International Journal of Advance Research in Science and Engineering
Vol. No.8, Issue No. 12, December 2019
www.ijarse.com
IJARSE
ISSN 2319 - 8354

A Review of Experimental Analysis of Tribological Behavior of Lubricating Oil with CuO & TiO_2 Nanoparticles

Miss. Shinde D. R.[1], Prof. N. V. Hargude[2]

[1]*PG Student, Mechanical Engineering Department, PVPIT Budhgaon, Sangli, Maharashtra (India)*

[2]*Associate Professor, Mechanical Engineering Department, PVPIT Budhgaon, Sangli, Maharashtra (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 copper oxide (CuO) and Titanium Dioxide (TiO_2) nanoparticles were added into the SAE10W40 or SAE20W40 base oil and tribological properties were examined. The concentrations of CuO and TiO_2 nanoparticles prepared in SAE10W40 OR SAE20W40 base oil are 0.2 wt. %, 0.4 wt. %, 0.6 wt. % and 0.9 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. The obtained results compared between CuO nano oil, TiO_2 nano oil and SAE10W40 or SAE20W40 base oil.

Keywords: *Lubricants, Nano particles, bearing oil, Tribotester, Titanium oxide.*

I. Introduction:

Tribology is defined as ‘the science and technology of interacting surfaces in relative motion and related subjects and practices. The subject Tribology generally deals with technology of lubrication, friction, and wears prevention of surfaces having relative motion under load. The successful design of machine elements depends upon essentially on the understanding tribological principles like wear and friction.

Nanotechnology is regarded as the most revolutionary technology of the 21st century. It can be used in many fields and ushers material science into a new era. There have been many investigations on the tribological properties of lubricants with different nanoparticles added.

Nano fluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, Nano fibers, nanotubes, nanowires, Nano rods, Nano sheet, or droplets) in base fluids. In other words, Nano fluids are Nano scale colloidal suspensions containing condensed nanomaterials.

A tribometer (tribotester) is the general name given to a machine or device used to perform tests and simulations of wear, friction and lubrication which are the subject of the study of tribology. The Pin on Disk test arrangement used to find out wear of materials during sliding.

Materials are tested in pairs under nominally non-abrasive conditions. The pin specimen is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. Wear results are reported as volume loss in cubic millimeters and linear dimensional loss for the pin and the disk separately.

II. Literature Review:

Very little work has been reported on nanoparticles used in tribology for friction and wear reduction. A brief review of some selected references on various types with application of nanoparticals is presented below.

[1] Wu e t al. [1] examined tribological properties of lubricating oils as API-SF engine oil and base oil with CuO, TiO_2 and Nano-Diamond nanoparticals used as additives. Friction and wear experiments were performance by using tribotester. CuO added in standard oil exhibit good friction-reduction and anti-wear property. The addition of CuO nanoparticals in the API-SF engine oil & the base oil decreased the friction coefficient by 18.4 and 5.8% respectively. And reduced warn depth by 16.7 and 78.8% respectively

[2] He-long et al. [2] studied wear and friction properties of surface modified Cu nanoparticles used as an additive in 50CC. The effect of temperature on tribological properties of Cu nanoparticles was investigated on a four-ball tester. The morphologies, typical element distribution and chemical states of the worn surfaces were characterized by SEM, EDS and XPS, respectively. In order to further investigate the tribological mechanism of Cu nanoparticles, a nano-indentation tester was utilized to measure the micro mechanical properties of the worn surface. The results indicate that the higher the oil temperature applied, the better the tribological properties of Cu nanoparticles are. It can be inferred that a thin copper protective film with lower elastic modulus and hardness is formed on the worn surface, which results in the good tribological performances of Cu nanoparticles, especially when the oil temperature is higher.

[3] Yu et al. [3] studied Cu nanoparticles dispersed into SN 650 oil to improve the lubricating properties of the oil. SEM, XPS and nano-indentation tester were utilized to investigate the morphology, chemical state and nano-mechanical properties of the film, respectively. Results show that the friction-reducing and anti-wear properties of SN 650 oil have been improved by adding Cu nanoparticles.

[4] Choi et al. [4] studied the friction coefficient for raw oil and nano-oil mixed with copper nanoparticles by using a disc-on-disc tribotester between mixed and full-film lubrication regime. The friction surfaces are investigated by using scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), and atomic force microscopy (AFM). The results show that the average friction coefficient for nano-oil with 25 nm and 60 nm copper nanoparticles under a load of 3000 N is decreased by 44% and 39%, respectively.

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ISSN 2319 - 8354

[5] Unlu et al. [5] studied, tribological and mechanical properties of journal bearings manufactured from metals like Copper, aluminum and tin–lead based alloys (Bronze and brass, white metals). He has used SAE 1050 steel shaft as counter abrader. Experiments were carried out in every 30 min for a total of 150 min by using radial journal bearing wear test rig. Results shows that highest friction coefficient and bearing temperature occurred in CuSn10 and CuZn30 bearings, whereas the lowest friction coefficient and bearing weight loss occurred in other ZnAl, AlCuMg2 and SnPbCuSb bearings. The highest journal weight loss occurred at CuZn30 and AlCuMg2 bearings. The highest bearing wear rate occurred in CuSn10 and CuZn30 bearings, and the lowest bearing wear rate occurred in ZnAl bearing. The mechanical properties of CuSn10, CuZn30 and AlCuMg2 bearing materials were better than those of ZnAl, and SnPbCuSb bearing materials.

[6] Cai-xiang et al. [6] enhanced the tribological properties of lubricating oil containing CeO2 and TiO2 nanoparticles with suitable surfactants such as Tween-20, Tween-60, Span-20 and Sodium sodecylbenzene sulfonate. The morphology and size of CeO2 and TiO2 nanoparticles were examined with a transmission electron microscope (TEM). The tribological properties of the oils were tested using an MRS-1J four-ball tribotester. The research results show that when the proportion by weight of CeO2 nanoparticles to TiO2 nanoparticles is 1:3, and the total weight fraction is 0.6%, the lubricating oil has optimal anti-wear and friction reducing properties. The addition of CeO2 nanoparticles reduces the required amount of TiO2 nanoparticles.

[7] Rameshkumar et al. [7] studied the Mechanical and Tribological properties of plain bearing alloys used especially in internal combustion engines. The mechanical properties namely Tensile strength and Hardness were investigated according to standard procedure. The sliding friction and wear properties of aluminum-tin alloy against high carbon high chromium steel were investigated at different normal loads as (29.43 N, 33.35 N and 36.25 N). Tests were carried in oil lubricated conditions with a sliding speed of 1 m/s. Prior to experimentation, the circulating engine oil 20w40 was heated to temperature of 800C using heater. The frictional behavior and wear property of aluminum-tin alloy were studied by means of pin-on-disk tribometer. The weight loss of the specimen was measured and wear and friction characteristics were calculated with respect to time, depth of wear track, sliding speed and bearing load. To determine the wear mechanism, the worn surfaces of the samples were examined using Scanning Electron Microscope (SEM). The optimum wear reduction was obtained at different normal loads and at same sliding speed.

[8] Thottackkad et al. [8] performed the analysis of coconut oil as a lubricant to find its tribological behaviour using a pin-on-disc tribometer. Copper oxide nanoparticles are added to the oil on weight-percentage basis, the variation of its friction-reduction and antiwear properties are analyzed. At an optimum concentration of nanoparticles, the coefficient of friction and the specific wear rate are found to be the lowest. Viscosity of oil is also seen to increase by an increase of concentration of nanoparticles. Flash-point remains constant while the fire-point increases as the nanoparticle concentration is increased. From dispersion analysis it is seen that the nano oil is not suitable enough for long stationary applications. Surface structure of the worn surfaces obtained by Atomic Force Microscopy

(AFM) and Scanning Electron Microscopy (SEM) shows that the optimum concentration of nanoparticles in this lubricant causes the roughness of the worn pin surface to reduce to a low value after sliding. Wear scar obtained in the presence of nano oil is smoother compared to that with bare coconut oil. When the level of nanoparticles increases above the optimum level, friction coefficient and wear rate are seen to increase.

[9] Ingole et al. [9] presented the effects of titanium dioxide additives on the lubricated friction and wear behavior of self-mated E52100 bearing steel using a reciprocating pin-on-disk apparatus. The friction and wear characteristics were examined at a constant applied load and rate of reciprocation. All concentrations of P25 increased the coefficient of friction, but the addition of TiO nanoparticles reduced the variability and stabilized the frictional behavior.

[10] Baskar & Sriram [10] studied the friction and wear behavior of journal bearing material using pin on disc wear tester with three different lubricating oils i.e. synthetic lubricating oil (SAE20W40), chemically modified rapeseed oil (CMRO), chemically modified rapeseed oil with Nano CuO. Wear tests were carried out at maximum load of 200 N and sliding speeds of 2 – 10 m/s. The results showed that the friction and wear behavior of the journal bearing material have changed according to the sliding conditions and lubricating oils. The journal bearing material has a lower friction coefficient for CMRO with Nano CuO than other two oils. Higher wear of journal bearing material was observed in SAE 20W40 and CMRO. Worn surfaces of the journal bearing material with three lubricating oils were examined using scanning electron microscope (SEM) and wear mechanisms were discussed.

a) Objectives:

The objectives of this dissertation work are as follows:

1) To study the Literatures related to dissertation work and collect the important information regarding the same

2) To select the test specimens for experiments made up of same materials used for machine components having surface contact with relative motion between them e.g. piston and Cylinder, journal bearing with shaft, gearing.

3) To analyze the tribological properties like coefficient of friction, wear rate by using Pin on Disk Tribometer for base oil only with above selected specimens.

4) To analyze the tribological properties like coefficient of friction, wear rate by using Pin on Disk Tribometer with nanoparticles (varying quantity) as an additives in base oil with above selected specimens.

b) Scope:

From the review of literature, the various types of nano-particles of varying size and types can be added in the lubricating oil. It is seen that only few studies have been reported on experimental analysis of tribological properties of lubricating oil with nanoparticles additives. In this dissertation work also, it is proposed to analyze the tribological properties of lubricating base oil as an additive of nanoparticles, by using one of the laboratory wear test method like Pin on Disk Tribometer in laboratory. As this test method is considered cheap, safe and quick thus serve a most useful function. Tribological properties like friction coefficient and wear rates are observed by varying the factors like normal load and sliding velocity. Wear testing of metals by using laboratory wear test methods in lubricants/fluids helps to avoid expensive damage to high value engines parts like shafts, bearings, gears, generators, turbines and other important equipment parts. Early detection of wear in materials with use of lubricants/fluids improves machinery reliability.

III. Methodology:

Phase I-Literature survey.

- In this phase literature survey of Lubricating base oil, various types of nanoparticles their properties, journal bearing and crankshaft materials will be carried out by referring journal like SAE journal, International journal of Tribology, Journal of Wear, Journal of Marine Science Application, Journal of Science Technology and Management, and Journal of Physics.

Phase II – Selection and Preparation of base oil and nanoparticles.

- Suitable base oil & nanoparticles will be selected considering the materials of test specimens. Details of base oil and Nano particles are as below.

Base Oil: SAE10W40 or SAE20W40

Nanoparticles	**Properties**
CuO (Copper Oxide)	Size: <100 nm Shape : nearly spherical Purity 99.95% trace metal basis
TiO_2 (Titanium Dioxide)	Size: <100 nm Shape : nearly spherical Purity 99.5% trace metal basis

- Preparation of samples of selected lubricating base oil with varying percentage of nanoparticles for testing.

Phase III – Fabrication of test specimens.

- Fabrication of test specimens which is made up of same material as that of the Journal bearing and crankshaft.

Phase IV – Testing of specimens.

- Tribological properties of testing specimens will be carried out by using pin-on-disc tribometer.
- Firstly, base oil without nanoparticles as an additive will be used for testing and readings for tribological properties will be noted. Then Base oil with nanoparticles as an additive will be used for testing and readings will be noted for different proportions of nanoparticles.
- By using the pin-on-disc tribometer the tribological properties such as coefficient of friction, friction force and wear rate will be evaluated firstly using base oil and secondly using base oil with nanoparticles as an additive.

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ISSN 2319 - 8354

- Parameters like proportion of nanoparticles (two types) and load applied will be varied, by keeping the speed of disc and time for each test reading constant.

IV. FLOW CHART:

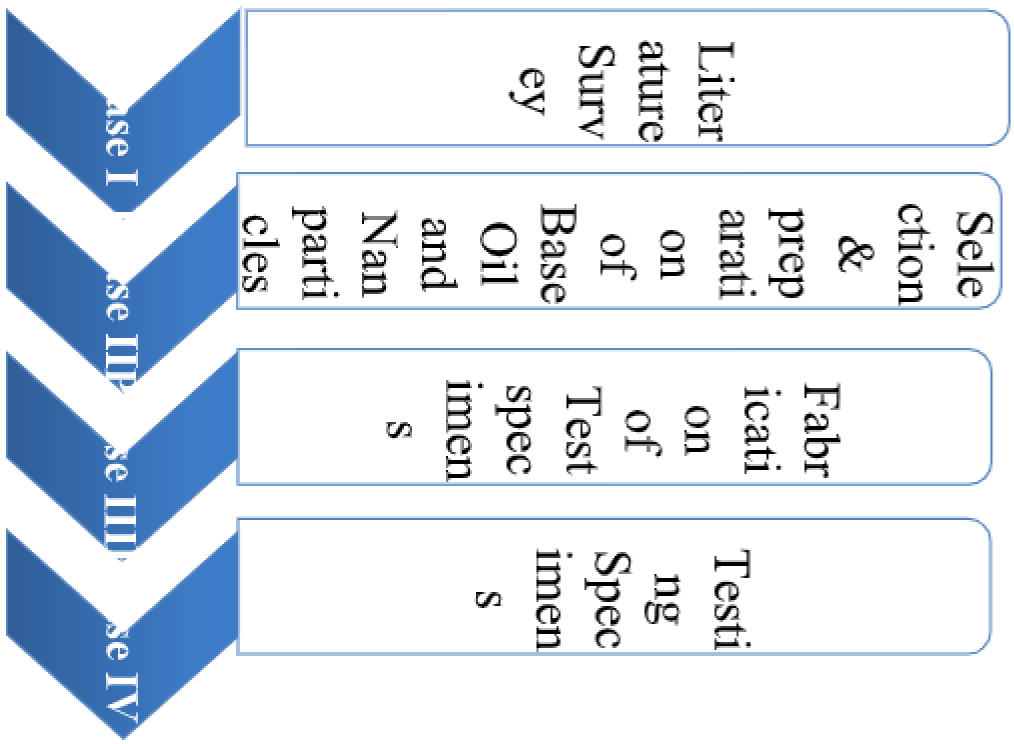

Fig. No. 1: Flow Chart

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ISSN 2319 - 8354

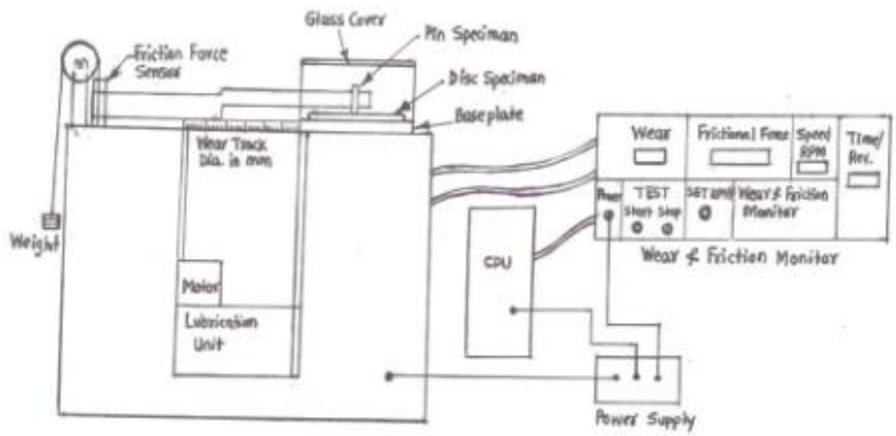

Fig. No.2 Block Diagram of Wear & Friction Monitor TR20LE

V.CONCLUDING REMARK:

Majority of literatures studies show use of nanoparticles used in different base oils. It is found that the nano-oil mixed with copper nanoparticles has a lower friction coefficient and less wear on the friction surface, indicating that copper nanoparticles improve the lubrication properties of raw oil. Also it is observed that nanoparticles have shown good friction and wear reduction characteristics even at concentrations below 2 wt%. However, in some cases, nanoparticles exhibit a deleterious effect, increasing either friction or wear.

From above I found that the scope to use nanoparticles like CuO and TiO2 with specific weight percentage (0.2%, 0.4%, 0.6%, 0.9%) of Nanoparticles in base oil (SAE 20W40) as additives to analyzed the improvement of lubricants properties.

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