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EFFECT OF FUNCTIONALIZED (COOH) MULTI-WALLED CARBON NANO-TUBES (MWCNTS) ON ANTI-WEAR PERFORMANCE OF AN ENGINE OIL

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ABSTRACT
Dissimilar materials with various nano forms were used as additives for improving properties of lubricants in the recent times. The potential of using functionalized (COOH) Multi-Walled Carbon Nano-tubes (MWCNTs) as additives in mineral oil grade SAE 20W40 was investigated in this study. High specific surface area of MWCNT might cause agglomeration and hence TRITON X-100 as surfactant was added to maintain MWCNT in the de-agglomeration state. However, the addition of Triton X-100 as surfactant in the mineral oil resulted in the variations of its tribological characteristics. The efficiency of MWCNT as anti-wear additive is also dependent on the properties of base oil. The weight percentage of MWCNT considered for preparing the nano-lubricant was taken to be 0.01%, 0.05%, 0.1%, and 0.2% of the lubricant weight. The surfactant Triton X-100 quantity using sonicator is taken to be 350 times the quantity of MWCNT by weight .The surface morphology of the samples was observed using Field Emission Scanning Electron Microscopy (FESEM). The experiments have been conducted to explore the optimum amount of MWCNT which can minimize the wear. The SAE 20 W40 lubricants containing different quantities of MWCNT were prepared with base oil using the Triton X-100 as surfactant to investigate its inference. The wear rate and frictional force was measured using pin on disk tester and anti-wear performance of the nano lubricants were studied. The results indicate that the quantity of MWCNT for base oil that was able to reduce the wear was found to be 0.05% by weight.

KEYWORDS: MWCNTs, Triton X-100, Anti-Wear, Engine Oil, FESEM, Pin on Desk Tester.

INTRODUCTION
Nano particles can be considered as modern lubricant additives. They present several major advantages over organic molecules that are presently used as lubricant additives. [1] Their nanometer size allows them to enter into the contact area like molecules. They are very quick effective even at ambient temperatures. Therefore, no induction period is necessary to obtain interesting tribological properties [2]. Lubricants mixed with nano particles are known to be the most effective method to reduce the friction and wear at contact metal parts. However, the presence of solid particles may also lead to oil starvation for lubrication regimes and these studies have been confined to those produced with millimeter or micrometer-sized particles [3]. Moreover, the lubricants with dispersed milli or micro-sized particles have not been applied to any industrial sectors [4] .Due to the problem of stability of suspensions that involve coarse-grained particles [5]. However, some of the researchers have done their investigations of nano tribology have revealed that nano particles have excellent properties for lubricant based tribological applications, such as heavy load capacity, resistance to wear and reduction in friction [6].

Recently nano materials are added in the lubricants to improve its physical and chemical properties. This will provide the new class of lubricants called as nano-lubricants [7]. Using the nano materials in the lubricant has the specific advantages such as very good thermal and chemical stability, high load carrying quality, increased heat transfer and very good anti-wear properties with reduced friction [8].

Among the various types of nano materials the MWCNT'S shows promising results such as very good anti-wear property and reduction in friction than the other nano materials, also it results in enhanced thermal properties [9]. In this study, the anti-wear performance including friction force of an engine oil using MWCNTs as a lubricant additive is investigated. In addition to this, the viscosity as one of the thermal properties of the nano lubricants is also measured.

MATERIALS AND METHODS
The COOH functionalized multi-walled carbon nanotubes (MWCNTs) are used as a lube oil additive with purity >97%. Fig.1 shows the field emission scanning electron microscope (FESEM) images of MWCNTs. The tubular and filamentous morphology of MWCNTs are shown clearly in these images. MWCNTs have an average diameter about 16-20 nm and an average length of 20 µm. The concentrations of MWCNTs are 0.01, 0.05 and 0.1, 0.2 wt % in nano lubricant. Due to high specific surface area of MWCNT might cause agglomeration and hence TRITON X-100 as surfactant was added to maintain MWCNT in the de-agglomeration state. The surfactant Triton X-100 quantity is taken to be 350 times the quantity of MWCNT by weight. The SAE 20 W 40 lube oil is used as base oil. The specifications of base oil are given in Table 1.

Table 1. Specifications of SAE 20 W 40 oil

Density at 15ºC	0.91
Kinematic Viscosity at 40ºC	28.40
Viscosity Index	115
Flash Point ºC	232
Pour Point ºC	-24

The dispersion and stability are the very important factors of nano particles inside the base nano fluids. When the nano particles are not dispersed perfectly in the nano fluids, there is a possibility of occurrence of agglomeration and precipitation of nano particles which will cause the damage to the frictional surface and stop the lubricants vents. There are three suitable methods such as bath and probe ultrasonic and ball-mill to disperse the MWCNTs inside the base oil. In the present work MWCNTs are dispersed in the base oil using the bath type ultra sonicator. High specific surface area of MWCNT might cause agglomeration and hence TRITON X-100 as surfactant was added to maintain MWCNT in the de-agglomeration state.

The weight percentage of MWCNT considered for preparing the nano-lubricant was taken to be 0.01%, 0.05 %, 0.1%, and 0.2% of the lubricant weight. The surfactant Triton X-100 quantity using sonicator is taken to be 350 times the quantity of MWCNT by weight using high precision weighing machine. Then the samples are kept in the bath type sonicator, with a power and frequency of 20KHZ for sonication period of 2 hours to de-agglomerate and disperse the surfactant and MWCNTs in the base oil.

Finally, the nano lubricant samples are kept for an observation for a period of 48 hours and properties are found. The photograph of bath type ultra sonicator is shown in Figure 1.

Figure1. Bath Type Ultrasonicator

The Multi walled carbon nano tubes (COOH) functionalized are characterized using Field Emission Scanning Electron Microscope. Figure.2 shows the FESEM images of COOH Functionalized MWCNT's.

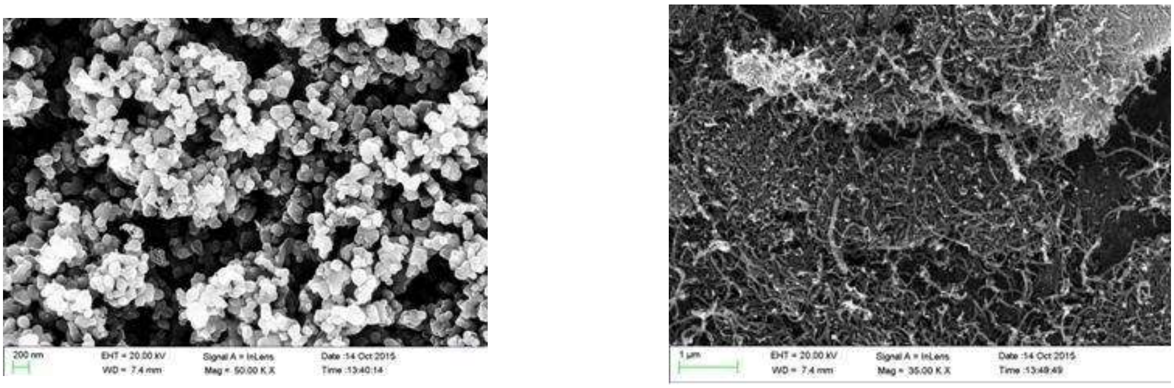

Figure 2. FESEM images of COOH Functionalized MWCNTs

The pin on disk tester was used to measure the frictional force. An aluminium static pin and grey cast iron test samples were made according to the ASTM G99 standards. These samples actually mimic the piston and cylinder liner surface in the engine. The photographic view of the pin and disk set-up and design of pin and disk are shown in Figure 3.

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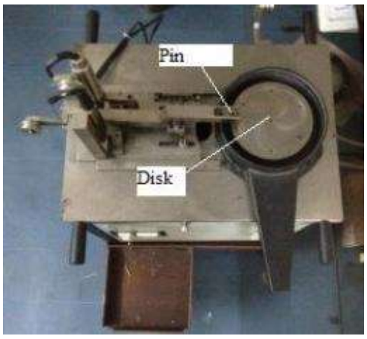


Figure 3. Photograph view of Pin-On-Disk set-up

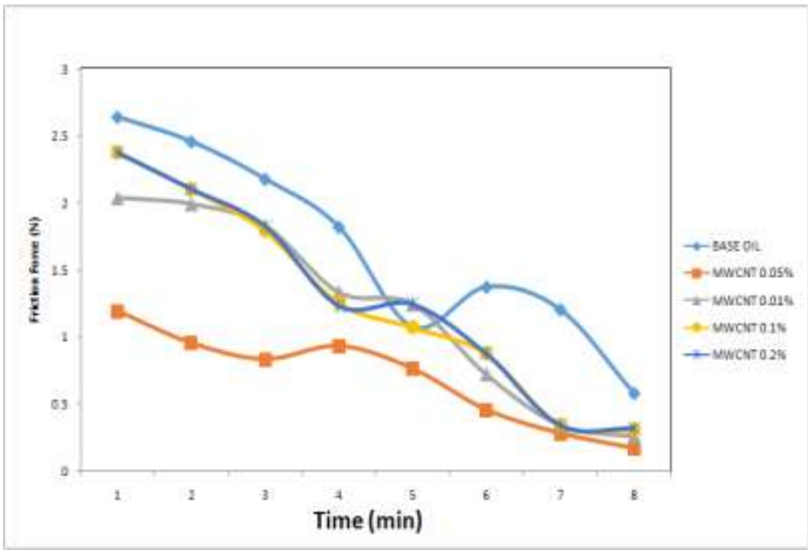
Figure 4. Design of pin and disk

RESULTS AND DISCUSSION

Frictional force:

The friction forces are measured by using pin on disc apparatus. The friction forces are generated in between the rotating grey cast iron plate and static aluminium pin are noted in tribology data acquisition system. Figure 5 shows the variation of the frictional forces for base lubricant and various concentrations of nano fluids will be value in time. At the initial stage the friction force is very high due to the direct contact of the pin on disk. Introducing the lubricants in between the pin on disk reduce the friction generated in between them. Figure 5 shows the using of 0.05% MWCNT'S reduce the friction forces. The reduction in friction is high at 0.05% concentration so it can be used as an optimum concentration of nano material for effective friction reduction.

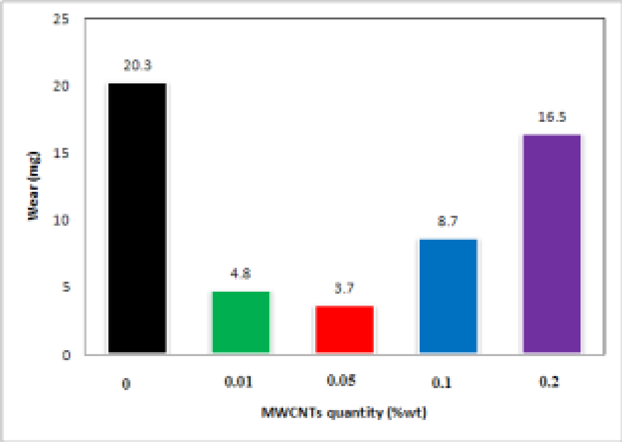
Figure 5. Variations of frictional forces for base oil and samples



Wear rate:

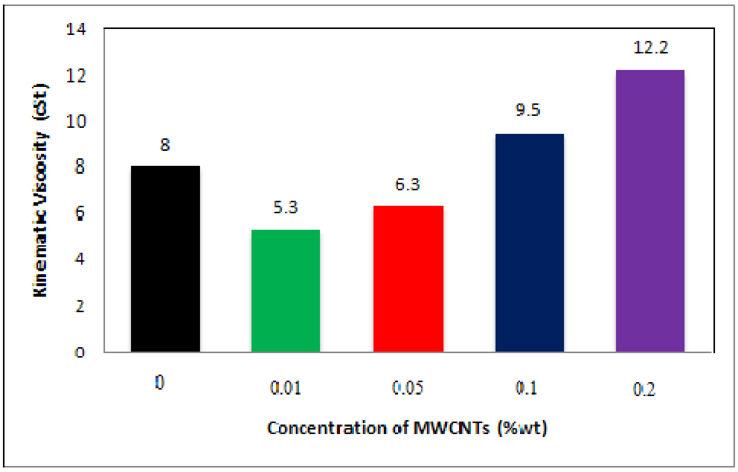
The wear rate of the static aluminium pin before and after friction measurement is calculated. For that an accurate weighing machine is used. The measurement was taken carefully since the weight decreases is very less. The results show that the wear rate is high in conventional lubricants compare to nano fluids. Figure 6 shows that adding MWCNT'S at 0.05 wt% concentration reduce the wear rate. The thin lubrication film avoids the direct contact of the frictional surface and decreases the wear rate.

Figur 6. Wear rate for base and nano lubricants



Viscosity:
The kinematic viscosity of the base and nano fluids is measured by using the Redwood viscometer.
Figure 7 shows the effect of viscosity on temperature for base and various concentration of nano material. As in general, adding the nano tubes to the lubricant should increase the viscosity. Due to the effect of dispersant present in the base lubricant decreases the viscosity of the nano fluids. Though the viscosity decreases the change in viscosity with respect to the temperature change is very low. This makes the nano lubricant suitable for the high temperature application.

Figure 7. Kinematic viscosity at 60ºC



CONCLUSION
Based on the experimental studies, following conclusions are made:

1. The wear of the pin descending against the disk is significantly reduced by use of MWCNT as additive in base oil.
2. The Quantity of MWCNT'S for base oil that was able to minimize the wear was found to be 0.05% by weight.
3. Adding the nano materials to the lubricant should increase the viscosity this makes the nano lubricant suitable for the high temperature application.

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