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Experimental analysis of antiwear property of 460cSt industrial mineral gear oil with MWCNT and ZnO nanoparticles using pin-on-disc apparatus

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ABSTRACT – In the present work, tribological study of nano particle based mineral oil has been carried out using pin-on-disk apparatus. Graphite(macro particles),multi wall carbon nano tube(MWCNT) and zinc oxide(ZnO) nano particles are used as additives on weight percentage basis(wt.%). It has been observed that MWCNT based lubricant sample shows significant decrease in frictional properties and wear than graphite based and pure mineral oil at an optimum additive concentration of 0.05wt.%. Flash point, fire point and viscosity also increases with the increase in addition of additives(nano and macro). SEM images shows high roughened surface in case of pure mineral oil and mineral oil with graphite as compared with nanoparticles based lubricant.

1. INTRODUCTION

With the advent in technologies and awareness of environmental pollutions many additives such as sulphur and phosphorous etc. has been discontinued. Researchers are now looking into the concept of "minimal additivation". Nanoparticles have attracted researchers because of their superior mechanical and physical properties. It has also been observed that the addition of nano particles has enhanced the anti-wear and load bearing capacity of the lubricant. Researchers have also proposed various mechanisms [1-4] which are responsible for improving the tribological behaviour of nanolubricants.

2. METHODOLOGY

Commercially available industrial gear mineral oil of viscosity 460cSt has been procured from local oil supplier. Mineral oil 460cSt has been chosen as it is commonly used in gear boxes of process plants. Graphite(0.2wt.%), multi wall carbon nano tube and zinc oxide nano particles (0.05wt.%,0.1wt.%,0.15wt.%,0.2wt.%) are suspended in mineral oil to formulate the nano lubricant which is to be used during tribo testing. The anti- wear tests were carried out using a pin-on-disk tribometer (Make:Ducom.Model TR20).The pin material chosen is EN24 (hardness 12HRc) as it finds its application in gear manufacturing. The disc of pin on disc is EN 31(hardness 60 HRc). Approximately 5±0.2mL lubricant was used during the test under 120N normal load and 0.7m/sec sliding speed. The pin was 10mm in diameter and 25mm in length. All pins were cleaned with acetone and dried before and after the tests. Oil was supplied drop by drop at the interface in order to maintain thin film lubrication/boundary lubrication [3]. Each test was performed six times and the average value of the test has been shown in this work. The surfaces of the worn pins were characterized using SEM. EDS of the pin surfaces were also performed to investigate the lubrication mechanism.

3. RESULTS AND DISCUSSIONS

3.1 Analysis of Viscosity

As observed from Table 1, the viscosity decreased with the increase in temperature but increased with the increase in concentration of the additives. As the concentration of nano particles increase they agglomerate and tend to form larger and asymmetric particles which prevents the movement of oil layers over each other; thus, increasing viscosity [4].

Table 1 Viscosity of lubricant.

Oil Sample	Viscosity at 40^0C (cSt)	Viscosity at 100^0C (cSt)
MO	390.28	33
MO+ 0.2wt.% Graphite	420.07	30.86
MO+ 0.05wt.% MWCNT	418.36	33.17
MO+ 0.1wt.% MWCNT	422.19	33.68
MO+ 0.15wt.% MWCNT	429.1	34.09
MO+ 0.2wt.% MWCNT	429.55	35.46
MO+ 0.05wt.% ZnO	440.22	32.02
MO+ 0.1wt.% ZnO	439.93	33.13
MO+ 0.15wt.% ZnO	439.95	33.24
MO+ 0.2wt.% ZnO	441.81	39.47

3.2 Flash and Fire Point

As observed from Table 2, both flash and fire point increases as the concentration of nano particles increases.

Table 2. Flash and fire point of lubricants.

Oil Samples	Flash Point(^{0}C)	Fire Point(^{0}C)
MO	220	262
MO+ 0.2wt.%Graphite	222	285
MO+ 0.05wt.% MWCNT	230	302
MO+ 0.1wt.% MWCNT	230	310
MO+ 0.15wt.% MWCNT	230	315
MO+ 0.2wt.% MWCNT	230	318
MO+ 0.05wt.% ZnO	222	262
MO+ 0.1wt.% ZnO	230	285
MO+ 0.15wt.% ZnO	230	295
MO+ 0.2wt.% ZnO	240	310

3.3 Analysis of Co-Efficient Of Friction and Specific Wear Rate

An increase in weight gain in the pins (after tribo test, Table 5) has been observed in case of all ZnO nanoparticles based lubricant tested pins but no such situation is observed in MWCNT based lubricants (Table 4). It may be due to the tribo chemical reaction between ZnO, base lubricant and EN 24 or may be due to adhesive wear. The result of ZnO looks little unusual and will be checked again.

Table 3. Co-efficient of friction.

Oil Samples	COF
MO	0.0430
MO + 0.2%Graphite	0.0310
MO+0.05wt.% MWCNT	0.0170
MO + 0.1wt.% MWCNT	0.0260
MO + 0.15wt.% MWCNT	0.0310
MO+ 0.2wt.% MWCNT	0.0320
MO + 0.05wt.% ZnO	0.0300
MO + 0.1wt.% ZnO	0.0220
MO+ 0.15wt.% ZnO	0.0230
MO+ 0.2wt.% ZnO	0.0231

Table 4. Weight loss and Specific wear rate after pin on disk experiment using MWCNT.

Oil Samples	Initial wt. of pins (g)	Final wt.of pin (g)	Volume loss x 10^{-10} (m^3)	Specific wear rate x 10^{-14} (m^2/N)
MO	15.818	15.8164	2.5518	2.02
MO+ 0.2wt.%Graphite	15.594	15.5938	1.0936	0.864
MO+ 0.05wt.% MWCNT	15.316	15.3157	0.9721	0.768
MO + 0.1wt.% MWCNT	15.250	15.249	1.2151	0.864
MO+ 0.15wt.% MWCNT	15.208	15.206	3.4025	1.73
MO + 0.2wt.% MWCNT	15.454	15.450	4.8670	3.12

4. CONCLUSIONS

The friction reduction properties of mineral oil can be enhanced by adding multi wall carbon nano tubes and ZnO nano particles. The MWCNTs and ZnO nanoparticles exhibits mechanism such as – nano bearing and protective layer [2] which protects the parent material from wearing. MWCNTs exhibits better anti wear property than ZnO and the required quantity of MWCNT is much lesser than ZnO nano particles and graphite. The pin surfaces as observed in Figure 1, are rougher with micro cracks and pits in case of mineral oil as compared with nano particles based lubricants. There exists an optimum concentration of 0.05wt.% MWCNT and 0.1wt.% ZnO nanoparticles beyond which frictional properties increases. The present work would be helpful in formulating new nano lubricants.

Table 5 Weight gain and specific wear rate using ZnO based lubricant.

Oil Samples	Initial wt. of pins (g)	Final wt. pin (g)	Volume gain x 10^{-10} (m^3)	Specific wear rate x 10^{-13} (m^2/N)
MO+ 0.05wt.% ZnO	15.1888	15.1996	1.3	1.061
MO+ 0.1wt.% ZnO	15.8202	15.8291	1.1	0.8750
MO+ 0.15wt.% ZnO	15.1749	15.185	1.2	0.9930
MO+ 0.2wt.% ZnO	15.8686	15.8855	2.1	1.6715

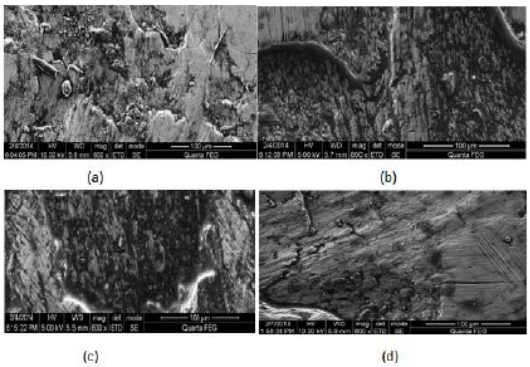

Figure 1 SEM micrographs of (a) Mineral oil (b) Mineral oil+ 0.5wt.% graphite (c) Mineral oil + 0.05wt.% MWCNT (d) Mineral oil + 0.1wt.% ZnO.

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