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Article

An Analysis on outcome of Addition of Nanoparticle Additives on Tribological Properties of Lubricants

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A B S T R A C T

The reduction of friction and wear is critical so as to proper functioning of machines. A more complex machine has a high quality lubrication requirement. Machine components and mechanism pairs depends on high-quality lubricants to enable withstanding high temperatures and Extreme Pressures (EP). Tribological investigations are to be performed on lubricating oil containing, Cu, Cu25C and Fe, Fe25C nanoparticles and their combinations to improve the tribological properties of the lubricant. The tribological behavior can be evaluated on a four ball oil tester machine and it is expected that the tests will show that each set of nanoparticles significantly reduce the friction coefficient and wear of friction pairs. The use of nanoparticles shall provide the most effective reduction of friction and wear in each combination of nanoparticles. Surface investigation will display the constituent elements of nanoparticles precipitate on the contact surface during the use of the oils with nano-additives. Different structures formed on the friction surface area will be observed in the contact zone and over the remnants of the ball surface. The Scanning Electron Microscope (SEM) micrographs and Energy Dispersive Spectroscopy (EDS) examination is to be done so as to authorize the formation of a tribolayer collected of the elements from the nanoparticles.

Keywords: Nanoparticles, Lubricating Oil, Friction Coefficient, Wear Behavior

Introduction

Recent investigation papers have described that the totaling of nanoparticles to lubricant is actual for the reduction of wear and friction in mechanical systems. Since of the extraordinary tribological properties of nanoparticles, nanotechnology is observed as the greatest revolutionary technology of the 21st century.[4]

The anti-wear apparatus of nanoparticles when they are cast-off as additives in lubricants can be clarified in three dissimilar behaviors: nanoparticles may be liquefied and welded on the rubbing surface, responded with the specimen to procedure a protective layer, or tribo-sintered on the surface. Though, some authors state that nanoparticles can also act as minor bearings on the rubbing surfaces. nanoparticles penetrate into lubricated EHD contacts via a mechanical entrapment mechanism to form a border film influencing friction and wear, and these nanoparticles are entrained into sliding contacts only when the film thickness is smaller than the particle size causative to the film thickness. The above-mentioned anti-wear mechanisms of the nanoparticles take place only under mixed and boundary lubrication. Results show that nanoparticles can improve the tribological properties of the base oil, exhibiting good friction and wear reduction appearances even at concentrations below 2 wt%.[7]

With the fast expansion of nanotechnology, nano lubricants with metallic additives have also been deliberate. Investigational consequences report that the use of metallic nanoparticles as additives to oils can advance the anti-wear possessions under extreme pressure conditions. The metallic nanoparticles can also act deprived of any corrosive effect and can be used at high temperatures. Therefore, they have the potential to developed a new generation of anti-wear and thrilling pressure additives.[4]

The tribological performance of lubricants with the addition of copper nanoparticles has been considered by some authors. In all these belongings, when copper coated nanoparticles (none of them was carbon-coated ones) were tested as oil additives, the results showed that the oils with the adding of these nanoparticles exhibit an excellent antifriction and anti-wear presentation and high load-carrying capacity. Lately used were surface-coated copper nanoparticles as oil additives. They presented that surface-coated nano-copper additives can importantly advance the wear resistance and load-carrying abilities of oil, as well as reduction the friction coefficient. They related the consequences to a soft copper protective film that is designed on the worn surface lubricated with oil containing nano copper additives, which separates the worn exteriors, avoids their direct contact and reduces friction and adhesive wear. On the other hand used graphene abridged copper nanoparticles as a lubricant additive. In this case, the additive also amplified the load-carrying capacity of the base oil, decreased the friction.

Coefficient and enhanced the anti-wear properties. Though, they did not associate the tribological behavior of coated nanoparticles used as emollient additives with the non-coated ones.[7]

Literature Survey

Several nanoparticles have newly been inspected for use as oil additives. Nano-powders of some metals and their compounds exert a typically real influence on the features of lubricants. The use of nanoparticles that include Cu, CuO, Fe, Ni, TiO_2 and other metallic nanoparticle additives in lubricating oils delivers good friction reduction and anti-wear behavior.

Chou R., Herna´ ndez Battez A observed the the influence of addition of 20 nm diameter nickel nanoparticles on the tribological conduct of synthetic oil (polyalphaolefin, PAO6). A TE53SLIM tribometer (block-on-ring configuration) for problematic at medium loads and a four-ball machine (ASTM D2783) were cast-off in this investigation. Wear surfaces were inspected by SEM and EDS. The learning chiefs to the assumption that the addition of nickel nanoparticles to PAO6 outcomes in a diminution in friction and wear and an increase in the load-carrying capacity of base oil. This tribological behavior is closely related to the deposition of nanoparticles on the rubbing surfaces.[1]

Hu ZS, Dong JX, Chen GX studies the Nanoparticle amorphous lanthanum borate with a subdivision size of 20–40 nm was ready with a Replacing Solvent Dry method and considered using TEM and XRD. Its tribological possessions as a wear resistance preservative of lubricating oil were assessed with a four-ball tribotester. The wear scar was considered with XPS. The wear resistance and load carrying capacity of 500 SN base oil was better-quality by the lanthanum borate. Diboron trioxide and FeB were formed on the wear scar surface. These tribochemical reaction products as well as some depositions formed a wear resistance film on the rubbing surface, which providing the oil with an excellent load carrying capacity.[2]

Ingole Sudeep, Charanpahari Archana, inspected the belongings of titanium dioxide additives on the lubricated friction and wear behavior of self-mated E52100 bearing steel were inspected using a reciprocating pin-on-disk apparatus. The additives were (a) nano-sized Titanium dioxide (TiO_2), in the form of natase, and (b) commercially obtainable TiO_2 (P25) which contains a mixture of rutile and anatase phase. These were added to a re-refined base oil. Nano TiO_2 powder was mass-producedby ethylene glycol mediated co-precipitation technique and considered by X-Ray Diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and Raman spectroscopy. Nanoparticles (20–25 nm in size) were also characterized by TEM and Scanning Electron Microscopy (SEM). The friction and wear appearances were inspected at a constant applied load and rate of reciprocation. All concentrations of P25 increased the coefficient of friction, but the addition of TiO_2 nanoparticles reduced the variability and steadied the frictional behavior.[3]

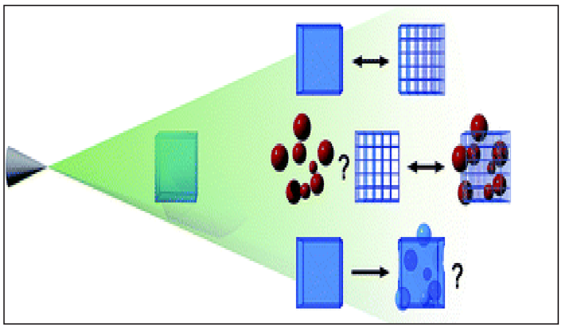
Padgurskas Juozas, Rukuiza Raimundas deliberate the Tribological soundings on mineral oil covering Fe, Cu and Co nanoparticles and their combinations. The tribological tests presented that each set of nanoparticles importantly condensed the friction coefficient and wear (up to 1.5 times) of friction pairs. The use of Cu nanoparticles delivers the most actual reduction of friction and wear in each mixture of nanoparticles. Surface analysis shows that the constituent elements of nanoparticles precipitated on the contact surface during the use of the oils with nano-additives. Dissimilar structures formed on the friction surface are observed in the contact zone and over the remainder of the ball surface. The SEM micrographs and EDX chemical analysis confirmed the development of a tribo-layer self-possessed of the elements from the nanoparticles.[4]

Peng D.X. Kang Y studies the tribological properties of liquid paraffin to which diamond and SiO2 nanoparticles, which organized by the surface modification method using oleic acid, had been added and observed by Scanning Electron Microscopy (SEM) and Infrared (IR) spectroscopy. Also, the dispersion capability and stability dispersity of both modified nanoparticles in liquid paraffin were measured using a spectrophotometer. The extents show the dispersion capacity and the dispersing stability of oleic acid-modified diamond and SiO2 nanoparticles in liquid paraffin. The tribological properties are evaluated using a ball-on-ring wear tester. The significances show that both nanoparticles as additives in liquid paraffin at a tiny concentration have better anti-wear and antifriction properties than the pure paraffin oil. Also, SEM was used to observe the plowing of nanoscale grooves of worn surfaces by diamond and SiO2 nanoparticles.[5]

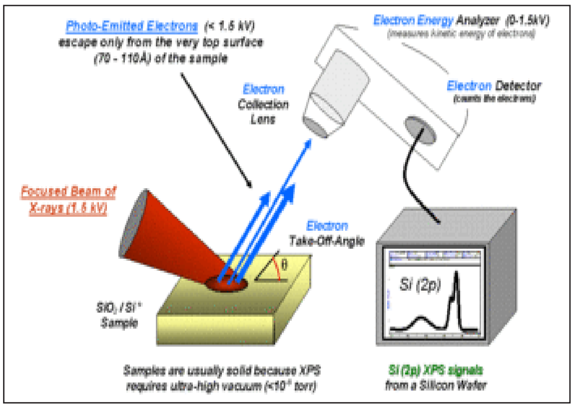
Viesca J.L. Herna´ndez Battez A deliberate the influence of the addition of 25 nm carbon-coated copper nanoparticles on the tribological behavior of a polyalphaolefin (PAO6) and associates this behavior with the case of non-coated copper nanoparticles, decisive the influence of coating. A block-on-ring tribometer, a four-ball machine, SEM and EDS were used in this investigation. The study accomplishes that the addition of carbon-coated copper nanoparticles reductions wear and upsurges the load-carrying capacity of PAO6. This tribological development is due to the statement of nanoparticles on the rubbing surfaces and possibly by their action as tiny bearings. The carbon-coated copper nanoparticles did not behave better than non-coated ones.[6]

Wu Y. Y. Tsui W. C study inspected the tribological properties of two lubricating oils, an API-SF engine oil and a Base oil, with CuO, TiO_2, and Nano-Diamond nanoparticles cast-off as additives. The friction and wear researches were achieved using a reciprocating sliding tribotester. The experimental consequences show that nanoparticles, especially CuO, added to standard oils exhibit good friction-reduction and anti-wear properties. The addition of CuO nanoparticles in the API-SF engine oil and the Base oil decreased the friction coefficient by 18.4 and 5.8%, correspondingly, and reduced the worn scar depth by 16.7 and 78.8%, correspondingly, as compared to the standard oils without CuO nanoparticles. In addition, researches were achieved using TEM, OM, SEM, and EDX to comprehend the conceivable mechanisms of anti-friction and anti-wear with nanoparticles.[7]

Zhou Jingfang, Wu Zhishen considered the LaF3 nanoparticle surface coated by organic compounds comprising S and P was manmade by the chemical surface adjustment technique. The particle size and structure were considered using a Transmission Electron Microscope (TEM) and Electron Diffraction (ED), their tribological behaviors were evaluated on a four-ball machine. The results showed that LaF3 nanoparticles as an oil additive can strikingly improve the load-carrying capacity and anti-wear possessions of the base oil and had better friction-reduction when compared to that of ZDDP.



The rubbed surfaces were examined by Scanning Electron Microscopy (SEM) and X-ray Photoelectron Spectroscope (XPS). It can be inventing that the boundary film on the worn surface was composed of LaF3 nanoparticles putting film and tribochemical reaction film of the rudiments of S and P, which underwrote to excellent tribological properties of LaF3 nanoparticle altered by composite containing S and P as an additive in liquid paraffin.[8]



Problem Statement

The conservative lubricants used for numerous mechanical systems contain of different types of conventional additives. The additives assistance to recover the lubricating and anti-wear properties of the lubricant. But these conventional additives have certain limitations at heavy loads. They are not able to support their original properties and thus show poor lubricating and anti-wear properties at these heavy loads. So, there should be growth in the additives so as to rise the employed range of the lubricant.

Objectives

The problematic statement terms the keen essential of expansion of additives so as to recuperate the lubricating properties of the lubricant. This can be complete by using the new emerging material i.e. nanoparticles as additives in the lubricant. So, the chief aim of this work is to check possibility and to inspect the tribological properties of different types of nanoparticle additives so as to recover the lubricating and anti-wear properties. The objectives of this report can be recruited as shadows:

- To decrease the coefficient of friction and wear of friction pairs
- To intensification the load carrying capacity of oil by using nanoparticle additives
- To learning the effect of blending of two or more kinds of nanoparticle additives on tribological properties of lubricating oil as anti-wear and EP properties
- To learning the result of numerous concentrations (wt%) of both carbon coated and non carbon coated nanoparticle additives on the tribological properties of lubricating oils

Methodology

Nanoparticles used

Material Preparation

The nanoparticles are dispersed in SAE10 engine oil. The dispersion is subjected to ultrasonication and mechanical agitation to break down aggregate particles and disperse them as a uniform suspension. Oleic acid is used as a surfactant in the dispersion procedure to prevent nanoparticle agglomeration and thus improve the dispersion stability of Cu, Cu25C & Fe, and Fe25C nanoparticles.

The challenging is to be achieved as per ASTM D-2783. The friction coefficient will be restrained by a four ball tribotester. Fig. 6.3.1 shows a diagram illustration of the tribotester that will be used for evaluation of the friction coefficient of the raw oil and the oils with nano-additives. The experiments will be performed at room temperature. Balls with a diameter of 12.7 mm are to be made of 100 Cr6 bearing steel. Beforehand and after each research, all

Table 1.Nanoparticles used and their Properties

Sr. No.	Properties	Copper (Cu)	Copper Carbon Coated (CuC)	Iron (Fe)	Iron Carbon Coated (FeC)
1.	Purity	99.8%	99.8%	99.5%	99.6%
2.	APS	35 nm	25 nm	25 nm	25 nm
3.	SSA	30-50 m^2/g	30 - 50 m^2/g	40 - 60 m^2/g	40 - 60 m2/g
4.	Colour	Black Brown	Black	Black	Black
5.	Morphology	Spherical	Spherical	Spherical	Spherical
6.	Bulk density	0.15-0.35g/cm^3	0.15 - 0.35 g/cm3	0.10 - 0.25 g/cm3	0.10 - 0.25 gcm3
7.	True density	8.94g/cm^3	8.94 g/cm3	7.87 g/cm3	7.87 g/cm3
8.	Melting point	1083 ° C	1083°C	1536°C	1536°C
9.	Boiling point	2595°C	2595°C	3000°C	3000°C

Table 2.Different Compositions of the Lubricants

Title of nano-oil	Nanoparticles	Content of metal (g/100ml oil)
SAE 10+Cu	CU	0.5
SAE 10+Fe	Fe	0.5
SAE 10+Cu25C	Cu25C	0.5
SAE10+Fe25C	Fe25C	0.5
SAE 10+Cu+Fe	Cu+Fe	0.25+0.25
SAE 10+CU+Cu25C	Cu+ Cu25C	0.25+0.25
SAE10+Cu+ Fe25C	Cu+ Fe25C	0.25+0.25
SAE10+Cu25C+Fe25C	Cu25C+ Fe25C	0.25+0.25
SAE 10+Cu	CU	1.0
SAE 10+Fe	Fe	1.0
SAE 10+Cu25C	Cu25C	1.0

SAE10+Fe25C	Fe25C	1.0
SAE 10+Cu+Fe	Cu+Fe	0.5+0.5
SAE 10+CU+Cu25C	Cu+ Cu25C	0.5+0.5
SAE10+Cu+ Fe25C	Cu+ Fe25C	0.5+0.5
SAE10+Cu25C+Fe25C	Cu25C+ Fe25C	0.5+0.5

of the suitable parts of the machine (i.e. the lower and upper ball holders, oil vessel and the test balls) are to be eroded in an ultrasonic bath with hydrocarbon solvents and then dried. The friction torque among the balls and the temperature alteration of a liquid sample is to be recorded during the test. Three identical tests will be attained for each example to minimize data scattering.

The wear will be assessed rendering to the wear scar diameter on the steel ball surfaces. The diameters of the circular wear spots on the three motionless balls are to be measured with an optical microscope (accuracy 0.007 mm). For each run, the spot dimensions are to be described in millimeters as an average of the wear spot diameter (WSD) of the three balls.

Surface analysis is to be achieved by Optical Microscope and SEM microscopy for willpower of the chemical content at selected wear spots of the specimens.

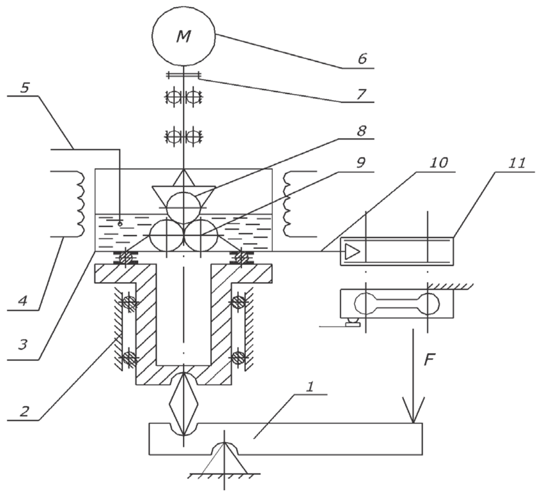


Figure 1.Schematic Diagram of Four-ball Tester with Friction Torque Measurement

Expected Results

The tribological examination of lubricant oils with nanoparticle excitements must demonstration that each mixture of Fe, Cu and Cu25C, Fe25C nanoparticles importantly decreases the coefficient of friction and wear of friction pairs. The propensities of the variable compositions of lubricant must authorize varying coefficient of friction. The nanoparticle additives in the lubricant oil should incline to form a friction and wear plummeting layer of the contacting surfaces during the commencement of heavy load. From the results obtained for the tribological testing, the comparative analysis of the unlike combinations of the nano additives can be done. This examination will lastly give out the most effective nanoparticle additive for the discount of friction and wear. Perhaps the additives having combination of nanoparticles will be more effective as associated to the additives of solitary nanoparticles.

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