Tribological Properties Of Sio_2 Nanoparticles Added In SN-500 Base Oil

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Abstract

This study examined the tribological behaviour of SiO_2 nanoparticles as additives in Paraffin based SN-500 Base 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 disk tribotester. The experimental results show that nanoparticles, such as SiO_2 added into base oil exhibit good friction reduction and anti-wear properties. Also SiO_2 nanoparticles in the SN-500 base oil decreased friction coefficient by 61%, 55% and 43% at 0.5wt% concentration and 36%, 76% and 17% % at 0.75wt% concentration respectively, as compared with standard base oil without SiO2 nanoparticles. This tribological behaviour is closely related to the deposition of nanoparticles on the rubbing surfaces. In addition, the topography of worn surfaces was analyzed by using Scanning Electron Microscopy (SEM).

1. Introduction

Nanocrystalline metals used as lubricant additives have been investigated in recent years [1, 2]. Compared with the traditional anti-wear and antifriction agents, eco-friendly nano-metals markedly enhance the tribological behaviour of the lubricating oil, such as excellent anti-wear, antifriction, extreme pressure and so on [3]. The reduction of wear depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding speed, surface roughness, lubrication, and vibration. In addition, anti- wear properties, load-carrying capacities, and friction-reduction are mainly controlled by the chemical additives in lubricating fluid under boundary lubrication conditions. Since stabilization of nanoparticles has been resolved by the addition of a dispersing agent or the use of a surface modification preparation technique, inorganic nanoparticles have received considerable attention in the lubrication field. In particular, the tribological properties of metal oxides, rare earth compounds, metals, metal borates and metal sulfide used as lubricate additives have been investigated. The anti-wear mechanism of a metal oxide nanoparticulate additive was tribo-sintering of nanoparticles on the wear surfaces. That process reduced the metal-to- metal contact and created a load-bearing film. Also the summarized mechanisms of the friction-reduction and anti- wear of nanoparticles in lubricants as the result of colloidal effect, rolling effect, protective film, and third body [4-6].

The results of these investigations indicate that nanoparticles used as a lubricating oil additive can improve the tribological properties of the base lubricant. However, most of the reported nano-additives contain heavy metals, sulphur, or phosphorus as active atoms, which can be potential threats to the environment.

Nanoparticles have attracted considerable interest in recent years because of their excellent physical and chemical properties. However, inorganic nanoparticles very easily agglomerate in many media and have poor dispersive capacity in organic solvents and oil. Therefore, the applications of many nanoparticles are quite limited. However, the dispersion problem can be solved using some physical and chemical approaches. Liand Zhu obtained SiO_2 nanoparticles by modifying the surfaces of organic compounds. SiO_2 nanoparticles can be dispersed stably using hydro- carbons as surface modification agents in lubrication oils [7-9].

R. Chou et al investigated nickel nanoparticles used in lubricating additives. It was found that All suspensions decreased the average friction coefficient and wear with respect to PAO6. The friction reduction was between 7% and 30% and wear was decreased between 5% and 45%. The PAO6+0.5% Ni20 suspension showed the highest friction and wear reduction with regard to PAO6 was the base oil. The analysis of the wear scar by SEM and EDS shows the nanoparticles deposition on the wear surfaces with an improvement of the tribological behaviour [10].

From the tribological point of view, the carbon-coated copper nanoparticles did not behave better than non-coated copper nanoparticles; and the analysis of the wear scar by SEM and EDS showed that the tribological improvements with the use of these suspensions are closely related to the nanoparticles deposition on the wear surfaces and probably also by the action of the nanoparticles as tiny bearings [11-13].

In present work, we have synthesized stable SiO_2 nanoparticles with an 'oleic acid' surface modifier which gives very good dispensability in organic solvents. In order to estimate the ranges of applications of SiO_2 nanoparticles, it was necessary to investigate its tribological behaviour under increasingly serve contact conditions.

2. Experiment

2.1 Materials

The selection of a synthetic oil to investigate the influence of metallic nanoparticles is mainly based on its better rheological properties compared with mineral oils. Paraffin based SN-500 base oil was chosen as the base oil, as it is considered among the more promising synthetic lubricants used for general purposes. This selection is also based on the fact that SN-500 is used in industrial bearing oils, hydraulic oils, aviation lubricants, drilling fluids, heat transfer fluids, dielectric fluids and greases. The properties of SN-500 base oil are listed in Table 1.

Figure 1 shows Silicon dioxide (SiO_2) in form of nano poweder.

SiO_2 nanoparticles, Figure 1 were purchased from Sigma Aldrich Company, India. Due to their high surface area and their dangling bonds, nanoparticles have a tendency to agglomerate and absorb moisture, oxygen, nitrogen, etc. According to the manufacturer's specifications, in order to break up agglomeration and help with degassing, SiO_2 nanoparticles were dispersed in oleic acid as surface modifier and by preparing lubricant samples in concentrations of 0.1 wt%, 0.5 wt%, 0.75 wt% and 1wt% using an ultrasonic probe for 30 min. These concentration values were established from the results of bibliographic research, where concentration of nanoparticles is in the range 0.1-1 wt%. A stability study was carried out by sedimentation with results showing that aggregates and flocks were not formed for equal or lower times than the ones used in the wear tests. The materials used in the experiments, together with their main properties, are shown in Table 2.

PROPERTY	**Range**
Viscosity Kin., @40°C (cSt)	85-102
Viscosity Kin., @100°C(cSt)	11-12
Viscosity Index	88 (MIN)
Density @ 15°C	0.885-0.896
Flash Point (°C)	235 (MIN)
Pour Point(°C)	-3 to -6
TAN (Mg KOH/gr)	0.05
Carbon Residue (% Wt)	0.05
Color	2.5(MAX)
Copper Corrosion (Stage)	1b
Water Content (PPM)	100 (MAX)
Demulsibility (Cc)	40/37β (15 MIN)
Foam (Cc)	10/0,30/0,10/0

Noak Volatility (%Wt)	4 (MAX)
Aromatic Content (%Wt)	10 (MAX)

Table 1 Properties of SN-500 Base oil

2.2 Anti-wear test procedure

All test-section components were cleaned ultrasonically for 5 min, rinsed in ethanol and dried with hot air before and after the tests. Wear testing was undertaken using a Magnum's Tribotester friction and wear testing machine set for pure sliding contact, with a pin-on-disk configuration. Test pins were run against a counter face disk (see properties in Table 2). All wear tests were performed with loading 10N, 30N and 50N. The disk was rotated at constant speed of 250 rpm at room temperature for 10 minute time. The friction coefficient and wear rate was recorded automatically using strain gauge in tester. Wear surfaces on disks were characterized using Scanning Electron Microscopy (SEM).

Nanoparticles	Properties
SiO2	Morphology: nearly spherical, purity; 99.5% APS; 25nm, density: 2.2-2.6 g/mL at 25 °C
Specimens	**Properties**
Disks	Steel-AISI D3, hardness=280HV_{500}, d=160 mm, Ra¼0.1 mm, E=200GPa, ν=0.3
Pins	Steel-AISI 1045, hardness=266 HV_{500}, d=10 mm, l= 30mm, E=200GPa, ν=0.3

Table 2 Properties of the materials

3. Results and discussion

3.1 Friction-reduction properties

In order to confirm the repeatability of experimental data, the friction coefficient was measured in triplicate using the pin on disk tribotester under 10N, 30N and 50N load conditions at 10 minute with concentration of particles constant for respective tests. The friction coefficients of SN-500 base oil without nanoparticles are displayed in fig. 2, which show a similar trend for different experimental results, and a maximum standard deviation of 0.114, 0.120 and 0.117 with respect to 10N, 30N and 50N load conditions among all sets of test data.

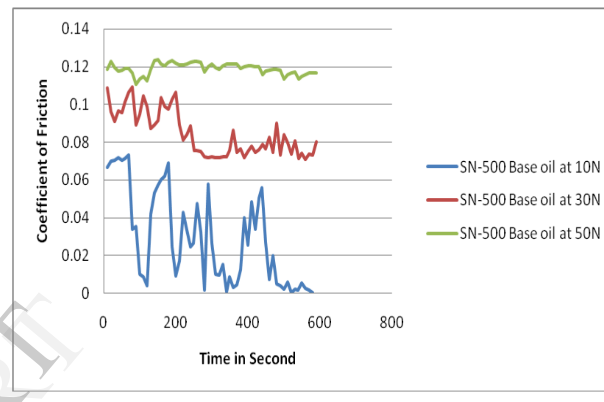

Figure 2 shows repetitive test of friction coefficient of SN-500 base oil without nanoparticles.

The friction coefficients of the SN-500 base oil with and without nanoparticles are shown in fig. 3 the x-coordinate shows the time elapse from start to end of single test. The coefficient of friction of SN-500 base oil containing nanoparticles, SiO_2 are slightly lower than those of SN-500 base oil without nanoparticles.

The addition of SiO_2 nanoparticles reduced friction coefficient with respect pure base oil (SN-500). The best results were found for the suspensions with a nanoparticle concentration of 0.5% and 0.75%. Fig. 3 the suspensions with 0.5 wt% of SN-500 base oil sample exhibited 61%, 55% and 43% of friction coefficient reduction with 10N, 30N and 50N load condition, respect to SN-500 base oil without containing nanoparticles. Fig. 4 On the other hand, the suspension with 0.75wt% of pure SN-500 base oil sample showed friction coefficient reduction of 36%, 76% and 17% respectively under loading conditions. As can be seen fig. 3 and 4, the SN-500 base oil containing nanoparticles yields better friction reduction behaviour. Such that the lubrication regime may change from boundary lubrication into mixed or hydrodynamic lubrication, so the lower coefficient of friction observed.

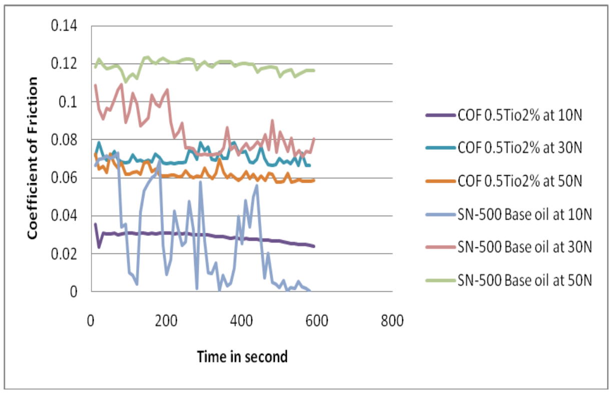

Figure 3 coefficient of friction of SN-500 base oil with and without nanoparticles at 0.5% concentration

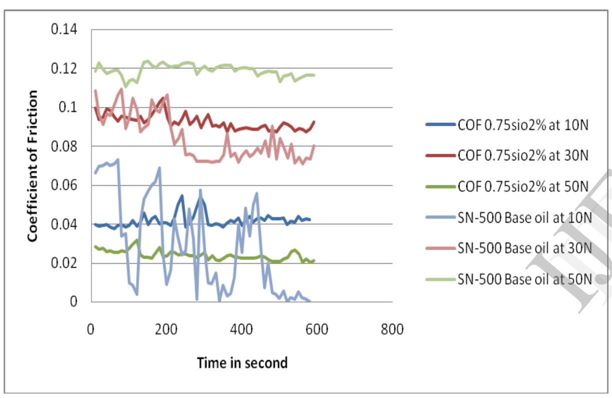

Figure 4 coefficient of friction of SN-500 base oil with and without nanoparticles at 0.75% concentration

3.2 Anti-wear Properties

The anti-wear properties are examined according to the results in form of graph from computerized data acquisition system. The wear in microns of SN-500 base oil without nanoparticles are displayed in fig. 5, which show a similar trend for different experimental values, and a maximum standard deviation of 16, 22 and 24 with respect to 10N, 30N and 50N load conditions among all sets of test data.

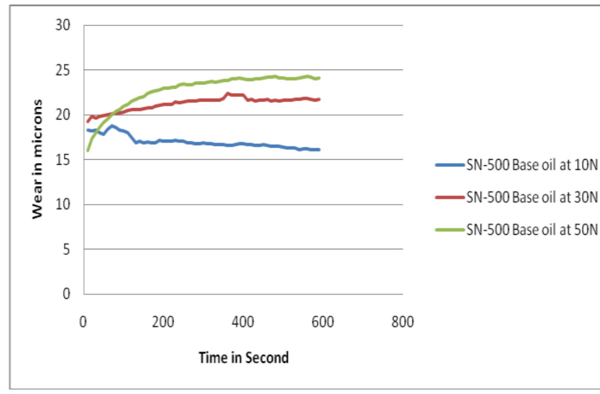

Figure 5 shows repetitive test of wear in micron with SN-500 base oil without nanoparticles.

The anti-wear property is a function of additive concentration in SN-500 base oil. Fig. 6 and 7 shows wear verses time. In fig. 7 the suspensions with 0.5 wt% of SN-500 base oil sample dramatically improved 4μ, 19μ and of wear reduction with 10N and 30N load condition with respect SN-500 base oil without containing nanoparticles. But at the load 50N wear can increases than that of pure SN-500 base oil (33μ>24μ). Fig. 7 On the other hand, the suspension with 0.75wt% of SN-500 base oil sample showed wear reduction of 12μ, 22μ and 13μ respectively under the same loading conditions.

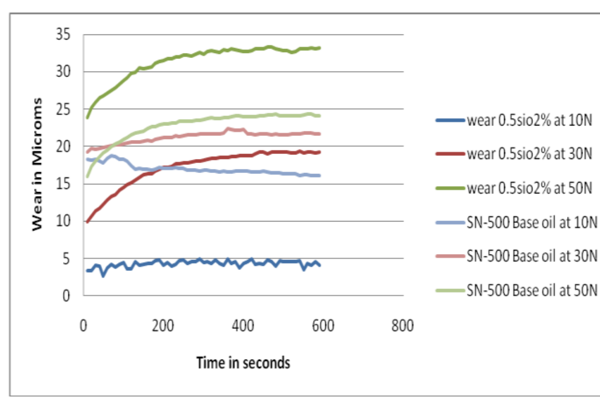

Figure 6 wear of SN-500 base oil with and without nanoparticles at 0.5% concentration

So as above discussion nanoparticle at 0.5% and 0.75wt% can be reduce wear compared with pure base oil. Since base oil does not contain any anti-wear additive, the tribochemical reaction film cannot be produced on rubbing surfaces. Therefore lower wear might be attributed to rolling effect of the nanoparticles.

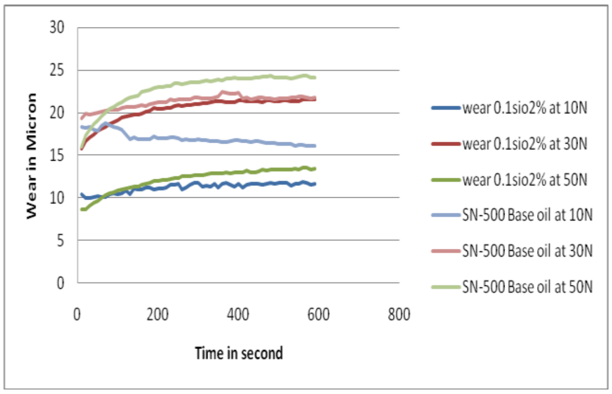

Figure 7 wear of SN-500 base oil with and without nanoparticles at 0.75% concentration

3.3 Analysis of rubbing surfaces

Fig. 8-a and b presents SEM images of rubbed surface lubricated of Virgin based SN-500 base oil with and without nanoparticles. All photographs taken at load are 30N and 50N at 250 rpm disk speed. At the load 10N wear is less so that it was not considered in SEM analysis. It shows evidently rough with many thick, deep furrows and many pits or spalls because of contact fatigue and adhesive fatigue. Also it indicates gradual removal process of metals fibers, normally occurring in the sequence of fiber thinning, fiber fracture and final removal of broken fiber pieces.

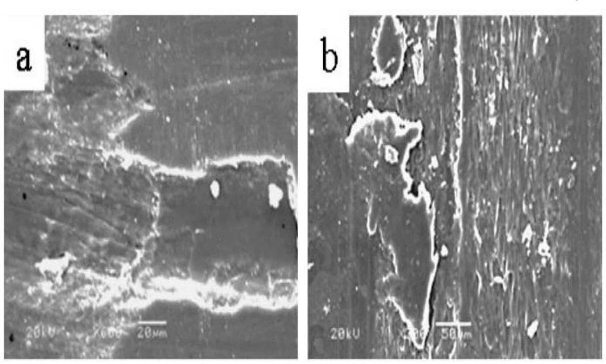

Figure 8-a and b shows SEM micrographs of worn surfaces with SN-500 base oil without nanoparticles at 30N and 50N load at speed 250rpm.

But the comparison with nanoparticles with lubricating oil was shown small wear depth. As shown in fig 9-c and d worn surfaces appear much smoother, even at the serve wear conditions of 30N and 50N load. The fibers were always removing gradually and fully contributed to the wear resistance of the composites. As the result, the specific wear of the material was much more stable, and load carrying capacity of the material was significantly improved.

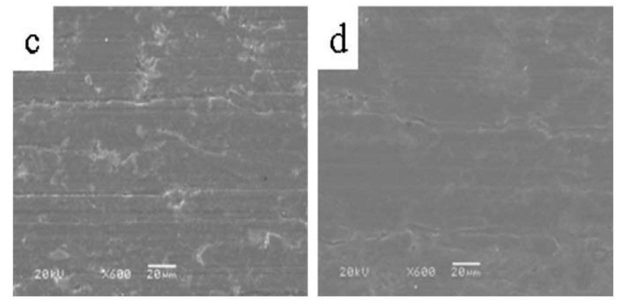

Figure 9-c and d shows SEM micrographs of worn surfaces with SN-500 base oil with SiO2 nanoparticles at 30N and 50N load at speed 250rpm.

As the solid substances is blogged down along with the worn scar directions. Therefore the presence of nanoparticle in the lubricating oil, the contact is closely related to improvement of tribological properties. Another interesting result from the wear surface analysis is the fact that higher nanoparticle concentration then higher nanoparticles deposition on the wear surfaces. The tribological performance of SN-500 base oil could be remarkably improved by using nanoparticles as additional fillers. Meanwhile, a three-body mild abrasive wear was suggested due to the presence of hard nanoparticles in the contact region. However, the three-body contact problem is very complex and depends on many variables, including particle characteristics such as size, hardness and shape and properties of the counterparts such as surface topography and lubricating and loading conditions. The presence of so many factors, and the interactions among them, makes a full characterization of the roles of these factors in friction and wear very difficult. Up to now, there is still a lack of fundamental understanding of the wear mechanisms when using nanoparticles in such wear conditions. This means that systematic investigation of all the relevant characteristics and properties of nanoparticles is still a matter of further research.

4. Conclusions

The following conclusions were drawn on the basis of the tribological tests and SEM wear surface analysis conducted in this research work.

1. The nanoparticles modified by oleic acid exhibit good dispersivity and stability in virgin SN-500 base oil.
2. Oleic acid surface modified SiO_2 nanoparticles in SN-500 base oil provide better tribological properties in terms of load carrying capacity, anti-wear and friction reduction than pure SN-500 base oil at 0.5wt% and 0.75wt% optimal concentration.
3. For the friction reduction test, when SiO_2 nanoparticles added into SN-500 base oil, the friction coefficients reduced by 61%, 55% and 43% at 0.5wt% concentration and 36%, 76% and 17% % at 0.75wt% concentration respectively, as compared to oil without nanoparticles.
4. The anti-wear mechanism is attributed to the deposition of SiO_2 nanoparticles on worn surfaces, which may decreases the shearing stress, thus improving tribological properties.

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