International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET

Chemico-Physical and Mechanico-Dynamical Behavior of Nanofluids

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Article Info
Volume 9, Issue 5
Page Number : 301-305

Publication Issue :
September-October-2022

Article History
Accepted : 01 Oct 2022
Published: 22 Oct 2022

ABSTRACT

The lubricating performances of lubricants can be enhanced by homogeneously dispersing nanoparticles as an additive. The factors influencing the chemico-physical properties of nanolubricants are particle concentration, particle size, particle shape, operating temperature, sonication time and base fluid properties in which the particle concentration plays a significant role in the lubricating performances of nanolubricants. The lubricating performance of any lubricants is estimated by mechanico-dynamical test. It is found that the addition of nanoparticles into conventional lubricants is a promising approach to enhance its lubricating performances by reducing the friction and wear of interacting surfaces

Keywords : Lubricants, Chemico-Physical Properties, Nanolubricants, Mechanico-Dynamical Test, Friction and Wear.

I. INTRODUCTION

The study of changes taking place on or between the interacting surfaces in relative motion are termed as tribological behavior which includes the study of friction, wear of interacting element with or without the application of active medium or interfacing element like lubricant. Liquid lubricants are manufactured by using refined natural crude oil known as mineral base lubricant oil as a main ingredient. These mineral oils are having hydrocarbon distillates which are obtained during the refining of natural crude mineral oil with or without having Extreme Pressure (EP) and AW additives. In general, lubricant oil is developed from synthetic hydrocarbon blends or mineral base oils. In order to increase the lubricating performances, nanoparticles are homogeneously dispersed into the base lubricant oils as an additive which leads to notable improvements in its lubricating performances such as anti-oxidation, thermal properties, physical properties, load wear index and load carrying capacity. Nanotechnology provides an opportunity to improve the lubricating performances of base lubricant oils via the homogeneous dispersion of nanoparticles. The addition of nanoparticles into conventional lubricants is a promising approach to enhance its lubricating performances by reducing the friction and wear of interacting surfaces. Estimating the on percentage of enhancement of chemico-physical and lubricity properties of conventional liquid lubricant oils with notable thermo-stability due to the percentage of addition of nanoparticles.

Nanofluid is prepared as a colloidal suspension by homogeneously dispersing nano sized metallic or non-metallic particles into lubricant oil by using ultrasonication process. The lubricating performance of any liquid lubricants can be estimated by their chemico-physical properties and mechanico-dynamical tests. Chemico-physical properties concentrate on certain vital lubricant properties, whereas mechanico-dynamical tests try to simulate the effects of speed, media, load and temperature on the friction and wear behavior of mechanical tribosystem. Chemical physics is a branch of physics used to study the chemical processes from the point of view of physics and characterizing the lubricant's chemical and physical properties like flash point, fire point, pour point, density, thermal conductivity, kinematic viscosity, oxidation resistance, etc. Generally, liquid lubricant oil testing is focused on mechanic dynamical tests which subject the lubricant oil and the mating material to load, temperature, relative movement and media. Further, an optimization of operating parameters, testing parameters, nano-lubricant formulation and manufacturing process on the friction and wear behavior can be evaluated by using this test.

Further, the mechanico-dynamical tests simulate the effects of speed, load, temperature and interfacing element on the friction and wear behavior of lubricant oil used in the tribosystem. The sliding speed, applied normal load, environment, operating temperature and the chemico-physical properties of the lubricants are the various parameters that affect the friction and wear behavior of mating gear teeth surfaces in relative motion during mechanico-dynamical lubricant oil tests. In this study chemico-physical and mechanico-dynamical behavior various nanofluids are discussed in detail.

II. Nanofluids

Nanofluids, a major field of nanotechnology, engineered as the colloidal dispersion of nanoparticles in a base fluid which are typically homogeneously dispersed with nano sized metals, oxides, carbides etc.

2.1 Preparation

In general, homogeneous nanofluids are prepared by one-step methods like chemical vapour condensation, direct evaporation, chemical precipitation, etc. and two-step methods like gas condensation and dispersions, mechanical ball milling and dispersion, etc. Two-step method is the most economic method of producing nanofluids in large scale, because nanoparticle synthesis methods have already been scaled up to production levels. In two-step method, nanoparticles are prepared in the form of dry powders by mechanical methods like ball milling or chemical methods like vapour condensation, precipitation method or sol-gel method in the first step. In the next step, nanofluids are produced by homogeneously dispersing dry nanoparticles produced from the first step by using ultrasonication method. Generally, nanoparticle possesses a high surface to volume ratio and the homogeneously dispersed nanoparticles in nanofluids act as a base fluid molecule. Further, the dispersed nanoparticles tend to form agglomerate to larger units by adhesion. The dispersion stability of nanofluids is depending on the sedimentation velocity of nanoparticles in the liquid medium. The sedimentation velocity depends on the buoyancy force, gravitational force, and friction force which are acting on the dispersed nanoparticles in the fluid medium.

2.2 Thermo-stability of Nanofluids

Thermo-stability is the ability of a nanofluid to resist breaking down under heat stress and a stable nanofluid should have resistance to decomposition at high temperatures. In practice, TGA, an analytical technique is used to estimate the thermo-stability by monitoring the weight loss that occurs during the heating of a sample of predetermined weight at controlled environmental condition.

III. Chemico-physical Properties of Lubricants

The factors influencing the chemico-physical properties of nanolubricants are particle concentration, particle size, particle shape, operating temperature, sonication time and base fluid properties in which the particle concentration plays a significant role in the lubricating performances of nanolubricants.

3.1 Density of nanofluids

Density of nanofluid is proportional to the dispersed nanoparticle concentration in the base fluid. Since the density of solids is higher than that of liquids, the density of nanofluid enhances due to the addition of nanoparticle concentration. The density of nanofluids is depending on the nanoparticle concentration and is independent to nanoparticle size. Further, density plays a significant role in the thermo-physical properties nanofluids. Chandrasekar et al. (2012) reported that addition of a small concentration of nanoparticles into a base fluid can increase its density. Ho et al. (2010) found approximately 10% density enhancement for Al_2O_3 (33 nm)-water nanofluid at 4.0% of volume concentration. Heyhat et al. (2012) reported maximum of 3% density enhancement for Al_2O_3 (40 nm)-water nanofluid at 2.0% of volume concentration.

3.2 Viscosity of nanofluids

The primary property of any lubricant oil is its viscosity which is strongly affected by the dispersed nanoparticle concentration and operating temperature. The increased operating temperature of lubricant oil reduces its intermolecular strength which leads to decrease in kinematic viscosity (Ghaednia et al. 2015). Wang et al. (1999) prepared and experimentally investigated the viscous behavior of Al_2O_3-water and Al_2O_3-EG nanofluids and found maximum viscosity improvement of about 86% at 6.0% volume concentration of Al_2O_3-water nanofluid and viscosity improvement of about 39% at 3.5% volume concentration of Al_2O_3-EG nanofluid. Xuan et al. (2000) proved that the nano-lubricant is stable when the nanoparticle concentration is less than one percentage. Anoop et al. (2009) discussed the temperature dependent viscosity behaviors of CuO-EG, Al_2O_3-EG and Al_2O_3-water nanofluids at a volume concentrations of 0.5 vol%, 1 vol%, 2 vol%, 4 vol%, and 6 vol%. They reported that the viscosity decreases with rise in temperature and improves with percentage of increase of nanoparticle concentration.

IV. Mechanico-Dynamical Test on Lubricants

Four-ball test is a standard mechanico-dynamical test used to determine the AW and EP properties of liquid lubricant oils, nanofluids and nano-lubricants (vadapalli et al. 2016). Many attempts have been made to explore the EP and AW properties of lubricant oils homogeneously dispersed with different kind of nanomaterials. In general, the lubricating performance of any lubricant oil is represented by its load carrying capacity and load wear index using Four-ball test.

4.1 Load Carrying Capacity of Lubricants

The EP properties of liquid gear lubricants are estimated by means of load carrying capacity which depends on the concentration of dispersed nanoparticles which is tested using Four-ball EP test. It has been recognized that the friction co-efficient decreases with decreasing viscosity of lubricant oil during lubrication. In general, as the viscosity of the lubricant decreases, the wear rate increases due to a decrease of load-carrying capacity of the lubricant (Lee et al. 2009). Binu et al. (2014) experimentally examined the influence of TiO_2 nanoparticle on the load carrying capacity of lubricating oil. They reported that the presence of TiO_2 nanoparticles, even at low concentrations of about 0.01 vol% is found to improve the load carrying capacity by 40% in comparison to lubricant without nanoparticle dispersion.

4.2 Load wear index of lubricants

The load wear index is a measure of the ability of any liquid lubricant to prevent friction and wear at applied loads which is estimated from the arithmetic mean value of wear scar diameter of stationary lower balls used in Four-ball test. Various metallic oxides have been used as lubricant oil additives and their friction and wear reduction mechanisms are tribofilm formation, rolling effect or sintering effect. Husnawan et al. (2007) examined the anti-wear behavior of SN500 base lubricant oil by dispersing 5%, 3% and 1% of commercial amine phosphate additives and their results show that nano additives enhance the anti-wear behavior of lubricating oil. Wu & Tusi (2007) investigated the tribological behavior of two lubricating oils namely API-SF engine oil and base lubricant oil by dispersing CuO nanoparticles as lubricant additives. The dispersion of CuO nanoparticles in API-SF engine oil and base lubricant oil decreased the coefficient of friction by 18.4 and 5.8%, respectively also which decreased the wear scar depth by 16.7 and 78.8%, respectively as compared to the lubricating oils without nano additives.

Zhang et al. (2013) dispersed advanced silicate additive into lubricant oil and examined their tribological properties. Their results showed that addition of 0.1 wt% concentration of silicate additive into lubricant oil reduced the co-efficient of friction by 40% due to its self-repairing nature on the rubbing interface. Padgurskas et al. (2013) investigated the lubricating performances of mineral oil containing Fe, Cu and Co nanoparticles. The tribological results show that the dispersed nanoparticles significantly reduced the co-efficient of friction and wear up to 1.5 times of mineral oil without additives due to the formation of an ultra-thin tribo-film and rolling action of dispersed nanoparticles between the relatively sliding surfaces.

V. Conclusion

In this study, an attempt is made to improve the lubricating performance of commercially lubricant by homogeneously dispersing different concentration of thermally stable garnet nanoparticles. The chemico-physical properties such as density, kinematic viscosity, relative viscosity and lubricity properties of nanofluids are discussed through coefficient of friction, load wear index, and wear ring width of tribo-elements used in Four-ball wear test. It is found that the addition of nanoparticles into conventional lubricants is a promising approach to enhance its lubricating performances by reducing the friction and wear of interacting surfaces.

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Cite this article as :

R. A. Arul Raja, J. Sunil, "Chemico-Physical and Mechanico-Dynamical Behavior of Nanofluids", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 9 Issue 5, pp. 301-305, September-October 2022.

Journal URL : https://ijsrset.com/IJSRSET229631