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Research Article

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Titanium oxide nano-particles as anti-wear and friction-reduction additives in lubricating oil

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ABSTRACT

This study examined the tribological behavior of titanium oxide nanoparticles as additives in mineral based multi-grade engine oil. All tests were performed under variable load and concentration of nanoparticles in lubricating oil. The friction and wear experiments were performed using pin on disc tribotester. It was demonstrated that the nanoparticles as additives in lubrication can effectively improve the lubricating properties. This was because the nanoparticles go into the friction zone with the flow of lubricant, and then the sliding friction changed to rolling friction with a result of the reduction of the friction coefficient.

Keywords: Titanium oxide, Nanoparticles, Engine oil, Tribology, Pin on disc.

INTRODUCTION

The main function of a lubricant is to keep two metal surfaces wet thus minimizing friction and avoiding wear [1]. Many studies have reported that the nanoparticle-dispersed lubricants are effective in decreasing the level of wear and friction. Various types of nanoparticles have been used to prepare nano lubricants, including polymers, metals, organic and inorganic materials [2]. Copper oxide nanoparticles are also being investigated by some researchers in context of their tribological and anti-wear properties [3, 4]. Vadiraj et al. investigated the effect of nano boric acid and nano copper based engine and transmission oil additives in different volume ratios (1:10, 2:10, and 3:10) on friction and wear performance of cast iron and case carburized gear steel [5]. Hwang et al. studied the effect of the size and morphology of nanoparticles suspended in lubricating oils on the lubrication performance [6]. It has been reported that the main mechanism behind friction reduction due to nanoparticles can be attributed to rolling/sliding effect, protective film, third-body, and mending effects [7]. It has also been found that different interactions occur when two or more nanoparticle additives are added to lubricants, such as adduct effect, synergy and antagonism effects [8]. It is observed that researchers have paid little attention to the tribological influences of these effects and mechanisms. This is especially so in cases wherein nanoparticles are used as additives, thus highlighting the need for this study [9]. Hsin et al. investigated the tribological properties of the two-phase lubricant oil and nanodiamond–polymer composite. Based on the results it is observed that nanodiamond–polymer composite possesses better anti-wear, friction-reduction and load-carrying capacity than the nanodiamond additive [10]. Chu et al. experimentally investigated the anti-scuffing performance of nano-diamond-dispersed oil with various concentrations of diamond particles. Falex wear test machine with a three-block-on-ring configuration was used to simulate the scuffing of the piston ring and cylinder wall pair in an engine. The effects of operating conditions on Friction coefficient, electrical contact resistance, and oil temperature were evaluated. The effect of concentration of diamond particles in base oil on the tribological performances was also evaluated. At 2% or/and 3% of the nano-diamond lubricant additive in a base oil gave a reduction in the friction [11]. Chu et al. experimentally studied the mechanisms and microstructures of surface seizure induced scuffing in oil lubrication. Experimental analysis showed that the nano-diamond particles additive is beneficial to resist scuffing. Because an additive reduces the formation of Benard cell-like structure and increase in the surface hardness and reduction in the frictional power [12]. Titanium oxide (TiO_2) is available in the form of nanocrystals or nanodots having a high surface area. They exhibit magnetic properties & are known for their ability to inhibit bacterial growth and prevent further formation of cell structures. They have no odour and a boiling point of 2640°C. It has been reported that the main mechanism of the friction reduction when nanoparticles were added can be attributed to rolling/sliding effect, protective film, third-body effect, and mending effect. It is also found that there are different interactions when two or more nanoparticles lubricant additives are added, such as adduct effect, synergy, and antagonism effects. Although these effects have obvious influence on the performance of lubricating oil when nanoparticles were used as additives, the present study is few and highly needed.

In present study, tribological properties of the lubricating oil were evaluated with and without the addition of copper oxide (TiO_2) nanoparticles using pin-on-disc tribotester under controlled conditions as per the ASTM standard ASTM G99.

EXPERIMENTAL SECTION

2.1 Materials
The selection of a mineral oil to investigate the influence of nanoparticles is mainly based on its applications in modern passenger cars And motorcycles, naturally aspirated petrol engines operating under severe conditions, supercharged petrol engines vehicles encountering continuous start-stop operation, high speed shipping trawlers with naturally aspirated/turbocharged engines, high speed engines having inter-cooler and specially formulated engine oil for marine environment. Lubricating oil was purchased from Castrol India Ltd, India. Titanium oxide nanoparticles were purchased from Nanoshell LLC, Wilmington, US. Average size of nanopraticles used was of 10-25nm.

2.2 Preparation of Nano-lubricant
The nanoparticles are added to the lubricating oil at different concentrations (0.5-2 % wt.) on the weight basis. The required quantity of nanoparticles was accurately weighed using a precision electronic weighing balance and mixed with the lubricating oil. A Film Stripping device and lathe machine (at highest rpm) was used for mixing the nanoparticle additives in the lubricating oil. The time of agitation was fixed as 30 minutes for device and the machine based on the past experience in producing a stable suspension with sufficient time for sedimentation to begin. After the device and the machine are agitated for 30 minutes, the nanolubricant was obtained.

2.3 Tribological Test
Tribological behavior of the lubricating oil was evaluated using a pin-on-disc tester (figure 1), with and without the addition of nano-particles. Load (40N, 60N & 90N), sliding speed (0.5 m/s, 1.0 m/s, 1.5 m/s), nano-particle concentration (0.5 wt%, 1 wt%, 1.5 wt%, 2 wt%) and constant sliding distance (600m) were selected as parameters to determine the optimum concentration of nano-particles. Experiments were carried out as per the ASTM standard G99. Pins and disc were polished by 600 grit size to make the surface flat and cleaned with acetone. Load was applied on pin by dead weight through pulley string arrangement. Lubricant was applied between the pin and disc such a way that boundary lubrication conditions prevail. Frictional force was read from the controller and electronic weighing balance (accuracy of 0.1mg) was used to measure the weight loss of the pin.

Figure 1 Tribotest rig

RESULTS AND DISCUSSION

A series of experiments were conducted to evaluate the friction and wear characteristics of the sliding elements first without the lubricating oil and then by applying the lubricant at the interface with and without the addition of nano-particles into the lubricating oil. Friction coefficient and wear rate values in the present work were obtained for various tests. Figure 2 shows the variation of frictional force versus sliding velocity at 40 N, 60 N & 90 N. Figure 3 shows the average frictional force versus sliding velocity in the absence of lubricating oil. Frictional forces are obtained at 1 m/sec, 1.5 m/sec and 1.5 m/sec at 40N, 60N and 90N load respectively. According to figure 3 minimum average frictional forces is obtained at 1.5 m/sec sliding velocity.

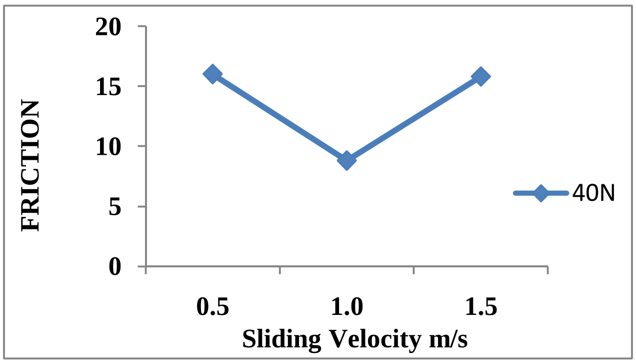

Figure 2 Frictional force v/s sliding velocity (dry)

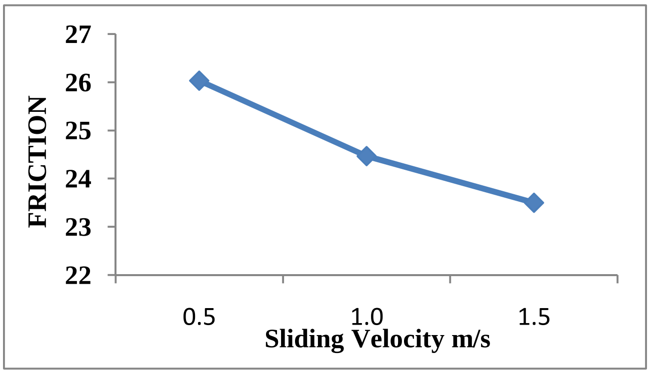

Figure 3 Average frictional force v/s sliding velocity (dry)

Figure 4 shows the variation of frictional force versus sliding velocity in the presence of lubricating oil. Minimum frictional force is obtained at 1m/sec, 1.5m/sec and 0.5m/sec at 40N, 60N and 90N load respectively. According to figure 5 minimum average frictional forces is obtained at 1m/sec sliding velocity.

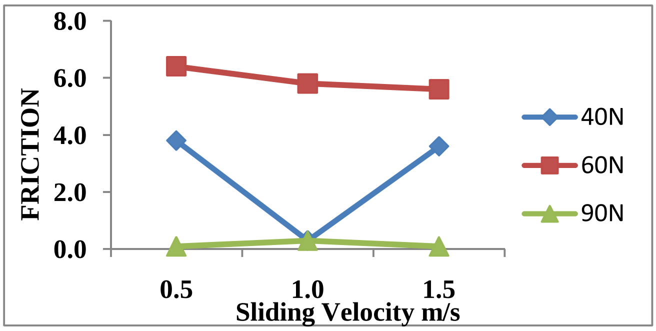

Figure 4 Frictional force v/s sliding velocity (wet)

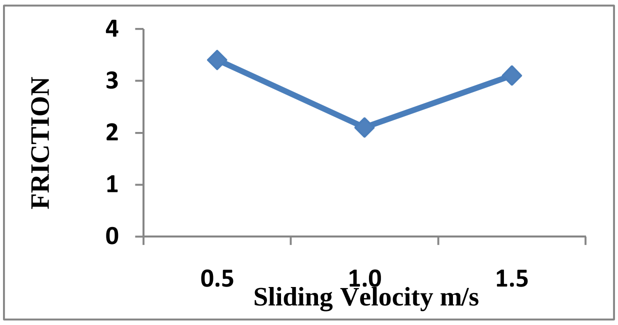

Figure 5 Average frictional force v/s sliding velocity (wet)

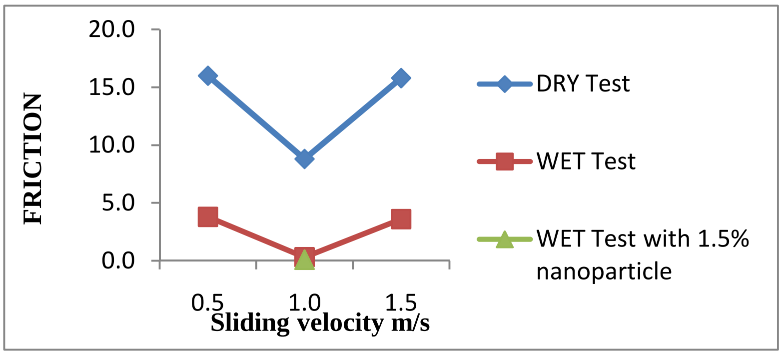

Figure 6 Test performed at 40 N

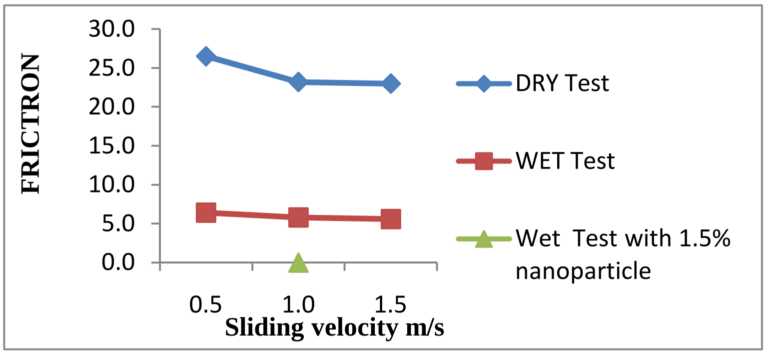

Figure 7 Test performed at 60 N

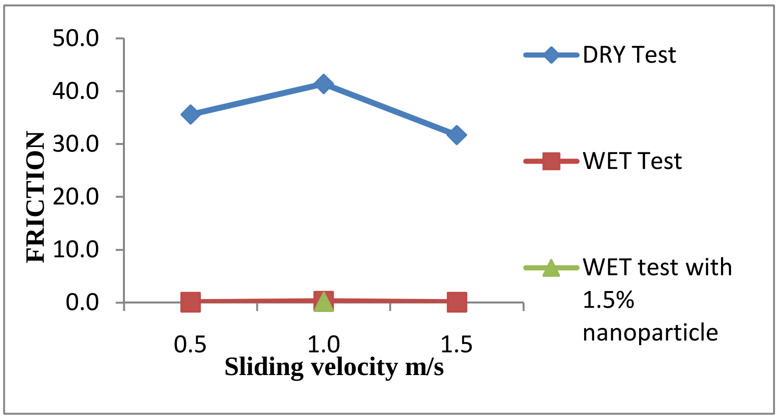

Figure 8 Test performed at 90 N

Figures 6, 7 and 8 compare friction force for dry test, wet test and wet test with 1.5% concentration nano-particle at 40N, 60N, 90N respectively. This shows that after adding nano-particle in engine oil the friction force reduces to a great extent.

Figure 9 shows the variation of wear rate versus sliding velocity in the absence of lubricating oil. Minimum wear rate is obtained at 1m/sec, 1.5m/sec and 0.5m/sec at 40N, 60N and 90N load respectively. According to figure 10 minimum average wear rates is obtained at 1.5 m/sec sliding velocity.

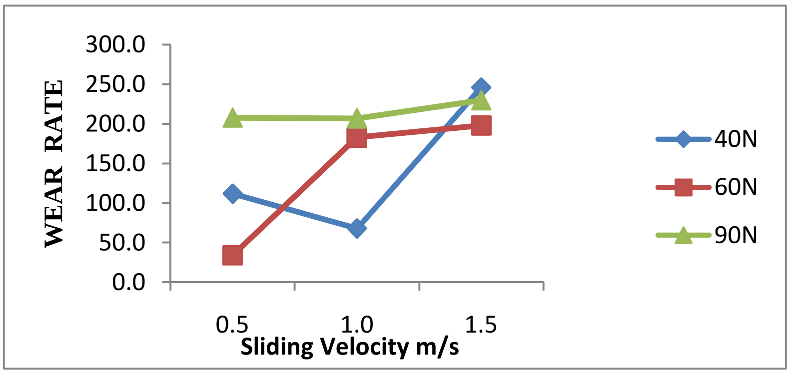

Figure 9 Wear rate v/s sliding velocity (dry)

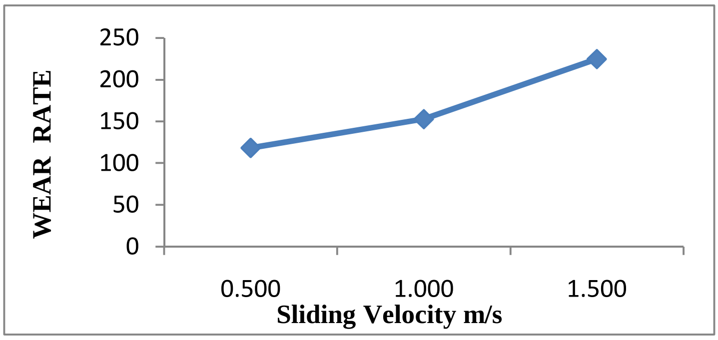

Figure 10 Average wear rate v/s sliding velocity (dry)

Figure 11 shows the variation of wear rate versus sliding velocity in the presence of lubricating oil. Minimum wear rate is obtained at 1m/sec, 1.5m/sec and 0.5m/sec at 40N, 60N and 90N load respectively. According to figure 12 minimum average wear rates is obtained at 1 m/sec sliding velocity.

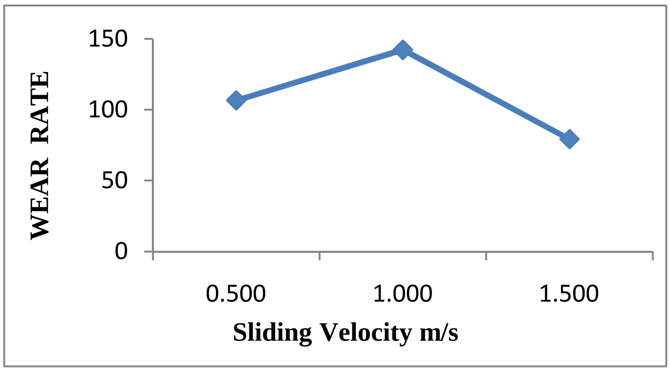

Figure 11 Average wear rate v/s sliding velocity (wet)

Figures 13, 14 and 15 compares wear rate for dry test, wet test and wet test with 1.5% concentration nano-particle at 40 N, 60 N, 90 N respectively. This shows that after adding nano-particle in engine oil the wear rate reduces to a great extent.

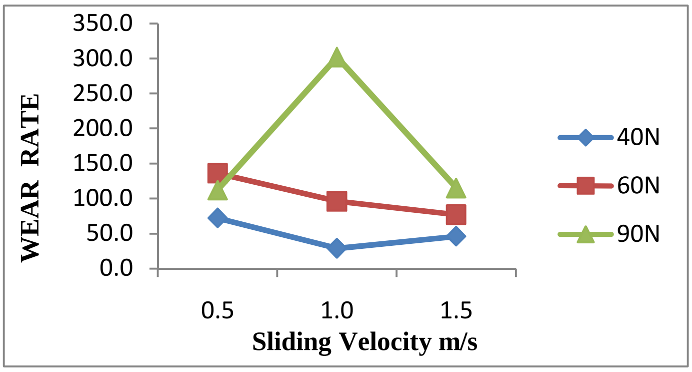

Figure 12 Wear rate v/s sliding velocity (wet)

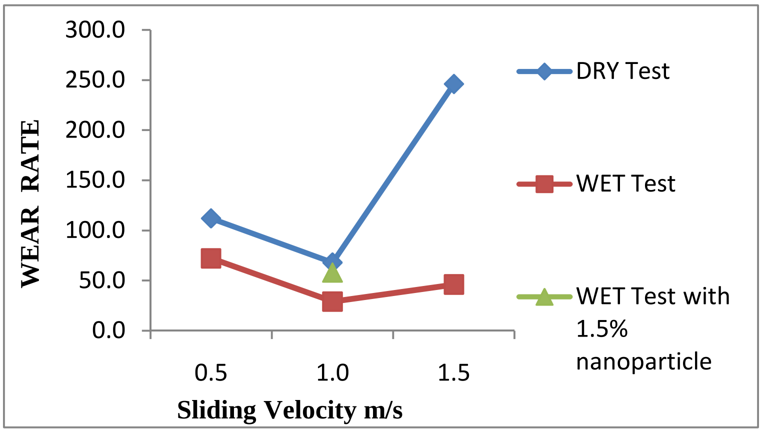

Figure 13 Test performed at 40 N

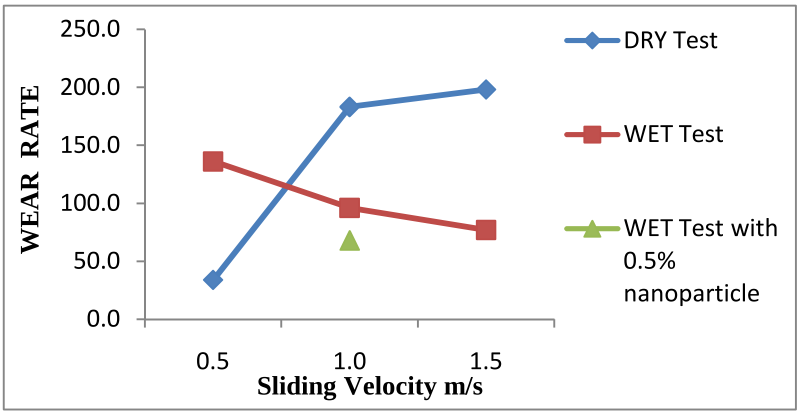

Figure 14 Test performed at 60 N

The anti-wear mechanism of the nano-particle additives could be depicted as follows. When nano-particles were added into a lubricant, a homogeneous and stable solution is formed. When the lubricant film between tribo-pairs becomes thinner and mixed lubrication or boundary lubrication occurs, the nano-particles may carry a proportion of load and separates the two surfaces to prevent adhesion occurring between the two tribopairs, thus benefiting the friction and wear reduction properties. Accordingly, nano-particles in lubricants as additives could generate a tribo-film through deposition mechanism under mixed lubrication and boundary lubrication conditions. The nano-particles penetrate in to the contact region and then deposit on the mating surfaces since they are smaller or similar in size compared to the lubricant film thickness. The material for the tribo film is extracted mainly from the nano-particles, which means that the formation of tribo-film does not consume the materials from the tribo-pairs.

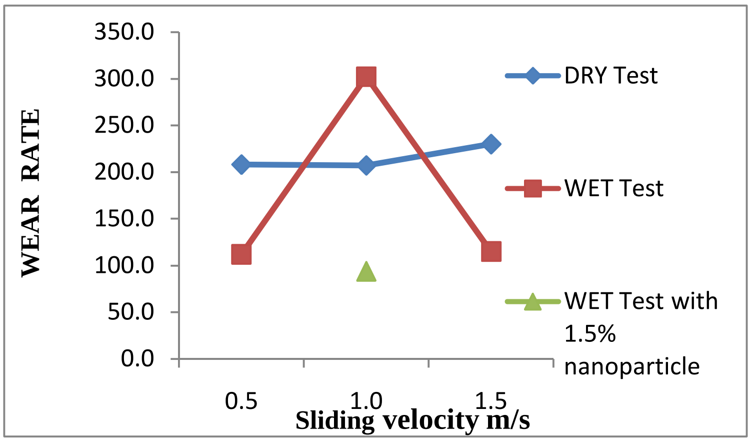

Figure 15 Test performed at 90 N

CONCLUSION

This work presented and discussed the tribological behavior of a TiO_2 Nanoparticles suspension (nanolubricant or nanofluid) in mineral based multi-grade engine oil. Friction reduction and anti-wear properties were obtained using a pin-on-disc tribometer. Test were carried under loads of 40 N, 60 N & 90 N, sliding speed of 0.5 m/s, 1.0 m/s and 1.5 m/s, nanoparticle concentration of 0.5 wt%, 1 wt%, 1.5 wt% & 2 wt%. This study led to the following conclusions:

i. All nano-lubricant tested exhibited reductions in friction and wear compared to the base oil;
ii. The antifriction and anti-wear behaviour mechanism is attributed to the deposition of soft TiO_2 Nanoparticles on the worn surface, which decreases the shearing resistance, thus improving the tribological properties.

Thus, it is evident that the addition of nano-particles improves friction-reduction and anti-wear properties of the lubricating oil.

REFERENCES

[1] SF Calhoun, *Tribology Transactions*, **1960**, 3, 208-214.
[2] E Ettefaghi; H Ahmadi; A Rashidi; S S Mohtasebi; M Alaei, *Int. J. Indust. Chem.*, **2013**, 4 (1), 1-6.
[3] Y Wu; W Tsuia; T Liub, *Wear*, **2007**, 262, 819–825.
[4] M V Thottackkad; RK Perikinalil; P.N. Kumarapillai, *Int. J. Precision Engg. Manuf.*, **2012**, 13(1), 111–116.
[5] A Vadiraj; G Manivasagam; K Kamani; VS Sreenivasan , *Tribology in Industry*, **2012**, 34 (1), 3-10.
[6] Y Hwang; C Lee; Y Choi; S Cheong; D Kim; K Lee; J Lee; SH Kim, *J. Mech. Sci. Technol.*, **2011**, 25(11) 2853-2857.
[7] F Chin-as-Castill; HA Spikes, **2003**, 125 (3) 552–557.
[8] G Sui; WH Zhong; X Ren; XQ Wang; XP Yang, *Mater. Chem. Phy.*, **2009**, 115, 404–412.
[9] W Li; S Zheng; B Cao; S Ma, *J. Nanoparticle Res.*, **2011**, 13, 2129–2137.
[10] Y L Hsin; H Chu; Y Jeng; Y Huang; MH Wang, CK Chang, *J. Mater. Chem.*, **2011**, 21 (35), 13213-13222.
[11] HY Chu; WC Hsu; JF Lin, *Wear*, **2010**, 268, 960-967.
[12] HY Chu, WC Hsu; JF Lin, *Wear*, **2010**, 268, 1423-1433.