Tribological Properties of Al_2O_3 Nanoparticles Added in SN-500 Base Oil

Mr. Shashikant. B. Dhokate[1] Prof.V.P.Mali[2]
[1]Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]PVPIT Bavdhan Pune, India

Abstract— Lubricants play a vital role in machine performance, machine life, reducing wear and friction and preventing component from failure. Poor performance of lubricant can cause significant energy and material losses. To improve the lubricating properties of bearing oil, nanoparticles can be added in bearing oils. In this research Aluminium Oxide (Al_2O_3) nanoparticles were added into the SN-500 base oil and tribological properties were examined. The concentrations of Al_2O_3 nanoparticles prepared in SN-500 base oil are 0.1 wt. %, 0.5 wt. %, 0.75 wt. % and 1 wt. %. The trials of friction and wear were carried out on a pin on disc tribotester, with varying the concentration of nanoparticle and by varying load (10N, 30N & 50N). The obtained results were compared between Al_2O_3 nano oil and SN-500 base oil. The results showed that 0.5wt% for Al2O3 nano fluid concentration was an optimum concentration for wear. For the friction reduction test, when Al2O3 nanoparticles were added into a base oil, the coefficient of friction reduced by 19%, 35% & 52% at 1wt% concentration as compared to base oil without nanoparticles.

Key words: Aluminium Oxide (Al_2O_3) Nanoparticles, Tribological Properties, Base Oil, Coefficient of Friction, Wear

I. INTRODUCTION

Already the large global demand for lubricants is expected to continue growing in the future. Engine oils account for approximately half of this demand, and industrial lubricants represent the second-largest and fastest-growing segment by volume. Performance-enhancing additives are a vital part of today's modern lubricants. Due to projected growth in manufacturing activities worldwide, the lubricant market is in need of lower-cost and higher-performing additives that meet end-user performance specifications and environmental safety requirements. In response to this need, many companies are preparing nanoparticulate lubrication additives that can significantly lower friction and wear in a wide range of industrial and transportation applications, and scaling up these additives for large-scale production.

Nanotechnology is regarded as the most revolutionary technology of 21st century. This technology can be applied in many fields. In the recent years, various studies have been carried out on nano oil. A research papers have stated that the nano oil is more effective in reducing friction and wear resistance [1-11]. Among those nanoparticles added into standard and base oils, Copper nanoparticles have gained considerable attention and shown remarkable applications for their good wear resistance and friction reduction properties due to good chemical and physical properties.

The preparation of organic–inorganic complex nanoparticles was causing more interest in industry and science. Now, a number of these nanoparticles have been synthesized and many of them have been studied as lubricant oil additive. In current years, with the advancement of nanomaterial's, many scientific researchers added nanoparticles into lubricating oils to get better extreme pressure, anti-wear and friction reducing properties, and the efficiency and service life of machinery were improved. The application of advanced nanomaterial has played an active role in improving and reforming traditional lubrication technology.

Y.Y. Wu et al. Investigated the tribological properties of API-SF engine oil and Base oil, with CuO, TiO_2, and Nano-Diamond nanoparticles used as an additives. The investigational results show that nanoparticles, particularly CuO, added to above oils show good friction-reduction and anti-wear properties. The addition of CuO nanoparticles in the Base oil and API-SF engine oil decreased the friction coefficient by 5.8% and 18.4%, respectively, and reduced the worn scar depth by 78.8% and 16.7%, respectively, as compared to the above oils without CuO nanoparticles. In addition, investigations were performed using Scanning Electron Microscopy, TEM, OM, and EDX to understand the possible mechanisms of anti-friction and anti-wear with nanoparticles [3].

In particular, the tribological properties of rare earth compounds, metal oxides, metals, metal borates and metal sulphide used as lubricant additives have been studied. Tribo-sintering of metal oxide nanoparticles on the wear surfaces tend to anti-wear properties. That process creates load bearing film and reduces metal to metal contact. Also the combined outcome of colloidal effect, rolling effect, protective film and third body results in the friction-reduction and anti- wear of the surface. The results of these studies show that nanoparticles deposit on the rubbing surface and increase the tribological properties of the base oil, displaying good friction and wear resistance [8].

In the current experimental analysis, we have mixed stable Al_2O_3 nanoparticles separately with an 'oleic acid' with the help of magnetic stirrer for 20 minute time which given very good dispersibility in base oil. In order to estimate the ranges of applications of Al_2O_3 nanoparticles, it was necessary to study its tribological properties under different loading conditions. Al_2O_3 has good lubrication and thermal conductivity property.

II. EXPERIMENTAL

A. Materials

The selection of a synthetic oil to examine the influence of metallic nanoparticles is mainly based on its superior rheological properties related to mineral oils. Paraffin based SN-500 base oil was selected as the base oil, as it is considered amongst the more promising synthetic lubricants used for common purposes. This selection is also based on the element that SN-500 base oil is used in industrial bearing oils, hydraulic oils, and aviation lubricants, heat transfer fluids, drilling fluids, dielectric fluids and greases. The SN-500 base oil properties are listed in Table 1.

Property	Range
Viscosity Kin., @40°C (cSt)	101
Viscosity Kin., @100°C(cSt)	10.5
Viscosity Index	95
Density @ 15°C	0.875-0.885
Flash Point (°C)	240
Pour Point(°C)	-6
TAN (Mg KOH/gr)	<0.002
Carbon Residue (%Wt)	0.12
Color	1.5

Table 1: Properties of SN-500 Base oil

B. Preparation of Nano-Oil

One of the most effective factors of the Nano fluid properties is the rate of dispersion and stability of nanoparticles inside the base oil. When dispersion of particles in the base oil is not good, it is possible that agglomeration and precipitation of nanoparticles occur on the surface, which may cause damage of the frictional surfaces. In the present study, to disperse nanoparticles inside the base oil, we used oleic acid as surface modifier and by preparing lubricant oil samples in weight percentage of 0.1wt%, 0.5wt%, 0.75 wt. % & 1wt% by using a magnetic stirrer for 45 min. These concentration values were obtained from the study of research papers, where concentration of nanoparticles is in the range 0.1 wt. % to 1 wt. % of base oil. The results confirm that the existence of the surface modification layer of oleic acid can effectively prevent the agglomeration of Cu & Al2O3 nanoparticles and provide good oil-dispersion ability. The materials used in the experiments and their properties are shown in Table 2.

Nanoparticles	Properties
(Al_2O_3)	Purity: 99.5%, APS: 30-50nm, Bulk Density:1.5 g/cm^3, True Density : 3.97 g/ cm^3

Table 2: Properties of Al_2O_3 Nano Pawder

Specimens	Properties
Disc	Grey Cast Iron, hardness=130-180BHN, d=165 mm, t=8mm, E=66-157GPa, ν=0.26
Pins	Aluminium alloy hardness=100-150BHN, d=12 mm, L= 30mm, E=73GPa, ν=0.33

Table 3: Properties of Disk and Pin

C. Anti-Wear Test Procedure

The nanoparticles are dispersed in SN 500 base oil. The precision balance was used for measuring weight of oil and nanoparticle additives and magnetic stirrer is used for dispersion of nanoparticle in base oil for the 45 minute time.All the components of the test were thoroughly cleaned with cotton waste. Testing was done on Ducom's pin-on-disc tribotester. The relative motion between disc and pin is pure sliding. A round shaped specimen can be fitted and pressed into contact of the disc by means of lever which is loaded by lever arm and dead weights. The pin holder carrying the pin is mounted on flat, which is free to slide in a direction at right angle to the axis about which the disc rotates. The tangential force exerted by the pin on the disc is measured by the beam type load cell connected to the indicator.

All friction and wear tests were carried out at load of 10N, 30N and 50N. These loads were selected from bibliograohic research. The disc was rotated at 1000 RPM for 10-minute time at room temperature. The track radius was taken as 50 mm. Sliding velocities for wear test was taken as 5 m/s. The frictional force and wear was recorded on computer by using the WINDUCOM 2010 software. Figure 1 shows a pin on disc tribotester.

Fig. 1: Friction and Wear Tribotester (TR20LE)

III. RESULTS AND DISCUSSION

A. Anti-wear Properties

From the computer software results were obtained and graphs were plotted. From these graphs anti-wear properties are studied. The wear in microns of SN-500 base oil without nanoparticles is shown in fig. 2, the average values are 10, 26 and 39 with respect to load conditions 10N, 30N and 50N among all sets of test data.

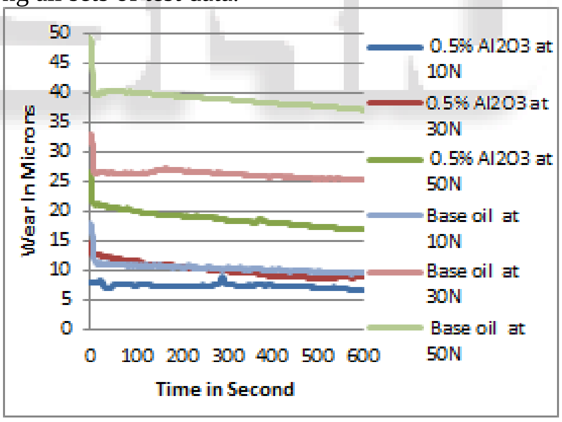

Fig. 2: Wear of base oil without nanoparticles and with 0.5 Wt. %. Al_2O_3 nano particles

The anti-wear property depends upon the nanoparticles concentration in base oil. Fig. 2 shows the graph of wear verses time in which 0.5% wt Al_2O_3 concentration of the base oil sample drastically improved the wear reduction at 10N, 30N and 50N loading conditions and the values are 7μ, 10 μ and 18μ respectively.

So as per the above discussion Al_2O_3 nanoparticle at 0.5% is the optimum concentration of nanoparticles in base oil. Since base oil does not contain any anti-wear additive, the tribochemical reaction film is not produced on contacting surfaces. Therefore, lower wear might be due to rolling effect of the nanoparticles.

B. Friction-Reduction Properties

The coefficient of friction was measured using the pin on disc tribotester under 10N, 30N and 50N load conditions for 10-minute time.

The friction coefficients of SN-500 base oil without nanoparticles are displayed in fig. 3, the average values are 0.198, 0.120 and 0.100 with respect to 10N, 30N and 50N load respectively. The Coefficients of Friction of the SN-500 base oil with and without nanoparticles are shown in fig. 3. On the X-coordinate time elapse is shown and on the Y-coordinate coefficient of friction is shown. From fig 3 it is clear that the addition of 1 wt. % Al_2O_3 nanoparticles in SN-500 base oil, reduce friction by 19%, 35% & 52% with respect to base without nano particles of load 10N, 30N and 50N.

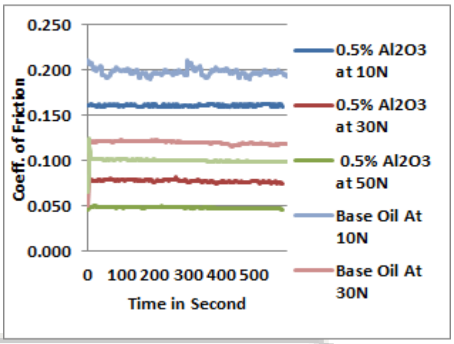

Fig. 3: Coefficient of friction of base oil with and without nanoparticles at 1% by wt. Al_2O_3 concentration

In this study an interesting result was obtained from the wear surface analysis that with increase in the concentration of nanoparticles, some of the properties of base oil improved, but it was noticed that an increase in concentration causes a reduction in lubricating properties of base oil due to agglomeration and precipitation of nanoparticles and as a result causes damage to the frictional surface on the wear surfaces. So determining the appropriate concentration to achieve better properties is a very important issue. The tribological properties of SN-500 base oil can be remarkably improved by using nanoparticles as additive. Meanwhile, a three body, mild abrasive wear was suggested due to the presence of hard nanoparticles between rubbing surface. However, the three-body contact problem is very complex and depends on many parameters, including particles physical properties such as size, hardness and shape and properties of the counterparts such as surface topography, loading conditions and lubricating. Because of so many factors, characterization of friction and wear is very difficult. Till now, there is still a lack of fundamental understanding of the friction and wear mechanisms when using nanoparticles as an additive in base oil. This means that systematic examination of all the related properties and characteristics of nanoparticles is still a matter of further research.

IV. CONCLUSIONS

1) As a lubricant, friction-reduction properties of base oil are enhanced by the addition of Al_2O_3 nanoparticles to a moderate concentration.
2) Dispersing nanoparticles inside base oil, due to the base oil's high viscosity, is a very difficult work. The nanoparticles modified by oleic acid exhibited good dispersibility and stability in base oil.
3) Base oil with Al_2O_3 nanoparticles increased tribological properties in terms of load carrying capacity, anti-wear and friction reduction than SN-500 base oil without nanoparticles. The results showed that 0.5wt% for Al_2O_3 nano fluid concentration was an optimum concentration for wear.
4) For the friction reduction test, when Al_2O_3 nanoparticles were added into a base oil, the coefficient of friction reduced by 19%, 35% & 52% at 1wt% concentration as compared to oil without nanoparticles.
5) The deposition of nanoparticles on the worn rubbing surface can decrease the shearing stress, and hence reduce friction and wear.

REFERENCES

[1] J Halme and P Andersson, "Rolling contact fatigue and wear fundamentals for rolling bearing diagnostics-state of the art". Proc. IMechE Vol. 224 Part J. Engineering Tribology (2009), pp.377-393.
[2] Koyo "Ball & Roller Bearings: Failures, Causes and Countermeasures", JTEKT CORPORATION, pp.B-300.
[3] Y.Y. Wu & W.C. Tsui, "Experimental analysis of tribological properties of lubricating Oils with nanoparticles additives", Wear 262 (2007), 10 October 2006, pp. 819–825.
[4] D.X. Peng, "Tribological properties of diamond and SiO2 nanoparticles added in paraffin", Tribology International 42 (2009), pp. 911–917.
[5] Ming Zhang, Xiaobo Wang and Yanqiu, "Performance and anti-wear mechanism of CaCO3 nanoparticles as a green additive in poly-alpha-olefin", Tribology International 42 (2009), pp. 1029–1039
[6] J.C. Sanchez-Lopez, M.D.Abad, L.Kolodziejczyk, "Surface-modified Pd and Au nanoparticles for anti-wear applications", Tribology International 44 (2011), pp. 720–726.
[7] R. Chou, "Tribological behavior of poly alpha olefin with the addition of nickel nanoparticles", Tribology International 43 (2010), pp 2327–2332.
[8] Harshwardhan H. Patil Prof. D. S. Chavan Prof. A. T. Pise, "Tribological Properties of Sio2 Nanoparticles Added in SN-500 Base Oil", International Journal of Engineering Research & Technology (IJERT), Vol. 2 May – 2013
[9] A. H. Battez, "CuO, ZrO2 and ZnO nanoparticles as antiwear additive in oil lubricants", Wear 265 (2008), pp. 422–428
[10] S.Tarasov, A.Kolubaev, S. Belyaev, M. Lerner, F. Tepper, "Study of friction reduction by nanocopper additives to motor oil", Journal of Wear, Vol. 252 (2002), pp.63–69
[11] Ehsan-o-llah Ettefaghi, Hojjat Ahmadi, Alimorad Rashidi, Seyed Saeid Mohtasebi and Mahshad Alaei, "Experimental evaluation of engine oil properties containing copper oxide nanoparticles as a nanoadditive", International Journal of Industrial Chemistry 2013, 4:28.
[12] Noreffendy Tamaldin, "Optimization of Tribological Performance of hBN/AL_2O_3 Nanoparticles as Engine Oil Additives", Procedia Engineering 68, 2013, pp.313–319.