EXPERIMENTAL STUDY ON THE TRIBOLOGICAL PROPERTIES OF ENGINE OIL SAE 20W40 USING TIO2 NANOADDITIVES

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ABSTRACT

Current paper deals with the tribological characteristics of base engine oil SAE 20W-40 immersed with titaniumdioxide (TiO_2) nanoadditives. Nanolubricant using 0.1% and 0.2% TiO_2 has been prepared with base engine oil. The tribological characteristics such as Coefficient of friction (COF) and wear rate are measured using Pin on disc tribotester; furthermore, these characteristics are compared with base engine oil. The COF and wear rate of nanolubricant have been obtained at different loads 20 N, 40 N and 60 N operating at 1200 rpm. Further, Optical microscope is used to understand the morphology of the worn surface. From the result, it has been found that the addition of TiO_2 nanoparticle exhibits significant reduction in COF at high load (60N) condition. Results are analyzed according to the deposition of nanoparticle on wear scar surface. It is observed that the accumulation of the nano-particles in the lubricants exhibits the good reduction in COF about 33.93% and wear of about 74.48% when compared to base engine oil. From the morphology of worn surface, it is also observed that the nanoparticle in base engine oil reduces the wear and friction properties by amendment of surface and hence enhances the tribological characteristics of base engine oil.

Keywords: Tribology; nanolubricant; nanoadditives; coefficient of friction; morphology.

INTRODUCTION

Nanolubricant found to be an emerging and promising area as it enhances the life period and performance of base engine oil SAE 20W-40. These lubricants mainly help in friction amendment, eradicate rust, take care of fuel and resolve the severe lubrication challenges. Formation of thin film within the sliding bodies not only reduces the wear and friction, but also withstands at high load and pressures that is flexible within the operating conditions. Therefore use of nanoadditives conserves the energy. Nano particles roll between the moving bodies and hence reduce friction, which in turn enhances the life of machinery.

In recent years, many researchers have shown interest in the era of 20th century, and has been reported that the mechanism that involve in reducing the wear and friction by adding nanoparticles in the base engine oil which slide or roll between the surfaces [1]. Therefore, after adding nanoparticle such as CuO, TiO2 and nano-diamond in various lubricating oil, it was concluded that CuO nanoparticle exhibit better tribological properties and hence significantly reduces the wear and friction properties [2, 3]. Furthermore, Tribologists develops and compared the tribological properties of a polymer composite using Nano-diamond, then reported that advanced composite – nanodiamond polymer exhibits better antiwear, load carrying capacity and significant reduction in friction [4]. Further focusing on the size of nanoparticle, after investigating it was reported that friction coefficient and other tribological properties depends on the shape and size of nanoparticles [5]. In support of study [5], Thottackkad et al. [6] reported the consequence of size and shape of copper oxide nanoparticles on the tribological properties of fabricated nanolubricant. For multiple sliding speeds, extensive tribological studies have been carried out for graphite, molebydnum sulfide (MoS_2), boric acid and TiO_2 and then compared with dry sliding condition. Molybednum sulfide and graphite exhibits appreciable reduction in mass loss and friction coefficient under multiple sliding speed when compared to other nanolubricants [7]. Initiating the research on nanotechnology, nanolubricants and nanoadditives experienced a pattern change in the tribological behaviour. In comparison to traditional materials, nanoparticles or nanoadditives show extensive unusual and favorable properties. And from multiple experimentations, several nanoparticles possess great potential to reduce wear and friction properties. Hence, it is concluded that, various parameters are involved for designing as well to determine the functioning of overall nanoparticle lubrication system [8]. Comparison of tribological properties of paraffin oil and TiO2 added bio-lubricant was also studied and concluded that biolubricants with TiO_2 nanoparticle posses better properties [9]. In addition use of bio-lubricants definitely lowers the toxicity and emissions to the environment. It also posses good lubricating and tribological properties along with advanced natural multi-grade properties, low evaporation rates and hence increased equipment service life [10]. Friction and wear are the major factor which reduces the efficiency of machines and hence hinders in the functioning of machinery. Mechanism and machines both depends on superior quality of lubricants to work under severe pressure (EP) and elevated temperature. Addition of nanoparticles enhances both physical and chemical properties of lubricants, hence improves the tribological performances which in turns reduces wear and tear of machinery at extreme conditions [11]. Furthermore, attraction towards nanofluid increases and researcher determines the tribological properties and further applied on the bench drilling machine [12]. Researcher investigate the tribological properties along with thermal properties for both Cu and CuO nano-lube oil and concluded that nano particles as an additive improves both thermal and tribological properties of the oil [13]. Further researcher shown attention on the direct and indirect effect on the mechanism of the nanofluid on friction and wear [14-16]. Tribologists discussed that nanoparticle forms protective layer between the mating surfaces and thus reduce the friction between the surfaces [17-19]. After film formation, researcher also shown that nanoparticle gets deposited on the wear surface and compensate the material loss from the surfaces [20, 21]. A researcher also studies the morphological analysis and concludes that addition of nanoparticles promotes the wear reduction and enhances the smooth working of machinery [22].

After going through the literature review, it has been found that the no work is available on the study of wear and friction at various load condition along with minimal weight percentage of nanoparticle used in the base engine oil. Therefore, the effect of nanoparticle on the tribological properties of engine oil has been under taken in the present work.

2. Experimental details

2.1. Fabrication and tribological analysis

The engine oil grade SAE 20W-40 and surfactant oleic acid has been procured from the commercial source whereas nanoparticle titaniumdioxide TiO_2 is procure from Nano Research Lab. The color of nanoparticles is white with relative density of 3.97g/cm^3 at 25^{o}C, melting point of 2103^{o}C whereas specific surface area is 13.1 m^2/g. Nanoparticle is mixed in SAE 20W-40 with weight percentage of 0.1 and 0.2. TiO_2 is synthesized in base engine oil SAE 20W-40 along with surfactant oleic acid is shown in Table 1. Exact volume of 20 ml oleic acid was mixed with nanoparticle further mixed with SAE 20W-40 (100 ml) using ultra-bath sonicator. Oleic acid plays the vital role in fabricating the non-sedimented stable nanofluid. A total volume of 120 ml solution is fabricated after 4 hours of rigorous mixing. Mixing time is decided by hit and trial method done for 40 days and keeping the sample for one day in order to determine the amount of sedimentation begins at the stage.

Table 1. Specifications of SAE 20W-40 Lube oil

S.No	Property	Value
1	Density in kg/m^3	848
2	Kinematic Viscosity at 100^{o}C in cSt	8.64
3	Kinematic Viscosity at 40^{o}C in cSt	16.62
4	Viscosity index	110

5	Flash Point (^oC)	200

2.2. Measurement of Tribological Properties

Tribological properties have been tested of the developed samples on pin-on-disk tribometer as sown in Figure 1. Wear scar diameter (WSD) formed after experimentation on the pin is further analyses by using optical microscope. The diameter of steel pins is 08 mm whereas height is 30 mm prepared by stainless steel 316 with an HRC of 59–61 hardness. Chemical composition of pin is shown in Table 2.
The operating parameters for the sliding test are shown in Table 3. Series of test have been carried out at the variable load condition and at an average speed for duration of 300 sec for determining the tribological properties of nanolubricant. Each test has been repeated for three times at similar test conditions. Various graphs were plotted which shows the outcome of each test as shown through Figure 2 to Figure 7.

Table 2. Chemical composition of 316 grade of stainless steel

Grade	C	Mn	Si	P	S	Cr	Mo	Ni	N
316	**0.04**	**2.0**	**0.75**	**0.045**	**0.03**	**16.0**	**2.0**	**10.0**	**0.10**

Table 3. Operating parameters for experiment on pin-on-disc test rig.

Test rig	Lubricant	Speed (rpm)	Track Dia (mm)	velocity (mm/s)	Time (sec)	Load condition
Pin on disc	SAE 20W-40	450	50	1500	300	Load: 20 N, 40 N and 60 N
	SAE 20W-40 + 0.1 % TiO_2 + 20% oleic acid					
	SAE 20W-40 + 0.2 % TiO_2 + 20% oleic acid					

Figure1. Pin-on-disc tribometer

2.3 Analysis of Coefficient of Friction using Pin-on-disc tribometer

Multiple numbers of experiments has been carried out in order to determine the tribological properties using pin-on-disc tribo tester. Nanolubricant is applied at the interface or in between the pin and disc, and the observation made for COF at different load condition of 40 N, 50 N and 60 N. It is concluded from figure 2 at 60 N load condition, lubricant with 0.2% wt Tio2 nanoparticle shows maximum reduction in COF about 33.93% whereas 0.1 % wt TiO2 nanolubricant shows the reduction of 30.60 % respectively. Hence higher the load more will be effectiveness of nanolubricant.

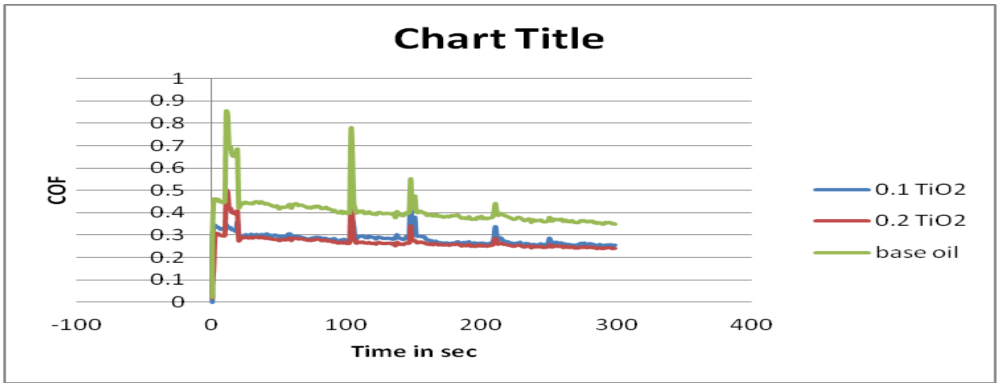


Figure 2. Coefficient of friction for SAE 20W40 with and without nanoparticle at 60 N

Further at 40N of load, nanolubricant with 0.2% wt of nanoparticle shows the reduction of 21.84% whereas with 0.1 % wt shows the reduction of 20.38%. From figure 3 it can be observed that maximum reduction in COF is recorded for nanolubricant with 0.2% wt of TiO2 nanoparticle when compared with base engine oil.

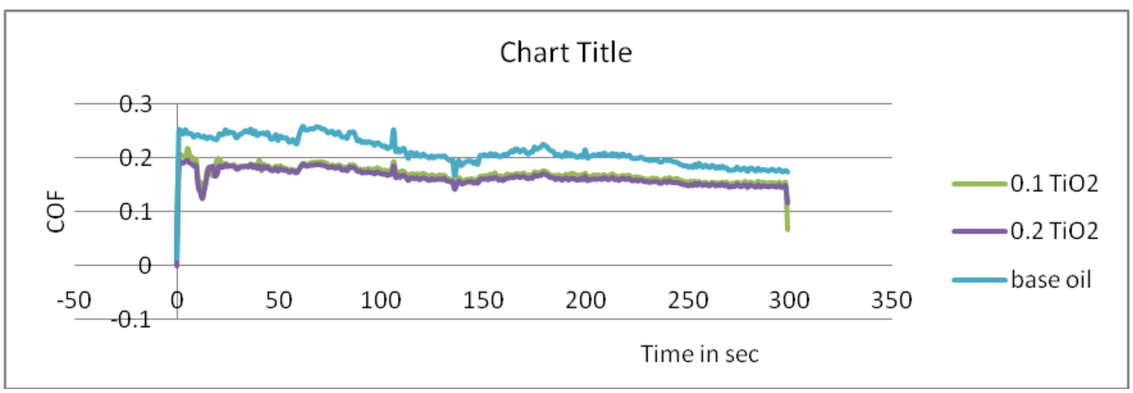


Figure 3. Coefficient of friction for SAE 20W40 with and without nanoparticle at 40 N

Whereas, at 20N of load, nanolubricant with 0.2% wt of nanoparticle shows the reduction of 24.742% whereas with 0.1 % wt shows the reduction of 21.163%. From figure 4 it can be observed that maximum reduction in COF is recorded for nanolubricant with 0.2% wt of TiO2 nanoparticle when compared with base engine oil.

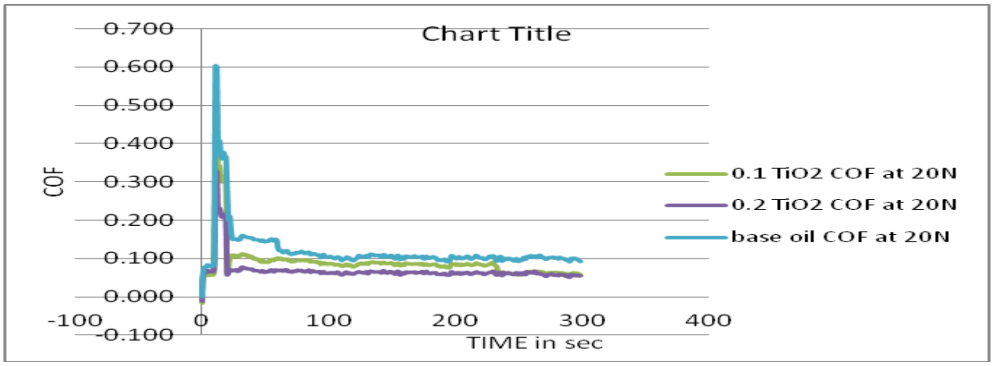


Figure 4. Coefficient of friction for SAE 20W40 with and without nanoparticle at 20 N

2.4 Analysis of Wear

In order to analysis wear at various load condition, series of experiments is conducted. Observations are made for wear at different load condition of 40 N, 50 N and 60 N. It is concluded from figure 5 at 60 N load condition, lubricant with 0.2% wt Tio2 nanoparticle shows maximum reduction in wear about 74.48% whereas 0.1 % wt TiO2 nanolubricant shows the reduction of 43.60 % respectively. Hence more the weight concentration of nanoparticle more will be reduction in wear of surface as nanoparticle rolls between the surfaces, which in turn minimized the contact between the surfaces.

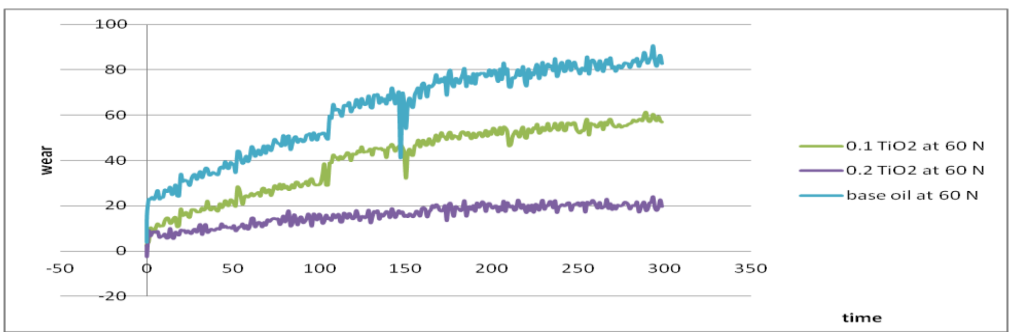


Figure 5. Wear for SAE 20W40 with and without nanoparticle at 60 N

Further at 40N of load, nanolubricant with 0.2% wt of nanoparticle shows the significant reduction in wear about 60.4% whereas with 0.1 % wt shows the reduction of 52.5%. From figure 6 it can be observed that maximum reduction in wear is recorded for nanolubricant with 0.2% wt of TiO2 nanoparticle when compared with base engine oil.

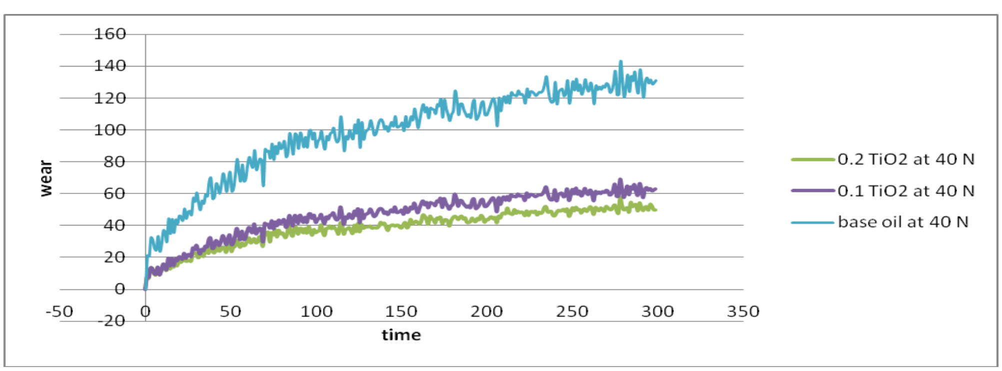


Figure 6. Wear for SAE 20W40 with and without nanoparticle at 40 N

Whereas, at 20N of load, nanolubricant with 0.2% wt of nanoparticle shows the reduction of 56.26 % whereas with 0.1 % wt shows the reduction of 33.62% in wear. From figure 7 it can be observed that maximum reduction in wear is recorded for nanolubricant with 0.2% wt of TiO2 nanoparticle when compared with base engine oil.

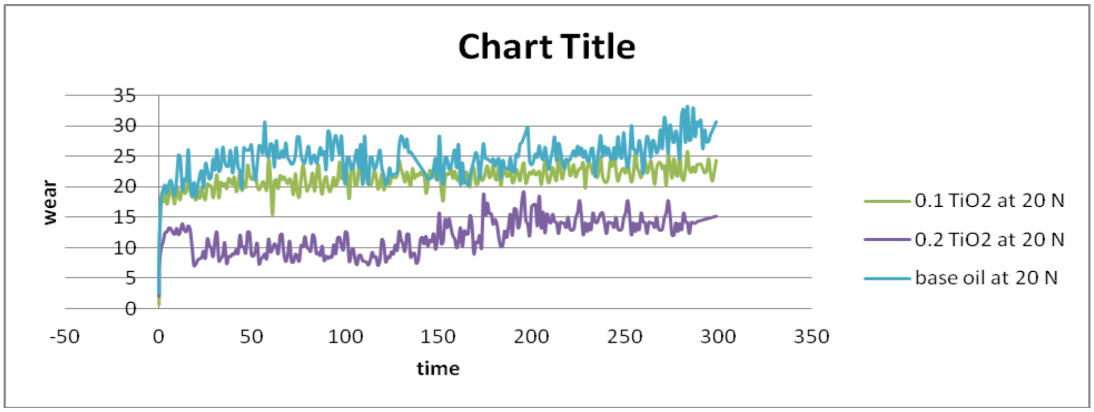
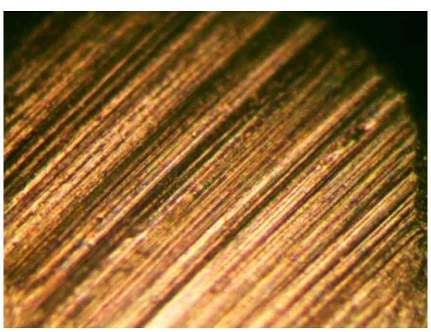
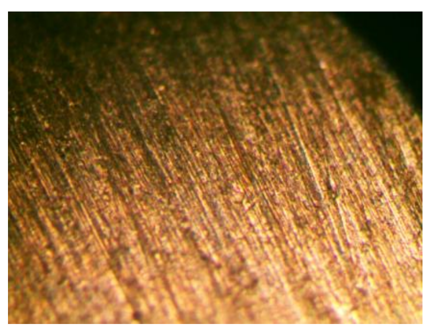


Figure 7. Wear for SAE 20W40 with and without nanoparticle at 20 N

2.5. Analysis of the Worn Surface

Metal oxides as an additive in lubricants shows promising effect as it forms tribo-fluid film and these particles began to rolls at high temperature, posses rolling effect which enhances the performance of lubricant at elevated temperature. Furthermore, mending effect or repair effect makes the lubricant more suitable for the machinery as it reduces the wear in the machinery.
TiO_2 as additives in engine oil SAE 20W40 enhances both lubricating and tribological properties of suspensions. As, it is observed, nano-film is developed between the two mating surfaces which evade the direct contacts between the asperities of surfaces. Furthermore TiO_2 as an additive also forms an adsorption film which reduces the friction between the sliding surfaces. TiO_2 shows the rolling effect, hence rolls between the sliding surfaces.





(a) (b)

Figure 8. Sample of microstructure of wear surface for the suspension with high anti wear behavior; (a) 0.1% TiO2 + base engine oil SAE 20W40 (b) 0.2% TiO2 + base engine oil SAE 20W40

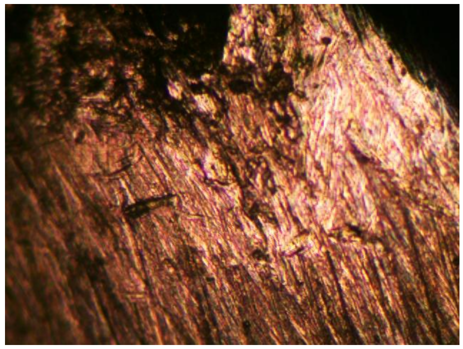


Figure 8. Sample of microstructure of wear surface for pure base engine oil SAE 20W40

Presence of nano particle in the engine oil shows the considerable reduction on the wear of the surfaces; however it is observed the surfaces are damaged because of adhesive wear. It can be seen from Figures 8 ((a) and (b)), that the marks on the worn surface are reduced effectively with increase in wt % of TiO_2 whereas, figure 8 shows the wear tract for pure base engine oil SAE 20W40. Addition of nanoparticle reduces the surface wear, and it is also observed that there is micro abrasion on the surfaces which is due to adhesive wear.

3. Result and Conclusions

As nanoparticles possess high surface energy and oleo-philic property, hence they did not dispersed in any of the lubricant or engine oil. From experimentation, it concludes that some nanoparticle along with surfactant could make a stable lubricant of oleo-phobic nature and can easily be mixed with base engine oil. During experimentation, newly developed suspension shows significant reduction in wear and friction when compared to base engine oil.

- Based on the outcome it is concluded that developed nanolubricant exhibits significant reduction in COF in compare to base engine oil. Hence, 0.2% weight TiO_2 nanoparticles show the maximum reduction in COF about 33.93% when compared to the pure base engine oil at 60 N loads.
- As nanoparticles get deposited on the surfaces, then there is a decrement in shearing resistance. Therefore, from the obtained results it is concluded that there is significant reduction in wear at higher load of about 74.48%.
- The novelty of this work deals with the solution provided for the sedimentation of nanoparticle in base engine oil. Use of Oleic acid as a surfactant with appropriate percentage gives the unique mixing process of base engine oil.

Continous reduction in wear and coefficient of friction is due to addition of nanoparticle in base engine oil, as nanoparticle rolls between the sliding surfaces and continous mending effect have been observed on the surfaces.

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