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A REVIEW OF NANO ADDITIVES FOR PERFORMANCE ENHANCEMENT OF LUBRICANT

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ABSTRACT

Additives enhance and improve the physical and chemical properties of base oil to effectively reduce the wear and friction of moving parts. Nanomaterials have emerged as environment friendly additives to enhance the tribological properties of lubricating oils like Engine oil, industrial oils, grease etc. Because of their properties like high surface energy, small size, thermal stability these are commonly used as anti-wear, anti-friction additives and extreme pressure additive. Thus this article covers the properties of various nanoparticles that are used in the market, their advantages and disadvantages along with the various lubricating oils that are currently used in the market. Metal oxides are mostly used as eco-friendly and as a sustainable additive in oil. Ionic liquid and Cellulose derived additives have shown good tribological properties. Halogen free ionic liquids have huge potential as bio lubricant additives.

Keywords: Lubricants, Additives, Nanoparticles, Cellulose Nano Crystal.

I. INTRODUCTION

Lubrication is important for any process having relative motion between two or more parts. Lubrication is done for reducing friction and wear in systems. Friction and wear are major reasons for failures in machineries; these are also reasons for reduced life & performance of machines. Energy loss is an important tribological issue that arises because of friction. Holmberg et. al. [1] conducted a study which concluded that upto one third energy from fuel in engines and other moving parts such as brakes, tires and transmission is wasted due to frictional loss. They also concluded that buses and trucks require 33% more fuel to overcome frictional loss in engines.

In order to overcome this problem lubrication is done in machineries. Lubricants are widely used in manufacturing units and industry to protect products and tools from wear and to maintain their surface quality. Also lubricants optimize the coefficient of friction and optimize the heat generation in mechanical systems. As a result of this, enhancing the lubricant properties are of great importance for protecting the machinery from highly probable damages and decreasing energy consumption [2]. But base lubricants, especially bio-lubricants lack the properties required to sustain extreme pressure and heat generated in machineries so small amounts of lubricant additives in percent weight or volume are added in lubricant oils to enhance their lubricating properties. A new type of additive called nano additives are introduced in industry. These additives possess great properties like suitable size to enter contact asperities, variety of particle chemistry, thermal stability, reaction rate with surface without an induction period which are important factors for conventional lubricant additives[3]. Various types of nano-additives like metal, metal oxides, metal sulphides, carbon materials, organic materials are used nowadays.

Nano additives have different size and shape depending upon the manufacturing/ production process of nano additives. Fatty acids present in vegetable and animal origins were once used as the main source of lubricants before the introduction of mineral and synthetic oil. As world agencies have introduced tough emission standards, eco-friendly lubricants have become essential to meet these standards.

II. ADDITIVES

Natural additives

Cellulose Nano Crystal is prepare by hydrolysis of natural cellulose fibers (example: Cotton, tunicate, wood, or other biomass). Cellulose is a biopolymer used in lubricant as a thicken agent. Cellulose is a renewable, biocompatible, bio-degradable and non-toxic alternative to other synthetic additives [4]. Surface modified CNC (mCNC) shows a good dispersive stability and increase of viscosity compared to pristine CNC. Surface

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modification of CNC by using stearoyl chains improves the hydrophobicity of cellulose nanocrystals and increases their compatibility with the base oil. When surface modified cellulose nanocrystals (mCNC) concentration was relatively high up to 2 wt%, the bond between the stearoyl chains on modified CNC surface and the base lubricant chains works like a physical crosslinking forming a colloidal solution. mCNC also reduces friction and wear compared to pristine CNC and pure base oil [5]. Cellulose nanocrystals occur in rod, sphere and networkstructured prepared using acid hydrolysis and freeze-drying of cotton cellulose. This structure explains a variety of lubrication mechanisms of CNC which includes rolling effect, mending effect and polishing effect [4]. The cellulose nanocrystals lost almost 40% of its mass between 150–300 ◦C and 70% mass loss between 300 and 600 ◦C. This show CNC should be used under 150 ◦C due to thermal decomposition [5].

Cystine is an amino acid having two cysteine molecules, these cysteine molecules are linked together by SS bond [6]. Cystine Schiff base additive is more stable than cysteine schiff base ester as presence of ester group make cystine schiff Base Ester thermally unstable. But esterification of cystine makes it soluble in the base oil. Cystine Schiff base additive can be used up to 150 degree celsius as it's thermal decomposition starts after the 150 degree celsius. Cystine schiff base have imine bonds which can increase metal chelating abilities. Metal chelating abilities will greatly improve antioxidant properties of cystine schiff base. Cystine Schiff base ester shows good anti corrosion, antiwear properties & reduced coefficient of friction at 3000 ppm concentration. [7]

METAL Nano Additives

Metal nanoparticles are used widely for many applications such as magnetics, semiconductors, catalysts etc. Nano metals with small size, low melting point and low shear stress are used for their friction reduction, anti wear and self-repairing abilities. Nano particles like Cu, Fe, Co, are used as lubricant additives, out of these additives Cu possess excellent properties being environment friendly. Cu nano additives possess most effective self-repairing and wear resistance properties. Igor et.al.[8] studied the tribological properties of nano-lubricants based upon Fe, Cu, and Co nano particles which were added individually and in pairs into mineral oil. Cu-containing nano-lubricants significantly reduced friction and wear compared to other nano particles when added individually. In particular, the presence of Cu, Fe, and Co NPs reduced friction by 49%, 39%, and 20%, respectively, compared to lubricants without additives. When they were added in pair nano lubricants containing Fe–Cu and Co–Cu showed a decrease in friction of up to 53% whereas Fe–Co exhibited upto 36% decrease. Zhang et.al.[9] investigated the effect of Cu nanoparticles on tribological behaviour of diesel oil, with 7.5% wt of Cu nanoparticles it is observed that the effect of friction and wear was reduced.

Metal Oxides

Many metal oxides such as CuO, ZnO, Al_2O_3, TiO_2, CeO_2, SiO_2 are commonly used in industry as nano additives. Metal oxide nano additives show combined effects of anti-wear and friction reduction properties. Nano-TiO2 as additive in API-SF engine oil and mineral oil demonstrated acceptable friction reduction and anti-wear behaviors[10].CeO_2 in polymeric lubricant shows improved load carrying capacity of up to 84%. It also reduces friction considerably but has weak anti-wear properties. It can be used as an Extreme pressure (EP) agent [11]. In Seyed et.[12] They studied the comparison between the tribological and thermophysical features of the lubricating oil using MoS2 and ZnO nano-additives. The common size of ZnO and MoS2 nanoparticles were 30 nm and 90 nm, respectively. The nanoparticles were introduced in three concentrations that are 0.1, 0.4, 0.7 wt. % in diesel fuel. Tribological properties like coefficient of friction, mass loss if pins, worn surface maophologies and thermophysical properties like viscosity, viscosity index, pour point and flash point of resulting nano lubricants were studied, evaluated and compared with that of diesel fuel. The worn surface morphologies were observed and also the overall result of this experiment showed that the addition of nano-MoS2 decreases the mass loss values of the pins by 93% because of the nano-MoS2 polishing effect. With 0.7 wt.% concentration, the viscosity of Zno and MoS2 nano lub ricants at 100 °C increased by about 10.14% and 9.58% respectively. Mohamed et.al. [13] studied the behaviour of Al_2O_3, TiO_2 and Al_2O_3/TiO_2 hybrid nanoparticles mixed in commercial engine oil in a concentration of 0.25 wt% for formulating nano-lubricants. The sizes of Al2O3 nanoparticles were within the size of around 8–12 nm while the TiO2 nanoparticles used had a size of around 10 nm. These experiments were performed using a tribotester to evaluate the lubricant. The experimental results showed that nano additives improved the viscosity index and other tribological properties. Nano-lubricants showed low kinematic viscosity and a rise in the viscosity index by 2%. Meanwhile, thermal conductivity was improved by 12–16% for a temperature of around 10–130 C by dissipation of heat generated due to friction and maintaining engine oil properties. Mello et.al. [14] did a comparison study with conventional additives like ZDDP and sulphur with oxide nanoparticles like ZnO and CuO, the oxide nano additives reduced more friction effectively than conventional additives and showed the same behavior as extreme pressure additives.

Metal Sulphides

Like Metal oxides; the metal sulphide nanoparticles are used for enhancing the tribological properties of lubricant, metal sulphides like MoS_2, WS_2, FeS are commonly used nano additives. They show remarkable anti wear and anti friction properties. According to studies a remarkable decrease in coefficient of friction is observed by adding metal sulphide nano additives under dry lubrication conditions. Rajendhran et al. [15] studied the effect of MoS_2 nano-additives on tribological properties of lubricating oils (mainly frictional properties). The results showed that the addition 0.5 wt.% nano-additives in pure could strikingly improve the tribological properties.

Carbon Nanomaterials

The carbon nanomaterials have recently been used as additives, the tribological behavior of material such as graphene, fullerene and diamond have been studied for their potential use as nano additives in oils.

V.Zin et. al.[16] studied single walled carbon nano horns in engine oil and it's tribological behavior at temperature range of 25-80ºC, which showed reduction in coefficient of friction at all temperature and concentrations and observed decrease in mean wear rate by 25 to 30% at every temperature. Lee et.al. [17] investigated the effect of various volume concentrations of fullerene nanoparticles in mineral oil for which they used a disc on disc fascility in their experiments to obtain the temperature of friction surface and friction coefficient (COF). Those two parameters were evaluated by changing normal forces and volume fraction of additive fullerene. The frictional surface wear and coefficient of friction is maintained by changing volume concentration of the fullerene nanoparticles in base oil. Furthermore, the reduction of contact surfaces of moving parts is achievable via the addition of nanoparticles to the lubricants. Graphene is a two-dimensional material arranged in honeycomb lattice, offering significant anti-wear and friction properties. It also has suitable thermal, electrical, mechanical, and optical properties, and is a good candidate for lubricating machineries [18]. Hadi et. al.[19] evaluated the effect of the concentration of multi-wall carbon nanotubes (MWCNTs)/ turbine meter oil nanofluids on thermophysical attributes of lubricants, including the viscosity index, kinematics viscosity, flash point, pressure drop, and friction factor. The results indicated that the viscosity of pure lubricant was enhanced with the addition of MWCNTs and increased with decreasing temperature. The viscosity index at a concentration of 0.3 wt% was increased by 2.43%. The flash point temperature at concentrations of 0.3 wt.% and 0.4 wt.% was increased by 4.4%. The friction factor was increased for all concentrations of MWCNTs in pure oil.

Benefits of Nano Additives

Nano additives possess several advantages over their conventional counterparts. Nano materials help in increasing lubricity, reduce wear and friction, increase load bearing capacity saving energy, helps damping vibration and reduce noise, and upgrades conventional lubricants, they also improve the thermal and tribological properties. The benefit of nano additives in lubricants can be categorized as: Operational, economic and environmental benefits. Operational benefit is reduced friction which will improve the performance of equipment and machineries as well reduction in wear i.e. the frequency of maintenance will reduce[20]. The economic benefit is less fuel consumption due to good lubricity and extended machine life. The environmental benefit is improved fuel efficiency and reduced particulate matter emission also nano materials are environment friendly.

The shape & size of particles helps in determining the mechanism of lubrication additives. Spherical shape additives are likely to have rolling effect if its hardness is appropriate for that application. Nanoparticles with surface modification and soft metal nanoparticles show good mending and polishing effects. Mending effect is an effect in which nanoparticles fill up the uneven spaces or cracked spaces so small particles can easily occupy the spaces on surface. Metal and Metal oxide nano particles tends to sediment at bottom due to strong Van der

Waals forces between nanoparticles but it can be compensated by surface modification or surfactant-assisted dispersion of nano additives in base oil to realize stable dispersion in the base oil medium which we have discussed this in above section of Cellulose Nano crystal. Concentration of nano-additives in the base oil plays a major factor which determines the performance of lubricant. Very high concentration can lead to wear on parts and very low concentration of additives lead to inconsistent protective layers of nanoparticles or direct surface contact [21].

III. CONCLUSION

Different potential nano additives which have shown good tribological properties or having potential to be used as nano additives commercially in future are discussed. Metal, Metal oxides and Metal sulphides nanoparticles are already commercially introduced in lubricants by many oil companies.[21]Natural nano additives discussed in this article lack tribological properties to be introduced in lubricants for many engineering applications due to low thermal decomposition temperature. They can be used in other low temperature applications such that in hydraulic oils. Rare earth metals and their oxides reduce coefficient of friction but have poor anti-wear properties. Concentration, shape and size, additives' physical and chemical properties determine its performance in base lubricating oils (synthetic and natural oil).

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