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A REVIEW ON NANOFLUIDS AS GEAR OIL AND TRANSMISSION FLUID IN TRANSMISSION SYSTEMS

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ABSTRACT

Transmission system is used to transmit power by using gear-trains, which requires lubrication, as metal wear occurs between high speeds rotational gears which also cause temperature rise of the fluids. Gear oil is generally intended for use in manual gearboxes and transmission fluid is for automatic transmission. But conventional fluids face problems such as rapid settling of particles, have inherently poor thermal conductivity, abrasion and clogging of micro-channels, which makes them inadequate for use in transmission. Nano fluids have a great potential to replace the conventional working fluids in different thermal management and heat transfer applications. In this paper, method for making nanofluids as gear oil and transmission fluid is described, which improves the power losses in transmission. Nanomaterial's with graphitic structure, such as carbon nanotubes are used to improve the viscosity index, shear stability, thermal properties and friction properties of gear oil. These nanoparticles are dispersed into a base fluid to obtain fluid viscosity capable of supporting loads typical of gear systems. Thus this paper presents an overview of the recent developments in the study of nanofluids as gear oil , preparation methods, benefits and its utilization in automotive sectors.

Keywords: Carbon Nano-plates, Gear oil, Nano fluids, Transmission fluids, Transmission systems

I. INTRODUCTION

Nanotechnology is the science that deals with matter at the scale of 1billionth of a meter (10^{-9}m). In today's world nanotechnology is paving its way into nearly every sector and automobile sector is exploring nanotech as well, to build cars that are shiner, safer, cost effective and more energy efficient. Nanotechnology has great potentials to improve automotive by increasing the efficiency, lowering the weight and reducing the complexity of thermal management systems. The applications of nanotechnology in auto sector are innumerable and use of nanofluids is one of them.

Transmission system is a very important part in modern vehicles, which provides controlled application of the power. Often the term transmission refers simply to the gearbox that uses gears and gear trains to provide speed and torque conversions from a rotating power source to another device. As gearbox consists of rotating pairs of gear, continuous breakdown of gearbox occurs at high rotational speed which increases temperature of gearbox. Due to increase in temperature, the viscosity of the oil which is used as lubricant decreases drastically. Thus it increases the power losses in gear box due to friction between the gears. The efficiency of transmission system influences both, emissions and fuel consumption of any automotive vehicle. Therefore if transmission efficiency could be improved, power losses can be minimized and utilization of fuel can be increased to maximum extent and also adverse effect on environment can be decreased. To overcome this problem a suitable material should be selected, which would not let the viscosity of oil to decrease, when temperature rises due to high rotational speed. Researches to produce better oils with longer life are developed in recent years. It has been shown that nanoparticles could improve lubricant behavior of conventional oils. Particles shape, size and concentration are influential parameters affecting wear and friction reduction. Therefore solution to this problem is provided by the use of nanofluids as gear oil, which uses nanomaterial's in oils that enhances thermal conductivity as well as viscosity index.

Nanoscale colloidal suspensions loaded with condensed nanomaterial's are named Nano-fluids. Nanofluids show many unique features and improved properties which include thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity, heat transfer coefficient, magnetic and versatility to vary these properties. These improved properties pave the way in the field of research and innovative applications. The field of research is still in its initial phase and hence it faces some challenges which are also focused in this paper for implementing these fluids as working fluids in a number of applications. Though nanofluids provide an alternative solution to be used as a working fluid in automobiles, the stability of nanofluids and its production is one of the most important concerns to be looked upon. However, there is still a lot of work and research to be done before.

II. LITERATURE REVIEW

Title 1: Effect of aggregation on the viscosity of copper oxide–gear oil nanofluids

Journal: Science Direct- International Journal of Thermal Sciences

Author: Madushree Kole, T.K.Dey

Results on viscosity of the stable nanofluids, prepared by dispersing 40 nm diameter spherical CuO nanoparticles in gear oil are presented. Viscosity of the studied nanofluids displays strong dependence both on CuO loading in the base fluid, as well as, on temperature between 10 and 80 °C. Viscosity of the nanofluids is enhanced by 3 times of the base fluid with CuO volume fraction of 0.025, while it decreases significantly with the rise of temperature.

Title 2: Heat transfer enhancement of nanofluids in rotary blade coupling of four-wheel-drive vehicles

Journal: Acta Mechanica

Author: S.-C. Tzeng, C.-W. Lin, K. D. Huang

In the nanofluid research applied to the cooling of automatic transmissions, Tzeng et al. dispersed CuO and Al2O3 nanoparticles into engine transmission oil. The experimental setup was the transmission of a four-wheel drive vehicle. The transmission had an advanced rotary blade coupling, where high local temperatures occurred at high rotating speeds. Temperature measurements were taken on the exterior of the rotary-blade-coupling transmission at four engine operating speeds (range from 400 to 1600 rpm),and the optimum composition of nanofluids with regard to heat transfer performance was studied. The results indicated that CuO nanofluids resulted in the lowest transmission temperatures both at high and low rotating speeds. Therefore, the use of nanofluid in the transmission has a clear advantage from the thermal performance viewpoint.

Title 3: Enhanced themophysical properties of copper nanoparticles dispersed in gear oil.

Journal: Elsevier-Applied Thermal Engineering

Author: Madushree Kole, T.K.Dey

Stable and well dispersed Cu gear oil (IBP Haulice68) Nanofluids having Cu nanoparticles Volume concentration between conductivity and viscosity measurements are performed both as function of Nanoparticle concentration and temperature between 10 and 80◦C. Thermal conductivity enhancement of 24% is observed with 2vol% of Cu nanoparticle loading at room temperature. The formation of interfacial layer at the nanoparticle liquid boundary and the ballistic transport of phonons across the percolating aggregates are believed to be responsible for the observed thermal conductivity enhancement. Viscosity of Cu (2 vol %) gear oil nanofluids shows 71% enhancement at 30◦C

III. NANOFLUIDS

Nanofluids are stable colloidal suspensions of nanomaterial's (Nanoparticles, Nano-rods, Nanotubes, Nano-wires, Nano-fibers, and Nano-sheets, other Nano-composites, or even Nano-droplets and Nano-bubbles) in common, base fluids. This system consists of two phases: liquid phase (base fluid) and solid phase (nanoparticles).

Nanostructured materials can be carbon based compounds, such as carbon nanotube, graphane, graphane oxide, graphite, etc. Base liquids are selected from water, ethylene glycol (EG), mixture of water and EG (W/EG), diethylene glycol (DEG), polyethylene glycol, engine oil, vegetable oil, paraffin, coconut oil, gear oil, kerosene, pump oil, etc. Nanoparticles exhibit a chemical, electrical, optical and magnetic properties compared to its bulk counterparts. This is achieved mainly due to the large fraction of surface atoms, surface energy, reduced imperfections and spatial confinement.

IV. NEED

Gear oils have specific requirements to provide protective elasto-hydrodynamic and boundary films over a broad temperature and torque range, in equipment such as rear axles and gear boxes. More recently there has been a focus on providing gear oils that also contribute to fuel efficiency by providing reduced traction and improved boundary lubrication. Heat dissipation has also become increasingly important. It is known that gear oils with high viscosity index will favor improved fuel economy and whereas lower gearbox temperatures favor improved durability. But viscosity of petroleum products generally varies greatly with temperature and for lubricating oils for automobiles, the temperature dependence of the viscosity is desired. Mineral oils, which are very effective lubricants at low temperatures become less effective lubricants at high temperatures. At high temperatures, their film-forming ability (in the hydrodynamic lubrication regime) diminishes because of a drop in viscosity. Viscosity modifiers are typically added to a low-viscosity oil to improve its high-temperature lubricating characteristics. But there is always some undesired viscosity increase at low temperatures caused by these viscosity modifiers as they function as thickeners.

When the surrounding temperature lowers, a wax component in the base oil is crystallized and tends to coagulate, which inhibits free flow within the mixture. A pour point depressant (PPD) is usually added to the lubricating oil to hinder the coagulation of these wax components. The viscosity at a low shear rate is most affected by the compatibility between the pour point depressant and Wax components.

Another purpose of a lubricant, including gear oil, is to function as a coolant, particularly under high torque conditions. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high performance cooling applications. Also, conventional oil poses a major problem of rapid settling of particles, abrasion, clogging of micro-channels.

V. BENEFITS OF NANOFLUIDS IN AUTOMOBILE

Adding Nano-sized materials like Nano-fibers, nanotubes, nanowires, Nano-rods and Nano-sheets to fluids results in producing new generation of fluids having superior properties in comparison with conventional fluids. Using nanoparticles, the thermoplastic properties such as thermal diffusivity, thermal conductivity, viscosity and convective heat transfer coefficient of the fluid will be significantly enhanced. Since nanoparticles are usually not polymer based, they do not cause compatibility issues with other polymeric additives/components in a lubricating fluid, and also do not contribute to wax formation by them.

VI. EXPERIMENTAL METHODOLOGY

The present paper presents nanofluid application as gear oils in transmission. This paper provides a method for making a composition for the gear oils that has improved permanent shear stability and viscosity index, improved performance in boundary and elasto-hydrodynamic (EHD) lubrication and enhanced thermal conductivity, up to 80% greater than their conventional analogues. In the present paper the fluid medium is targeted in its viscosity, friction, and antioxidant characteristics to perform in modern gearing systems.

Carbon Nano-plates are prepared with a graphitic structure or a roughly disc shape type of nanoparticles. In this method bulk graphite or larger graphite particles or fibers are milled to form a thick pasty liquid of particles, named as carbon Nano-plates, with mean size less than 500 nanometers in diameter. The pasty liquid is then used as concentrate to prepare lubricants of various viscosity grades, and can be easily diluted to make a suitable lubricant to function as gear oil when combined with the appropriate base oil and additives. In preferred form a dispersing agent or surfactant is used for the purpose of stabilizing the nanomaterial.

Many compositions of nanoparticles could be used to achieve the viscosity index and shear stability improvement; however, many will be excluded due to other unfavorable characteristics. One preferred nanomaterial is high thermal conductivity graphite, exceeding 80 W/m-K in thermal conductivity. Bulk graphite or larger particle graphite is ground, milled, or naturally prepared by a process to create a new type of nanoparticles for carbon Nano-plates, with mean particle size most preferably less than 50 nm. The carbon Nano-plates or other graphitic nanoparticles are dispersed in the fluid by one or more of various methods, including ultra sonication, milling, and chemical dispersion. Another preferred nanomaterial is aluminum oxide

Nano-particles. These particles are surface-treated to improve dispersability in fluid. Typical particle size is 25 nm or less. The Nano-fluid thus produce will have a viscosity index higher than the conventional fluid of the same type. Furthermore fluid can have any other chemical agents or other type particles added to it as well, to impart other desired properties.eg friction reducing agents, antiwear or anticorrosion agents, detergents, antioxidants, dispersants, defoamers, viscosity index improvers, pour point depressants, demulsifiers, or thermal property booster. Dispersing agent for nanofluids helps to remove wear debris and avoids lubricant degradation within the moving parts of gear systems.

An important aspect of this paper is that the final lubricant should be prepared to give an acceptable lubricant film thickness at the maximum shear rate, load and temperature of use in the target application. The resulting fluids have unique properties due to the improved friction properties (reduced traction coefficients and reduced boundary friction), high thermal conductivity, and high viscosity index obtained from the nature of suspended graphite nanoparticles, as well as their small size.

VII. WORKING

The preferred method is to disperse the graphite by ball-milling in a viscous fluid of certain additives (detergents, dispersants, etc.) and then diluting the obtained concentrate with base oil and other additives as needed to attain the final viscosity and performance characteristics. If the material is in bulk state, it must first be size reduced into powders (With average size less than 100 microns). Then a 5% to 20% by weight of powder form of the material, and more preferably 10% by weight of the powders, in base oil dispersion is milled into a paste state. Usually this step takes about 3 to 4 hours. Then add an appropriate amount of dispersing agent(s) into the mill, usually 1 to 2 times of the Weight of carbon already in the mill. With the addition of dispersing agent(s) the paste changes from paste into liquid almost instantly.

The pastes can be made from larger size commercially available graphite, e.g. Poco FOAM and graphite powders. Poco Foam is a high thermal conductivity foamed graphite, thermal conductivity typically in the range 100 to 150 W/m-K. Still another preferred nanomaterial is the high thermal conductivity bulk graphite. Either of these types of graphite is prepared by pulverizing to a new powder, dispersing chemically and physically in a fluid of choice, and then ball milled or otherwise size-reduced until a particle size of less than 500 nm diameter mean size is attained.

High impact mixing is necessary to achieve a homogeneous dispersion. A ball mill is one example of a high impact mixer. An Eiger MINI MILLTM (Model: M250-VSE-EXP) is used as the high impact ball-mill. It utilizes high Wear resistant Zirconia beads as the grinding media and circulates the dispersion constantly during milling. To achieve the best milling effect and therefore the best viscosity index improvement, the proper milling procedure has been developed.

VIII. METHODOLGY

The instant method of forming a stable dispersion of Nano-materials in a solution consists of three steps.

First select the appropriate concentrate of dispersant or mixture of dispersing and other additives for the nanomaterial and the oily medium, and dissolve the dispersant into the liquid medium to form a concentrate solution (keeping in mind the final additive concentrations desired following dilution).

Secondly add a high concentration of the Nano-materials, e.g., graphite Nano-particles or carbon nanotubes, into the dispersant-containing solution.

Finally initiate strong agitation: ball milling, or ultrasonicating, or any combination of physical methods named; following an agitation time of several hours, the resulting paste will be extremely stable and easily dilutable into more base oils and additives to give the final desired concentrations of additives and the desired final viscosity.

8.1 TRANSMISSION FLUIDS

The following example of the process is illustrated with lubricant formulations of transmission fluids. Graphite particles are obtained by pulverizing big graphite chunks, and subsequently passing the pulverized graphite through a 75 um mesh filter, then 30 grams of the filtered graphite particles and 270 grams of BP Petrochemical DURASYN 162TM (a commercially available 2 centistokes polyalphaolefin, abbreviated as 2 cSt PAO) are added into the Eiger Mini MILLTM (Model: M250-VSE-EXP). The milling speed is gradually increased to 4000 rpm. After about 4 hours the above mixture turns into thick paste. Sixty (60) grams of the paste is removed and labeled “Paste A”.

Forty-eight (48) grams of a dispersant and inhibitor package (DI package), LUBRIZOL 9677MXTM, is subsequently added into the mill and the remaining paste becomes fluid enough that successful recirculation is restored. The milling of the paste is stopped after an additional 4 hours and the paste is labeled “Paste B”.

Paste C is obtained by milling a mixture of 30 grams of graphite with diameter less than 75 um, 60grams of LUBRIZOL 9677MXTM, and 270 grams of DURASYN 162TM at 4000 rpm for 8 hours. Note that the dispersing agent, LUBRIZOL 9677MXTM, is added into the mill at the beginning of the milling process.

Three transmission fluids, A, B and C, are subsequently formulated and their final concentrations are the same: 2% graphite, 4% LUBRIZOL 9677MXTM, 18% BP Petrochemical DURASYN l62TM, 76% BP Petrochemical DURASYN 166TM (a commercially available 6 centistokes polyalphaolefin, abbreviated as 6 cSt PAO) (all percentages by Weight).

Table 1-RESULT:

Concentrate	Paste A	Paste B	Paste C
Kinematic viscosity at 100° C [cSt]	7.55	19.68	10.83
Kinematic viscosity at 40° C [cSt]	28.44	29.32	28.77
Viscosity Index	254	634	395

8.2 GEAR OIL

The same principles and methods can be followed in preparing gear oils, except that the ATE additive package is replaced with a fully formulated gear oil additive package, or combinations of individual gear oil additives.

Graphite is obtained as powders from UCAR, and milled in 4 cSt PAO/additive package to obtain a concentrate before the other ingredients are added to make the final formulation.

Comparison of Typical Formulations of Synthetic Gear Oils Formulated With and Without Carbon Nano-Plates:

Table 2-COMPOSITION:

Component	Conventional Synthetic Gear Oil[%]	Gear Oil containing Nano-plates[%]
YUBASE 100 N TM	47.70	0.00
DURASYN 164 TM	15.00	9.00
DURASYN 166 TM	0.00	67.00
LUBRIZOL Gear Oil	10.00	10.00
Additive Package		
LUBRIZOL 3174 TM	26.30	12.00
VISCOPLEX 0-112 TM	1.00	1.00
Graphite Nano-plate	0.00	1.00

Table 3-RESULTS:

Properties	Conventional Synthetic Gear Oil	Gear Oil containing Nano-plates
Thermal Conductivity[W/m-K]	0.1399	0.1712
Viscosity at 100° C.	14.21	14.79
Viscosity at 40° C.	98.63	65.06
Viscosity Index	148	240
Kinematic Viscosity before shear[cSt]	14.90	18.14
Kinematic Viscosity after shear [cSt]	13.96	17.47
Percent Viscosity Loss by shear	6.31	3.69

IX. CONCLUSION

With suitable viscosity for a desired application, nanofluids can be used as an automotive fluid such as gear oil or transmission fluid in transmission system. The viscosity losses of the nanofluid lubricant at high operating temperature, typically 100 ◦C and the 40 ◦C. will be less than matched with conventional fluid, thus the fluid viscometry of nanofluids will be more stable over the same temperature range than the viscometry of a conventional lubricant. This means that the viscosity index of the particle containing lubricant mentioned in this paper will be higher than that of the conventional fluid. As the particle concentration increases and the particle size decreases, the viscosity index is improved by the Nano-materials. The smaller particles also give the best thermal conductivity increase, but may also contribute to temporary viscosity loss in shear yields. Nanofluid obtained showed a heat transfer improvement of 20% at 100◦C and an improvement of 60% or at 40◦C when compared to a conventional fluid. Although temporary (reversible) shear loss is a good way to obtain fuel efficiency, it is preferred to balance the size and shape distribution of the particles to maintain viscosity under conditions. Full fluid films formed protect the gear durability. Hence Nanofluids can be used and produced on a mass scale in automotive industries so as to function as gear oil.

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