*International Journal of Research in Advent Technology (IJRAT) Special Issue "*ICADMMES 2018*"*
E-ISSN: 2321-9637
Available online at www.ijrat.org

Experimental Investigation of Tribological Properties of Multi Grade Engine Oil With Tio_2 Nano Particles

P.Suresh Kumar[1] , N. Prasanthi kumari[2] , Ghanta Ravi Kumar[3],
Department of Mechanical Engineering University of Petroleum and Energy studies, Dehradun, India,
Department of Electronics & Instrumentation,University of Petroleum and Energy studies,Dehradun, India,
Department of Mechanical Engineering Malla Reddy Engineering College, Hyderbad, India
psuresh@ddn.upes.ac.in, prasanti@ddn.upes.ac.in , raviveera@gmail.com

Abstract - Wear is theenergy loss of the material from the surface of machine due to relative motion between surfaces. The fruitful design of machine elements depends upon essentially on the considerate tribological principles like wear and friction. The blood of the machine is lubricating oil whereas it is in operation and admitting a lubricant between two surfaces that are in contact and in relative motion. Nanoparticles adding to friction reducing oils can improve the properties of withstanding capacity on extreme pressure and control the overheating of the components, corrosion, wear and friction. In this research titanium oxide (TiO_2) nanoparticle cast-off as additives in the inorganic based multi ranking machine oil servo 4T Synth 10 W-30 and tribological properties are investigated. All experiments were executed under different concentrations of nano particles in engine oil (0.5, 1 and 2 wt. %) and variable loads. Tribological behavior of the testing lubricating oil with TiO_2 nanoparticles and without were tested using pin-on disc tribometer. The results shows that TiO_2 nanoparticles as spices in lubrication can meritoriously increase the lubricating properties in engine oil. The fallouts confirms that TiO_2nano-particles supplementary in locomotive oil exbhits worthy reduction properties of friction and anti-wear. The coefficient friction at 40 N load decreased by 35.59%, 52.9% and 41% at 0.5, 1 and 2 wt. % concentration respectively and also wear reduced to 1.96%, 2.58% and 1.96% respectively at same operating conditions as likened with the regular engine oil without titanium oxide (TiO_2) particles. This was because the nano particles flow in along with the lubricant oil and sliding friction converts to rolling friction with a outcome of the decrease in coefficient of friction wear. Scanning Electron Microscope (SEM) is used for analyze the topography of worn surface.

Keywords—Tribology, Lubrication, Nanofluids, titanium oxide and Tribometer.

1.INTRODUCTION

At a very careering speed, worldwide increases in human needs and demands for comforts. In manufacturing process, increases in energy consumption and the reduction in the life of mechanical parts due to friction and wear [1]. An automobiles of engine have a major losses occurring is due to friction between the moving parts. The main purpose of lubricating oil is to lessen the roughness and attire. By interposing of a low shear strength substance between the two moving surfaces can be minimized the friction. Lubrication is the art of admitting of lubricating oil between two rough surfaces. Hence, lubrication is the essential to the job of all manufacturing mechanisms. However, with the advance of mechanical manufacturing systems, high temperature and pressure during friction process make the lubricating oil work not so well, which requires enhancing the lubrication characteristics of oil [2-5]. The level of Friction and wear are efficiently reduced by dispersed-nanoparticles in lubricants. The preparation of nano lubricants with different types of nanoparticles, like polymers, inorganic-organic materials and metals. Nano particles have special physical and chemical properties due to this considerable attention is acknowledged. Switching off traditional methods to nano technique because of simple, fast, clean and economical for the synthesis a variety of organic molecules provided the momentum [6]. Increase in load carrying capacity, decrease wear, improve extreme pressure, efficiency and the service life of machinery were improved and prolonged by the use of lubricant additives that are based on inorganic nano particles coated with organic outer layer. Investigators stated that the shape, size and concentration of the nanoparticles added in the lubricating oil is effect the friction and wear. In gear lubrication and cutting lubrication play an important role of the compounds containing in conventional lubricant additives areSulphur, phosphor, or chlorine, among others. Lubricating additives have the pungent odor, extreme corrosion, and the poor thermal stability because of these kind the commercial applications are unsatisfactory [7]. Therefore, new kinds of additives are developed as a substitute for traditional lubricant additives. The use of nanoparticles as oil spices and lubricants is a current idea. Wide variety of nanoparticles have been investigated in modern years. The solid particles in oil additives and their custom is not straightforward and only freshly has been accepted as viable. Oil additives of a nanolubricants have many advantages compared to traditional additives like insensitive to temperature and tribochemical reactions are limited. In previous literature the nanoparticulate additives have been explained by using different anti- wear and anti- friction mechanisms. Even at low concentration of nanoparticles used as additives in oil lubricants proves that improve the tribological properties of the base oil with good friction and wear reduction features. Titanium dioxide (TiO_2) nanoparticles as lubricant additive gives good performance on pleasant odor, non-volatility, anti-oxidant features and relatively low toxicity [8-13]. Nanoparticles applications in lubricants have certain limits due to the presence of oleo-philic property which results not well dispersed in nonpolar organic solvents [14-17]. There are two methods to solve this problem. Addition of dispresent into base oil is the first method. The main disadvantage of above first method is that sedimentation is obvious after a long-time storage and then adverse effect of same dispersants on tribological properties.

In particular, the tribological properties on different volume ratios of nano boric acid and nanocopper based engine and transmission oil additives are effect the friction and wear performance of cast iron and case carburized gear steel. Wu et al. studied that outcome of additives on the tribological properties of different lubricating oils like CuO, TiO_2 and Nano-diamond nanoparticles and witnessed that with CuO additive, oils pointedly presented upright friction decrease and anti-wear properties [18]. Tribo-sintering of nanoparticles on the wear surfaces was due to the antiwear mechanism of a metal oxide nano particulate additive. This process generated a load bearing film and reduced the metal-to –metal contact. Nanoparticles in the lubricant acts as friction reduction and anti-wear due to the result of summarized mechanisms of colloidal effect, rolling effect, protective film and third body. The research shows that nanoparticles deposit on the rubbing surface and develop the tribological properties of the base oil, exhibiting upright friction and wear decrease characteristics [20]. As per research literature metal, oxide and hydrate nano particles oil solubility changes under the effect of surface modification—even transfer from water tool phase. Titanium (Ti) atoms are framed to hybridized to a planar or three-dimensional structure by coordinate with either two or three oxygen atoms and form TiO2 or Ti2O3 groups [21]. Such various combinations are formed through different typical groups which lead to a construction of structure more multifaceted and cause the exertion of surface alteration of TiO_2The formation of a fine TiO_2tribofilm is due to the transfer and adhesion of the TiO_2 nanoparticles that accelerates surface modification, self-reduction and surface modification. The TiO_2tribofilm reduces the coefficient friction, pressure and temperature in contact area and hence wear [22]. The oil solubility of TiO_2 nanoparticles have their own defects. This assertion is supported by the works of numerous researcher. The two classical methods was named the traditional process (TP). The base oil is not suitable for TiO_2 nanoparticles after the traditional process, for the sedimentation is unavoidable in time, tribological properties are in negative direction.

2. Experimental Details

2.1 Preparation of TiO_2nano fluids

Servo 4T synth 10W-30 oil was used as the test base oil. It is a multigrade engine base oil. To reduce friction and anti-wear this pure lubricant engine oil mixed with some additives. The base oil contains has properties, these are discussed in given table no.1.

Properties	**Range**
Density	885 (in kg m^{-3})
Viscosity	10–12 (at 100 °C in cSt)
Viscosity	125.4 (at 40 °C in cSt)
Viscosity index	150

The TiO_2nanoparticules were purchased from supplier Sigma Aldrich Company, India. The most important thing of the TiO_2nanoparticules fluid is the dispersion rate and steadiness of nanoparticles inside the main fluid. In the present research work 0.5% wt, 1% wt and 2%w of TiO_2 nanoparticles were added to the lubricating oil. The concentration of nanoparticules is in the range 01- 2.5 wt% as per the results of literature of bibliographic research. The mixing of the nanoparticles homogeneously in the lubricating oil by using of chemical shaker. The results confirm that the existence of the surface modification layer can effectively prevent agglomeration of TiO2 nanoparticles and provide good oil-dispersion ability.

2.2 Test Procedure

Tribological property deeds analysis was steered by means of a tribotester. A pin and disc configuration type of friction and wear testing machine give good results on pure sliding contact. Using of the above tester, the evaluating of tribological behavior for testing oil with addition and without the TiO_2 nanoparticles. In pin-on-disc tests the below said three parameters were considered. Those three are concentration of nanoparticles, Load and sliding speed. The loading conditions of 90N, 60N and 40N were use for all wear tests procedure. Sliding distance and Sliding speed is 200 m and 1.0 m/s respectively. The concentration is about 0.5% wt, 1% wt and 2%wt of TiO_2 nanoparticles, to make the surface flat the Pins and disc were polished up to 600 grit size and acetone cleaning. Lubricant was admitted in the middle of the pin and disc to mollify border lubrication situations.Electronic weighing balance (accuracy of 0.1 mg) is used for measuring weight loss of the pin frictional force by controller. All tests the procedure was same. The disc was interleaved cautiously in the holding device so that it remained upright to the axis of the resolution.

The pin specimen was inserted in the holder and adjusted to make it perpendicular to the disc surface when in contact to maintain the necessary contact conditions. Proper mass was added to the system lever to the selected force pressing the pin against the disc. The electric motor was started and the speed of the disc was adjusted to the desired value. The revolution counter was set to the desired number of revolutions. The experiment started with the specimens in contact under load. The test was stopped when the desired numbers of revolutions were achieved. The specimen was removed and cleaned. The existence of features on or near the wear scar such as: protrusions, displaced metal, discoloration, micro cracking, or spotting were noted. The tests were repeated with additional specimens to obtain sufficient data for statistically significant results. UV spectrometer was employed for dispersion analysis of the TiO_2 nanoparticles in the lubricating oil.

3. Results and Discussion

3.1 Influence of TiO_2 nanoparticles on friction reducing property of Lubricating oil

All the tests were completedwith and without TiO2 nanoparticles in the lubricating oil for assess the wear and friction characteristics of the sliding elements using pin and disc tribometer applying the lubricant at the interface (600m sliding distance).

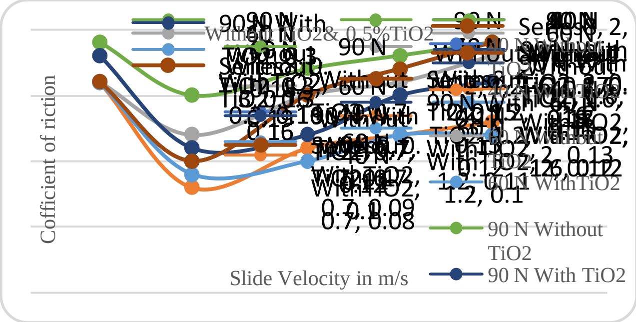

FIGURE 1 coefficient of friction of base oil with and without nanoparticles at 0.5% concentration.

FIGURE 1 shows the coefficient of friction versus sliding velocity at 40 N, 60 N and 90 N. The base oil containing TiO_2nano particles yields better friction reduction behavior which helps the lubrication regime to change from boundary lubrication into mixed or hydrodynamic lubrication, as a result the lower coefficient of friction is observed. This indicated that Tio2 nanoparticles played an important role in reducing the friction coefficient.

Figure 2 and 3 shows the coefficient of friction versus sliding velocity at 40 N, 60 N and 90 N with 1% and 2% wt of TiO_2 nanoparticles respectively. A decreaseof coefficient of friction was observed for the loads 40 N, 60 N and 90 N.

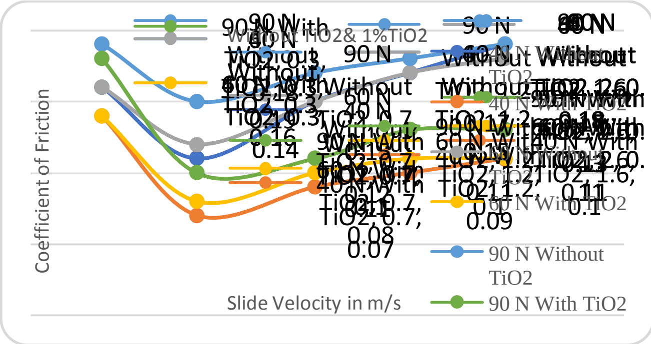

FIGURE 2 coefficient of friction of base oil with and without nanoparticles at 1% concentration

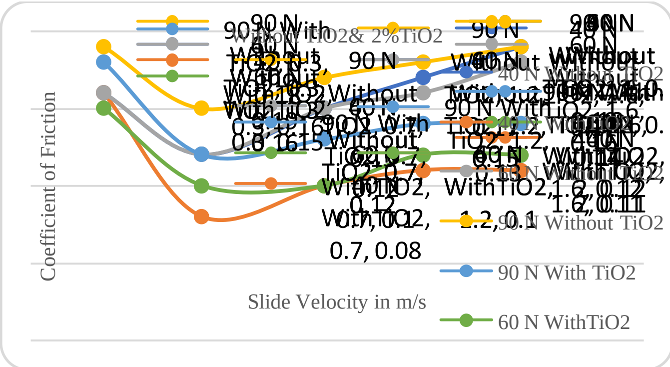

FIGURE 3 coefficient of friction of base oil with and without nanoparticles at 2% concentration.

Table 1 Comparison of coefficient friction between lubricating oil without and with 0.5% wt TiO_2nanoparticles for loads 40 N, 60 N and 90 N.

Load (N)	Coefficient of Friction (Lubricating oil)	Coefficient of Friction (Lubricating oil + 0.5% TiO2 nanoparticles)	Percentage of decrease (%)
40	0.154	0.114	35.59
60	0.154	0.118	30.37
90	0.176	0.15	17.3

Table 2 Comparison of coefficient friction between lubricating oil without and with 1% wt TiO_2nanoparticles for loads 40 N, 60 N and 90 N.

Load (N)	Coefficient of Friction (Lubricating oil)	Coefficient of Friction (Lubricating oil + 1% TiO2 nanoparticles)	Percentage of decrease (%)
40	0.156	0.102	52.9
60	0.156	0.108	44.4
90	0.176	0.13	35.38

Table 3 Comparison of coefficient friction between lubricating oil without and with 2% wt TiO_2 nanoparticles for loads 40 N, 60 N and 90 N.

Load (N)	Coefficient of Friction (Lubricating oil)	Coefficient of Friction (Lubricating oil +2% TiO2 nanoparticles)	Percentage of decrease (%)
40	0.158	0.112	41
60	0.154	0.118	30.5
90	0.176	0.144	22.2

Table 4 Comparison of wear reduction between lubricating oil without and with 0.5% wt TiO_2 nanoparticles for loads 40 N, 60 N and 90 N

The coefficient of friction of base oil containing nanoparticles, TiO_2 are slightly lower than those of without nanoparticles. It was observed that coefficient of friction varied with the increase in load for lubricating oil without TiO_2. The variation in coefficient of friction for a sliding distance 600 m was observed to be more for the load of 90 N in comparison with 40 N and 60 N loads. Table (1, 2 and3) shows comparison of percentage of decrease in coefficient of friction lubricating oil without and with 0.5% wt, 1% wt and 2% wt TiO_2 nanoparticles with 40 N, 60 N and 90 N respectively. The best results were found for the suspensions with nanoparticle concentration of 1% at 40 N, 60 N and 90 N load, the reduction in coefficient of friction is 52.9%, 44.4% and 35.38% respectively. As can be seen table (1, 2 and 3) the base oil containing nanoparticles yields better friction reduction behavior which helps the lubrication regime to change from boundary lubrication into mixed or hydrodynamic lubrication as a result the lower coefficient of is observed.

3.2 Influence of TiO2 nanoparticles on wear reduction capability of Lubricating oil.

The following table 4,5 and 6 shows the variation in wear with the applied load of the sample pins which were fabricated from the aluminium alloy (LM 25). The main observations were that the wear of the pin increased with time and the load for lubricating oil without TiO_2 nanoparticles.

Load (N)	Wear(Lubricating oil)	Wear (Lubricating oil +0.5 % TiO2 nanoparticles)	Percentage of decrease (%)
40	17.2	5.8	1.96
60	21.2	7.8	1.71
90	24.6	19	0.294

Table 5 Comparison of wear reduction between lubricating oil without and with 1 % wt TiO_2 nanoparticles for loads 40 N, 60 N and 90 N.

Load (N)	Wear(Lubricating oil)	Wear (Lubricating oil +1 % TiO2 nanoparticles)	Percentage of decrease (%)
40	17.2	4.8	2.58
60	21.2	6.4	2.31
90	24.6	11.8	1.084

Table 6 Comparison of wear reduction between lubricating oil without and with 2 % wt TiO_2 nanoparticles for loads 40 N, 60 N and 90 N.

Load (N)	Wear(Lubricating oil)	Wear (Lubricating oil +2 % TiO2 nanoparticles)	Percentage of decrease (%)
40	17.2	5.8	1.96
60	21.2	7	2.02
90	24.6	10.2	1.141

Table 4, 5 and6 shows the variation of wear rate versus sliding velocity in the presence of lubricating oil with nanoparticles. Minimum wear rate is obtained at 40 N and 60 N with 1% of TiO_2 nanoparticles at 90 N with 2% of TiO_2 nanoparticles in the lubricating oil. The percentage of decrease is 2.58%, 2.3% and 1.41% at 40 N, 60 N and 90 N respectively. This shows that after adding nano-particle in engine oil the wear rate reduces to a great extent. 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 tribo-pairs, 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.

4. CONCLUSIONS

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%, & 2 wt%. This study led to the following conclusions:

a. All nano-lubricant tested exhibited reductions in friction and wear compared to the base oil;
b. 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.
c. The anti-wear mechanism of the nano-particle additives could bed epicedia's follows. When nano-particles were added into a lubricant, a homogeneous and stable solution is formed.
d. Base oil with TiO_2 nanoparticles improved tribological properties in terms of load carrying capacity, and friction reduction that 1 wt% was an optimum concentration at 40 N, 60 N and 90 N load.
e. For the wear reduction test , when TiO_2nano particles were added into base oil, the wear reduced 2.58% and 2.31% with 1wt% concentration at 40 N and 60 N and 2wt% at 90 N respectively.
f. However the wear was significantly reduced with TiO_2 nanoparticles as additives for the same load value.
g. The deposition of TiO_2nano particles on the possess good stability, decrease the shearing stress and hence reduce friction and wear.

REFERENCES

[1] SF Calhoun, *Tribology Transactions*, **1960**, 3, 208-214.

[2] E Ettefaghi; H Ahmadi; A Rashidi; 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.

[13] Xue Q J, Liu W M, Zhang Z J. Friction and Wear Properties of a Tio2 Nanoparticle as an Additive in Liquid Paraffin. Wear, 1997, 213(1-2): 29-32

[14] Zhou J F, Wu Z S, Zhang Z J, Liu W M, Dang H X. Study on an Antiwear and Extreme Pressure Additive of Surface Coated Laf3 Nanoparticles in Liquid Paraffin. Wear, 2001, 249(5-6): 333-337

[15] Li W, Zheng S H, Cao B Q, Ma S Y. Friction and Wear Properties of Zro2/Sio2 Composite Nanoparticles. Journal of Nanoparticle Research, 2011, 13(5): 2129-2137

[16] Choi S U, Eastman J, Argonne National Lab., IL (United States), 1995

[17] Saeedinia M, Akhavan-Behabadi M A, Razi P. Thermal and Rheological Characteristics of Cuo–Base Oil Nanofluid Flow inside a Circular Tube. International Communications in Heat and Mass Transfer, 2012, 39(1): 152-159

[18] Taha-Tijerina J, Narayanan T N, Gao G, Rohde M, Tsentalovich D A, Pasquali M, Ajayan P M. Electrically Insulating Thermal Nano-Oils Using 2d Fillers.Pdf. ACS Nano, 2012, 6(2): 1214-1220

[19] Lipp A, Schwetz K A, Hunold K. Hexagonal Boron Nitride: Fabrication, Properties and Applications. J Eur Ceram Soc, 1989, 5(1): 3-9

[20] Kimura Y, Wakabayashi T, Okada K, Wada T, Nishikawa H. Boron Nitride as a Lubricant Additive. Wear, 1999, 232(2): 199-206

[21] Pawlak Z, Kaldonski T, Pai R, Bayraktar E, Oloyede A. A Comparative Study on the Tribological Behaviour of Hexagonal Boron Nitride (H-Bn) as Lubricating Micro-Particles-an Additive in Porous Sliding Bearings for a Car Clutch. Wear, 2009, 267(5-8): 1198-1202