Experimental investigation of Tribological Properties of lubricant Engine oil with Mos2 Nanoparticles

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Abstract - **To improve the lubrication property to reduce wear and tear nanoparticles are very useful. In this project mos2 nanoparticles are added to engine oil 10W30 & 5W40 and Tribological properties are investigated. Samples were prepared of varying percentage of mos2 nanoparticles in engine oil (0.25, 0.5, 0.75 and 1 wt. %). The wear and friction experiment was carried on three tribal Tribotester and the tests were performed with varying load, speed and varying concentration of nanoparticles in engine oil. The obtained results show that mos2 nanoparticles added in engine oil exhibits good friction reduction and anti-wear properties and also decreased the coefficient of friction by 21% and 51% at 0.4wt% concentration respectively, as compared with standard engine oil without mos2 nanoparticles. This tribological behavior 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).**

keywords - **Lubrication, 10W30, Nanoparticle, Tribological, SEM**

I. INTRODUCTION

In mechanical systems, the frictional loss is one of many factors in energy consumption. To reduce friction and wear, nanoparticles have been studied to be used as lubricant additives that have promising effects on friction and wear reduction in automotive, mining, and other industrial applications. Nanoparticles of various compositions and sizes have demonstrated certain degrees of friction modifying and anti-wear effects. We recently reported that in the boundary lubrication region, the addition of nanoparticles can reduce the friction coefficient up to 70%, and wear use as high as 75%. Such lubricants consisting of a base oil and dispersed nanoparticles emerged as a new class of Nano lubricants, the bottleneck for further development, however, is the aggregation of nanoparticles in a base oil. A stable suspension of nanoparticles is essential for a usable lubricant. The aggregation of nanoparticles limits their ability to lubricate the contact area TheMoS_2nanoparticle can reduce 75% of friction when mixed with lubricant oil. Such reduction was achieved by ultrasonic dispersion immediately before testing, the aggregation of nanoparticles could increase friction due to the reduced "shear" effects. Understanding the principles of dispersion is essential to developing novel lubricants. This review is divided into two parts. The first part reviews the methods used to disperse nanoparticles in lubricant oil.

Nanotechnology is regarded as the most revolutionary technology of the 21st century. It can be used in many fields and usher's material science into a new era. After investigations on the tribological properties of lubricants with different nanoparticles added in it. A large number of papers have reported that the addition of nanoparticles to lubricant is effective in reducing wear and friction. MoS_2 nanoparticle is found better among all added into the oil. Among those that were added into oils, MoS_2 nanoparticles have received much attention and exhibited excellent applications for their good friction reduction and wear resistance properties. The reduction of wear depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding speed, surface roughness, lubrication, and vibration. Chemical additives in lubrication fluid controls anti-wear properties, load-carrying capacities, and friction under the specified 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. Nanoparticles have received considerable attention because of their special physical and chemical properties. The preparation of organic–inorganic complex nanoparticles was causing more interest in science and industry. Experimental done on number of nanoparticles for lubrication oil additive. However, few of them were used and studied as water base lubrication additives. With the research and development of nanomaterial, many scientific researchers added nanoparticles into lubricating oils to improve extreme pressure, anti-wear and friction reducing properties, and the efficiency and service life of machinery were improved and prolonged. The application of advanced nanomaterial has played an active role in improving and reforming traditional lubrication technology. Y.Y. Wu et al. examined the tribological properties of two lubricating oils, API-SF engine oil and Base oil, with MoS_2 and Nano-Diamond nanoparticles used as additives.

The experimental results show that nanoparticles, especially MoS_2 added to standard oils exhibit good friction-reduction and anti-wear properties. The addition of MoS_2 nanoparticles in the API-SF engine oil and the Base oil decreased the friction coefficient by 16.4 and 4.8%, respectively, and reduced the worn scar depth by 16.7 and 72.8%, respectively, as compared to the standard oils without nanoparticles. In addition, investigations were performed using TEM, OM, SEM, and EDX to interpret the possible mechanisms of anti-friction and anti-wear with nanoparticles.

The tribological properties are investigated for metal oxides, rare earth compounds, metals, metal borates and metal sulphides used as lubricate additives. The anti-wear mechanism of a metal oxide Nano particulate additive was tribo-sintering of nanoparticles on the wear surfaces. That process reduced the metal-to- metal contact and created a load bearing film. The mechanisms change due to colloidal effect, rolling effect, protective film, and third body on the friction-reduction and anti- wear of nanoparticles in lubricants as the result of. The results of these investigations show that nanoparticles deposit on the rubbing surface and improve the tribological properties of the base oil, displaying good friction and wear reduction characteristics. The synthesis is done on MoS_2 is done in our study which gives very good dispensability in organic solvents. In order to estimate the ranges of applications of MoS_2 nanoparticles, it was necessary to investigate its tribological behaviour under increasingly severe contact conditions.

i. STRIBECK CURVE

Stribeck curve describes the friction levels of contacts with different film thickness to surface roughness ratios with lubrication regimes of the major components in automotive engines such as piston rings, engine bearings and valves as shown in Figure 1. Internal combustion Engine lubrication is categorized into three main regimes: boundary, mixed and elasto-hydrodynamic lubrication. In piston rings/liner assembly, the previous lubrication regimes can be obtained over the stroke depending on operating conditions. Generally, boundary lubrication exists under the effect of low speed and high load conditions. Hence, Nano-lubricant additives are very important in boundary lubrication because of the higher friction coefficient. Current challenges for reducing the friction and wear require an adaptable lubricant for different operating conditions. Thence, most researchers have focused on Nano-lubricant concept in the internal combustion engines as the main strategy for suppressing the friction coefficient and the wear of contact surfaces, in a manner that will ultimately lead to an improved tribological performance.

The main advantages of the nanoparticle's additives compared to conventional lubricant additives are stated as follows:

1) Nanoparticles are often efficient at room temperature.
2) Activation of nanoparticle surface.
3)Increase of surface area and extreme small sizes.
4)Nanoparticles sized smaller than 100 nm have thermal conductivity higher than of the fluids.
5)Nanoparticles provide excellent tribological performance as solid lubricant

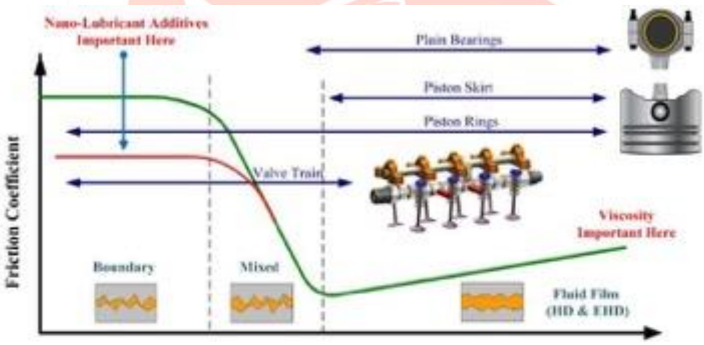

Figure 1Figure 1. Lubrication stribeck curve of the major components in an internal combustion engine.

ii. IMPORTANT CONSIDERATIONS WHILE NANOPARTICLES SELECTION AND NANO LUBRICANT PREPARATION

Designing of Nanoparticles Selection and Nano lubricant Preparation depends upon so many factors. These factors are analysed to get design inputs for Nanoparticles Selection and Nano lubricant Preparation The list of such factors is mentioned below

(a) Study of lubricant oil and finished quantity size and property.
(b) Type and capacity of the lubrication oil, its extent of automation.
(c) Provision of lubrication preparation devices in the machine.
(d) Available nanoparticle and their property.
(e) Available indexing devices, their accuracy.
(f) Evaluation of variability in the performance results of the preparation.
(g) Rigidity and of the preparation under consideration.
(h) Study of experiment machine, safety devices, etc.
(i) Required level of the accuracy in the work and quality to be produced.

iii. PROBLEM STATEMENT

1) Previous techniques are more time consuming. And more frication.
2) less surface area and extreme small sizes.
3) It may cause frication due to high temp or increase cycle time of replacement of part
4) Chances of slippage are more while higher applied force chance to accident occur.

iv. NECESSITY OF WORK

The principal motivation for formulating new additives using nanoparticles as a promising solution for improving the tribological behaviour is that nanoparticles have the potential to offer significant tribological benefits of both solid and liquid lubrication and extend the life of the mechanical components. The decline of the friction coefficient between the rings/liner assembly plays a critical role in improving engine performance and fuel efficiency. Nano lubricant additives play a significant role in the formation of a tribo-film layer on the worn surfaces via physical or chemical absorbed mechanism to enhance protection of the worn surfaces and create a rolling effect

v. METHODOLOGY

Aim: Experimental Investigation of Tribological Properties of Engine oil with MoS_2, nanoparticles

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Problem Definition: The principal motivation for formulating new additives using nanoparticles as a promising solution for improving the tribological behaviour

⇩

Existing Problem:

1. Previous techniques are more time consuming. And more frication.
2. less surface area and extreme small sizes.

⇩

Solution: The decline of the friction coefficient between the rings/liner assembly plays a critical role in improving engine performance and fuel efficiency. Nano lubricant additives play a significant role in the formation of a tribo-film layer on the worn surfaces via physical or chemical absorbed mechanism to enhance protection of the worn surfaces and create a rolling effect between sliding surfaces

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Analysis: -

1. Preparation of Prototype sample of "of Tribological Properties of Engine oil with MoS_2, nanoparticles".
2. Experimental workout of "of Tribological Properties of Engine oil with MoS_2, nanoparticles".
3. Study of comparative result of "of Tribological Properties of Engine oil with MoS_2, nanoparticles Finite Element Analysis

⇩

Result

II. LITERATURE

i. Evaluation of Tribological Properties of Jatropha Curcas Oil by Addition of Nanoparticle Additives

This work discusses the tribological properties of bio lubricating oil with nanoparticles additives. The objective of this work is to evaluate the tribological properties of Jatropha curcas Oil with addition of Cu, Graphite, MoS_2 nanoparticle additives. The effect of additives on tribological properties of Jatropha curcas Oil has been investigated on four ball tester. Test balls are made from chrome alloy steel of AISI standard. Instead of traditional materials, new bio lubricant and nanoparticles have been investigated as lubricants or lubricant additives because of their environment friendly, bio degradable properties. Now, there are numerous different types of nonmaterial with potentially interesting friction and wear properties described the literature.

ii. Conclusion from review

The principal motivation for formulating new additives using nanoparticles as a promising solution for improving the tribological behaviour is that nanoparticles have the potential to offer significant tribological benefits of both solid and liquid lubrication and extend the life of the mechanical components. The decline of the friction coefficient between the rings/liner assembly plays a critical role in improving engine performance and fuel efficiency. Nano lubricant additives play a significant role in the formation of a tribo-film layer on the worn surfaces via physical or chemical absorbed mechanism to enhance protection of the worn surfaces and create a rolling effect between sliding surfaces

III. DESIGN METHODOLOGY

i. Design step and Introduction of properties on nano particle

In traditional contact theories for two objects in contact with each other under external forces, for instance, the simplest case of two interacting elastic spheres deduced by Hertz in surface forces were not included. In these models, the displacement and the contact area are equal to zero when no external force is applied. However, as the size of the object is decreased to the nanoscale, the surface forces play a major role in their adhesion, contact and deformation behaviours. Modern theories of the adhesion mechanics of two contacting solid surfaces are based on the Johnson–Kendall–Roberts (JKR) theory The JKR theory is applicable to easily deformable, large bodies with high surface energies. Strong, short-range adhesion forces dominate the surface interaction; the effect of adhesion is included within the contact zone. In contrast, the DMT theory better describes very small and hard bodies with low surface energies. In this case, the adhesion is caused by the presence of weak, long-range attractive forces outside the contact zone. Tabor introduced a no dimensional physical parameter, often referred to as Tabor's parameter, to quantify the limits of JKR, DMT and the cases between them. The intermediate regime between the JKR and the DMT theories has also been described by Maugis] using the Dugdale model a 'transition parameter' roughly equivalent to Tabor's parameter was defined. A summary of the different conventions used for defining the 'transition parameter' was given by

Greenwood. Carpick et al provided a simple analytic equation to determine the value of the 'transition parameter'; it could closely approximate Maugis' solution. The expansion of the JKR theory by Maugis and Pollock leads to the additional description of plastic deformation.

ii. 3.2Other forces—solvation, structural and hydration forces

Apart from vdW forces and EDL forces, some other forces, i.e. solvation, structural or hydration forces, come into play when two surfaces or particles approach very close (separation less than a few nanometers) in the liquid. These forces can be monotonically repulsive, monotonically attractive or oscillatory and they can be much stronger than either the vdW forces or EDL forces at small separations. Solvation, structural or hydration forces (in water) arise between two particles or surfaces if the solvent or water molecules become ordered by the surfaces. When the ordering occurs, an exponentially decaying oscillatory force with a periodicity equal to the size of the confined liquid molecules, micelles or nanoparticles appears. Solvation forces depend not only on the properties of the liquid medium but also on the surface physicochemical properties, such as hydrophilicity, roughness, crystalline state, homogeneity, rigidity and surface micro-texture.

iii. 3.3 Capillary force

Capillary force is mainly due to the formation of liquid menisci (also termed the meniscus force), the significance of which was realized by Haines and Fisher. Capillary force can be classified into two types: normal capillary force and lateral capillary force. A comprehensive review of the normal capillary force was given by Butt and Kappl. Denkov et al and Kralchevsky and Nagayama contributed a lot to the study of the structure of colloid nanoparticles due to the lateral capillary force. Capillary forces should be considered in the studies on powders, soils and granular materials, the adhesion between particles or particles to surfaces and the station in micro/nano-electromechanical systems. It is also relevant to nanoparticle assembling or living cells self-assemble technologies.

iv. Lubricant Characteristics Specific Gravity

Specific gravity is the ratio of the weight of a given volume of substance at 60-degree F. to that of water.

v. Viscosity

Viscosity is a measure of the oil's resistance to flow? The more the viscosity of the oil more will be its resistance to flow, e.g. compare water and molasses. Water is less viscous and hence flows freely. Whereas molasses, which has a high viscosity, flows sluggishly. An ideal oil film on a bearing depends on selecting an oil with the right viscosity to maintain separation of two metal surfaces. The speed of the journal and viscosity are closely allied in maintaining a good oil film in the bearing. The slower the journal speed, the higher viscosity or thicker oil we must use. As journal speeds are increased, a thinner of lower viscosity oil is needed. Bearing loads must also be considered because the oil must have sufficient viscosity to maintain a good oil film to support the load. Technically speaking, it is defined as the force required to move a plane surface of one square centimeter area over another plane surface at the rate of one centimeter per second, when the two surfaces are separated by a layer of liquid one centimeter in thickness. The unit of this force is poise and is called absolute viscosity. Kinematic viscosity is the ratio of absolute viscosity to the specific gravity of the oil at the 4-5 maintenance engineering and management temperature at which the viscosity is measured. Its unit is stoking. For practical purposes, viscosity of petroleum oils is expressed in time in seconds taken by a given quantity of oil to flow through a standard capillary tube. It is expressed as Say bolt universal seconds at 100-degree F. or 210-degree F.

vi. Viscosity Index

Viscosity index is an expression of effect of change of temperature on the viscosity of oils. This change can be evaluated numerically and the result is expressed as Viscosity Index

vii. Pour Point

Pour point of oil is an important quality. It is a temperature at which oil will still remain fluid. It reflects on the capability of the oil to work at low temperatures.

viii. Flash Point

Flash point is the temperature at which the oil gives off sufficient vapours which can be ignited. It reflects on the capability of the oil to work at higher temperature without any fire hazard.

ix. Lubricant Additives

The purification and manufacturing processes impact good qualities to lubricating oils. But still they cannot be used directly. They will be prone to contamination and decomposition in the exacting working conditions. Hence certain chemical compounds and other agents which are termed as additives are added to the oil. Most modern lubricant additives can be classified as follows: 1. Those designed to protect the lubricant in service by maintaining deterioration. 2. Those that protect the lubricant from harmful fuel combustion products. 3. Those which improve existing physical properties or impart new characteristics. Use of chemical additives in lubricants is very wide. They are used in the lightest instrument and spindle oils to the thickest gear lubricants; automotive lubricants; cutting oils; and hydraulic fluids. There are over 50 characteristics of lubricating base oils which can be improved by the additives. Generally speaking, the additives must have the following properties:

a) Solubility in base petroleum oil
b) Insolubility in and lack of reaction with aqueous solution.
c) Should not impart dark colour to the oil
d) Low volatility
e) Additives must be stable in blending, storage and use.
f) Additives should not impart unfavourable odour. 4-6 maintenance engineering and management

Additives are substances formulated for improvement of the anti-friction, chemical and physical properties of base oils (mineral, synthetic, vegetable or animal), which results in enhancing the lubricant performance and extending the equipment life. Combination of different additives and their quantities are determined by the lubricant type (Engine oils, Gear oils, Hydraulic oils, cutting fluids, Way lubricants, compressor oils etc.) and the specific operating conditions (temperature, loads, machine parts materials, environment). Amount of additives may reach 30%.

- Friction modifiers
- Anti-wear additives
- Extreme pressure (EP) additives
- Rust and corrosion inhibitors
- Anti-oxidants
- Detergents
- Dispersants
- Pour point depressants
- Viscosity index improvers
- Anti-foaming agents

x. Friction Modifiers

Friction modifiers reduce coefficient of friction, resulting in less fuel consumption. Crystal structure of most of friction modifiers consists of molecular platelets (layers), which may easily slide over each other. The following Solid lubricants are used as friction modifiers: • Graphite;

- Molybdenum disulfide;
- Boron nitride (BN);
- Tungsten disulfide (WS_2);
- Polytetra fluoro ethylene (PTFE). Anti-Wear Additives

Anti-wear additives prevent direct metal-to-metal contact between the machine parts when the oil film is broken down. Use of anti-wear additives results in longer machine life due to higher wear and score resistance of the components. The mechanism of anti-wear additives: the additive reacts with the metal on the part surface and forms a film, which may slide over the friction surface. The following materials are used as anti-wear additives:

- Zinc dithiophosphate (ZDP);
- Zinc dialkyldithiophosphate (ZDDP);
- Tricresylphosphate (TCP). Viscosity Index Improvers

Viscosity of oils sharply decreases at high temperatures. Low viscosity causes decrease of the oil lubrication ability. Viscosity index improvers keep the viscosity at acceptable levels, which provide stable oil film even at increased temperatures. Viscosity improvers are widely used in multigrid oils, viscosity of which is specified at both high and low temperature. Acrylate polymers are used as viscosity index improvers in lubricants. Anti-Foaming Agents

Agitation and aeration of a lubricating oil occurring at certain applications (Engine oils, Gear oils, Compressor oils) may result in formation of air bubbles in the oil - foaming. Foaming not only enhances oil oxidation but also decreases lubrication effect causing oil starvation. Dimethylsilicones (dimethylsiloxanes) is commonly used as anti-foaming agent in lubricants

IV. EXPERIMENTAL

i. Materials

The SAE 20W40 engine oil was used as the base oil. The Pure lubricants engine oil contains some additives for friction reduction and anti-wear, but the Base oil purchased does not. Pure lubricants are manufacturers of industrial lubricant, automobile oil and greases. It is an India Standards certified company. The properties of base oil are given in table no.1.

Table 1 Properties of Base oil

Properties	Range
Appearance	Br & clear
Color	1.6 ASTM
Density @ 29.5 D.C.	0.980 gm/ml
K. V. @ 40 D.C.	84 cSt
K. V. @ 100 D.C.	11.54 cSt
Viscosity Index	44 (MIN)
Flash Point (oC)	252
Aniline Point (oC) Pour Point	105.5. L-6

ii. Preparation of Nano-oil

The rate of dispersion and stability of nanoparticles inside the base fluid are the most effective factors of the Nano fluid properties is. When dispersion of particles inside the base fluid is not good, it is possible that agglomeration and precipitation of nanoparticles occur; which may cause damage of the frictional surfaces. We used oleic acid as surface modifier and by preparing lubricant samples in concentrations of 0.25 wt%, 0.5 wt%, 0.75 wt% and 1wt% using an ultrasonic probe for 45 min. The bibliographic research shows the concentration of nanoparticles in the range of 0.2-1 wt%. The results show effective prevention of the agglomeration of nanoparticles and provide good oil-dispersion ability. The materials used in the experiments and their properties are shown in Table 2.

Figure 2 Nano Particles

Table 2 Properties of the materials MoS_2

Nanoparticles	Properties
MoS_2	Morphology: nearly spherical, Purity:87.95+%, APS: 18-45nm, Bulk Density: 0.69 g/cm3, True Density: 6.4 g/m3

iii. Anti-Wear Test Procedure

All test-section components were cleaned thoroughly. Testing was conducted using a Tribo-tester. The friction and wear testing machine were set for pure sliding contact, with a pin-on-disk configuration. The manufactured test pins were run against a counter face of the manufactured disk (properties given in Table 2). All wear tests were carried out at loading condition 10N, 20N and 50N. The disk was rotated at constant speed of 1000 rpm at room temperature for 10-minute time. The coefficient of friction and wear rate was recorded using strain gauge in tribo-tester. Wear surfaces on pin were characterized using Scanning Electron Microscopy (SEM).

V. EXPECTED CONCLUSION

i. As a lubricant, friction-reduction properties of base oil are enhanced by the addition of MoS_2 nanoparticles to a moderate concentration.
ii. Dispersing nanoparticles inside engine oil, due to the base oil's high viscosity, is a very difficult work. The nanoparticles modified by oleic acid exhibited good dispensability and stability in base oil.
iii. Base oil with MoS_2 nanoparticles improved tribological properties in terms of load carrying capacity, anti-wear and friction reduction than base oil without nanoparticles. The results showed that 0.5wt% concentration was an optimum concentration.
iv. For the friction reduction test, when MoS_2 nanoparticles were added into base oil, the coefficient of friction reduced by 24% and 53% at 0.5wt% concentration as compared to oil without nanoparticles.
v. The deposition of nanoparticles on the worn surface can decrease the shearing stress, and hence reduce friction and wear.

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