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Experimental Tribological Performance Evaluation of Nano Lubricant Using Multi-Walled Carbon Nano-Tubes (MWCNT)

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Abstract

The tribological properties of the mineral base oilsare enhanced significantly with the addition of Multi-Walled Carbon Nano-Tubes (MWCNT) particularly under extreme contact pressure conditions. However, agglomeration of MWCNTs significantly deteriorates the performance and therefore a suitable surfactant is essential to maintain the MWCNTs in the de-agglomerated state. Studies on the surfactant for the water solvent are available, however the same is to be identified for mineral oil based nano lubricants. Therefore,in the present research work experimental investigations have been conducted to identify the effect of surfactanton the tribological performance of mineral oil containing MWCNT.A comparison of the results obtained from various experiments for the nano lubricant samples and base oil has been presented.

Keywords:MWCNT, Surfactant, tribological performance, wear, friction

Introduction

Bearing isan essential component in any rotating machineryasit affectsthe system performance and reliability. Selection of right bearing based on the application is very essential [1]. Present research is focused on the bearingsthat are subjected to heavy load, low rotational speed and humid conditions (like, sugar mill bearing [2-4], bearing used in cement-manufacturing plants [5] and steam turbine bearing [6]). Performance of most of the bearings [1-26] deteriorates in such operating conditions. The nano lubricants containing anti-wear additives have been very effective in improving the tribological performance [3, 22] of these bearings. In the present research, sliding bearings lubricated with mineral oil containing suitable anti-wear additives have been recommended to be used in the operating conditions arising due to heavy-load, low-speed and humidity. A review of available nano-additives has been presented. It has been perceived that Multi Wall Carbon Nanotubes (MWCNT) additivesprovide the desirable performance.

The MWCNTs, due to their unique physical and chemical properties [27, 28], have raised possibilities of their usage in various applications. In fact MWCNTs have found their usage in ultra-strong fibers [29], sensors [30]and field emission displays [31]. However, there is need to explore the advantages of MWCNT in the tribological field. The poor solubility and agglomeration (due to the high surface area and surface activity) of MWCNTs in aqueous media has been a major obstacle for the implementation of MWCNT in tribologicalapplications (i.e. bearings, gears, cam-followers). In agglomerated condition, the nano sizedparticles accumulate to form irregular shaped micron size particle which results in more wear compared to the base oil and reduces the performance of the system. It has been observed that surfactant can be used to enhance the stability of nanoparticlesin fluids. As per the available literature, Triton X-100 surfactant is commonly used to maintain the MWCNTs in the de-agglomerated state in the base lubricant. Rastogi et al[32]recommended an optimum percentage of surfactant quantity to be 350 times the weight of the MWCNT. Rastogi et al [29] have used this surfactant quantity to disperse MWCNT in the water solvent, while in the present work mineral oil has been used as solvent.Therefore, experimental verification is required to justifywhether adding same quantity of surfactant (350 times the quantity of MWCNT)in mineral oil as used in water solvent will enhance the tribological performance or not. Four nano lubricant samples were considered for testing, namely, (A) Mineral oil only, (B) Mineral oil with surfactant, (C) Mineral oil with MWCNT, and (D) Mineral oil with both surfactant and MWCNT. The experiments were performed on block on disc test setup using these lubricants. The tribologicalperformance was evaluated by measuring the frictional force and wear. Since the viscosity of the lubricant significantly affects the tribologicalperformance, therefore the rheometer was used to measure the viscosities of the different lubricant samples. The analysis of the experimental results will be carried out and the reasons for the change in tribological property of different lubricant shall be addressed.

Experimental Details

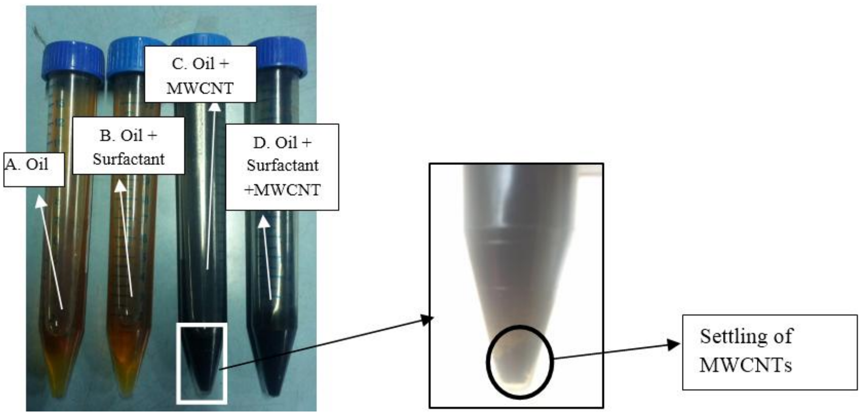
The experimental work has been completed in three phases: (i) Sample preparation, (ii) Friction and wear tests, and (iii) Viscosity measurement.

Sample preparation

Due to the high surface area and surface activity, nano particles have the tendency to agglomerate which is the major concern in developing a nano-lubricant. The nanoparticles agglomerate and forms micron size particles which acts as third body abrasive particles and causesincreased wear compared to the base oil. The important technique to enhance the stability of de-agglomerated nanoparticles in fluids is the use of suitable surfactants. Surfactant has both polar and non-polar structure which binds polar liquids/functionalized particles and non-polar liquids (lubricant) and increases the dispersion of the nanoparticles. In the present work –COOH functionalized MWCNT was purchased to prepare the nano-lubricant. The weight percentage of MWCNT considered for preparing thenano-lubricant in the present work was 0.05% of the lubricant weight, which provided optimum friction and wear. 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. 1. For the preparation of the fourth sample, “Sample D”, initially a dispersion of surfactant and MWCNT was prepared and then this dispersion was homogenized with the mineral oil for one hour

Figure 1: Ultrasonic homogenizer

The four lubricant samplesare shown in Fig. 2. It was observed that,after few minutesmost of the MWCNTs in sample C (i.e. MWCNT in oil) got settled as shown in Fig. 2(b).

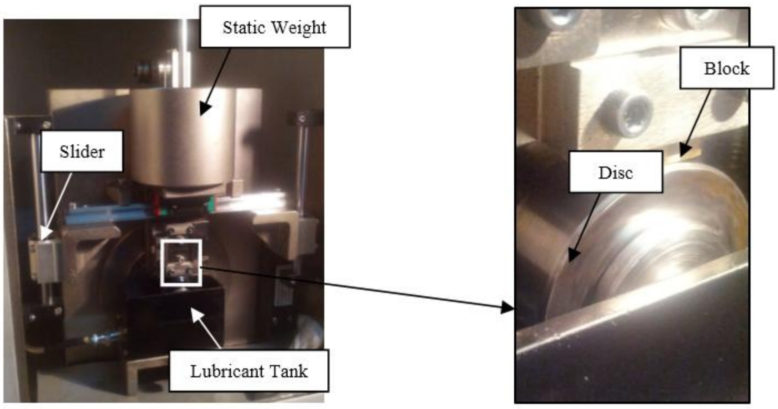


(a) Four nano lubricant samples (b) Settling of MWCNTs in sample 2

Figure 2: Different samples considered for experiment

Friction and Wear Tests

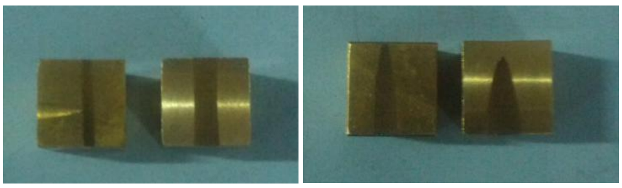
To evaluate and compare the performance of the prepared lubricant samples, the wear tests were conducted usingblock-on-disk test setup(as shown in Fig. 3). Figure 3(a) shows the front view of block-on-disk test setup and Fig.3(b) shows the block and the disc used for the present work. The test setup employs a block (made of phosphorus bronze material) on hardened steel disk (diameter = 40 mm, width = 15mm), which is driven by induction motor. Half of the steel disk is immersed in the lubricant tank. The lubricant inside the tank is maintained at the desired temperature by the help of heaters and thermal cut-off switch. The static load is applied on the platform on which the block is fixed. The tests were conducted at a load of 50N. The disk was rotated at a speed of 25 rpm.



(a) Experimental setup (b) Block on disc

Figure 3: Block on DiscExperimental Setup

The block on disc experiments and preparation of block were performed as per the ASTM standard G77–05. As per the standard the test is qualified if the wear on the block causes a rectangular scar with straight edges (as shown in Fig.4(a)). The testdo not qualifies if the wear scar is tapered or with jagged edges (as shown in figure 4(b)).



(a) Rectangular scar with straight edges (b) Tapered scar with jagged edges

(b) Figure 4Wear Scar on the test blocks

Viscosity measurement

The viscosity of prepared lubricant samples was measured using the Rheometer shown in Fig. 5.

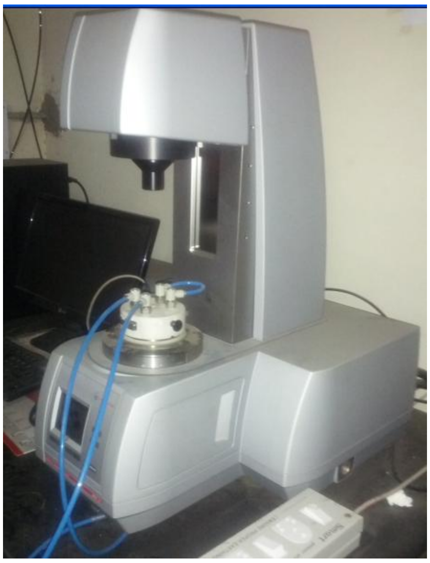


Figure5: Rheometer

Results and Discussion

Three trials of each test were performed on block on disc test setup for 1 hour and mass of the block was measured before and after the experiment. The frictional force was measured using the load cell. The results of these experiments for the four lubricant samples are shown in Table 1.

Table 1: Wear and friction for different lubricant samples

Nano lubricant samples	Wear (Weight Loss (mg))			Frictional Force (N)		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
A. Oil	44	46	49	6.3	6.5	6.7
B. Oil + Surfactant	57	54	53	4.2	4.58	4.3
C. Oil + MWNT	62	61	63	6.9	7.4	7
D. Oil+MWCNT+Surfactant	22	26	24	2.1	2.5	2.3

It is inferred from table 1 that wear for the nanolubricant sample D(oil+ surfactant + MWCNT) is the lowest among the four samples.The sample B, MWCNT in the mineral oil without the surfactant caused the maximum wear. The possible reason for increase in the wear may be due to the agglomeration of the MWCNT. As observed for sample C, the addition of surfactant caused higher wear as compared to sample A, i.e. base oil.However in the case of frictional force, it is observed that the sample D providedthe lowest value of frictional force.The sample B, MWCNT in the oil, increased the friction but adding surfactant as in sample C reduced the friction force. Therefore, it can be concluded that addition of MWCNT with surfactant in a mineral oil, sample D, reduces the wear and friction.

To investigate the reason for the increase in wear by using only surfactant in the oil, the viscosity of the four samples were measured at 50^0C temperature and the results are tabulated in table 2.

Table 2: Viscosity for the prepared lubricant samples at 50°C

Lubricant samples	Viscosity (cPs)
A. Oil	0.2228
B. Oil + Surfactant	0.0742
C. Oil + MWCNT	0.48
D. Oil+MWCNT+Surfactant	0.58

From Table 2, it can be inferred that by addition of surfactant reduces the viscosity and increases the contact between the block and disc surfaces causingmore wear.

Conclusion

In the present research work, four lubricant samples have been prepared and their dynamic viscosities were measured using a Rheometer. The wear tests were conducted on the block-on-disc test setup and the tribological performance was measured in terms of friction force and wear. Based on the results of the friction and wear tests and the measurement of viscosity of the lubricant samples the following conclusion can be made:

1. The nanolubricant containing MWCNT dispersed with surfactant (sample D) caused the minimumwear among all the four lubricant samples.
2. The nano lubricant containing MWCNT dispersed with surfactant (sample D) provided the lowest frictional force.
3. The viscosity of the nano lubricant containing MWCNT dispersed with surfactant (sample D) is highest among all samples.
4. The lubricant with only MWCNT (sample C) caused the maximum wear due to agglomeration of MWCNT.
5. The addition of surfactant in mineral oil (sample B) caused increased wear compared to the base oil.
6. The addition of surfactant in the base oil (sample B) has caused reduction in the friction force as compared to base oil only (sample A).

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