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Influence of monodispersed CuO nanoparicles on the tribological behavior of hydraulic oil

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Abstract

The purpose of this paper is to investigate the effects of copper oxide nano particles on the friction and wear properties of AISI 316 steel material when the CuO nano particles are used as hydraulic oil additive. CuO were dispersed at 0.2, 0.5 and 1wt% in hydraulic oil using an ultrasonic for 5 min. Wear and friction coefficient were obtained using sliding tribometer with pin-on-disk configuration, tests were runed under 15 kg, sliding speed of 0.09 m/s and total distance of 1200 m. The worn steel surfaces were analyzed by scanning electron microscope(SEM) after wear. The results showed that CuO nanoparticle that were used as a hydraulic oil additive exhibited reduction in friction coefficient and wear. Addition of CuO nanoparticles to hydraulic oil decreased friction coefficient and wear by 22 and 65% respectively as compared pure hydraulic oil. Suspension with 0.5wt% of CuO had the lowest friction coefficient and wear.

Keywords: nanoparticles, friction, wear, hydraulic oil, tribometer, CuO

Introduction:

Lubricant industry has become an important part of the development of car industry and associated industries. In addition, with the introduction of new issues such as efficiency and conservation of non-renewable resources and environmental obligation, lubricants has found a special place in the sciences.

Hydraulic is the technology of production, control and transfer of power via compressed fluids. Water was the first fluid to have been used for such a purpose including weal lubrication, limited span of working temperatures and rust, wich in turn bound its use in advanced and new system, sending industry owner to seek other liquid, including oil type. the task of hydraulic fluids, which is always the same is to transfer power, provide system pressure, reduce friction and erosion, reduce the corrosion effect, seal the system and transfer the systems produced heat. After engine oil, hydraulic oil, is the most important group of lubricant.

Approximately hydraulic oil constitutes about %15 of at the lubricant wold's consumption. Hydraulic oil that are used under high pressure and high speeds, must have anti-wear addetives. Wear is one of the majore cause of metal loss in idusrtrial process. this situation do not let a lubricant layer is formed to protect surfaces as a result boundary lubrication condition is accured. Anti-wear additives form a protective layer on the surfaces to reduce the amount of wear.

Many researcher have investigated that nanoparticles as lubricant additives significantly reduces the friction coefficient and wear. The studies show that nanoparticles improved tribological property of lubricant by deposited at the rubbing surface and create a protective layer. The mechanisms behind friction reduction have been suggested to be the ball bearing effect, rolling effect, mending effect, protective film and polishing effect. Tao et al (1996) suggested the nanoparticles had ball bearing or rolling effect. They proposed that spherical particles suspended in lubricant play the role of ball bearing and acting as spacer between the frictional surface. Liu et al. (2004) explained the mending effect as lubrication mechanism. The copper nanoparticles suspended in the lubricant agglomerated into cluster under severe condition of high temperature and load. During friction nanoparticles deposited on the friction surface and filled the grooves. Chiñas-Castillo (2003) they had been proposed colloidal effect model. They showed that colloidal nanoparticles in thin film contacts can penetrate elastohydrodynamic contact in thin film. The reduction of wear and friction are dependent on the characteristic of nanoparticles such a shape, size and concentration. Yujin et al (2011) examined the effect of the shape of various nanoparticles including graphite, carbon black and carbon nanotube(vanak,et al,2015) suspended in mineral oil, on the properties of friction. The results showed that the friction coefficient reduced when spherical nanoparticles were dispersed in mineral oil. Spherical nanoparticles prevented direct contact between frictional surface. Alves et al. (2013) reported that a low concentration of nanoparticles is sufficient to improve the friction and wear behavior.The result showed that the optimum concentration of nanoparticle was less than 2wt%.various metal and metal oxide have been used as lubricant additives such as Au (Patton, et al., 2008), Pd,Au (Sánchez-López, et al, 2011), Cu (Zhang, et al, 2011), Si (Guerrero-Martínez, et al, 2010), Ti (Zhang, et al, (2011), Zr (Yan, et al, 2010). Result show that this nanoparticles can deposit on the rubbing surface and improve tribological properties of lubricant.

This paper were investigated the influence of the addition of CuO nanoparticle suspended in hydraulic oil. The anti-wear behavior of CuO was studied using pin-on-disk tribometer. The friction coefficient of rubbing surface were measured under various force at fixed rotation speed. The wear surface was examined by SEM.

Research methodology:

The base lubricant used in this paper was a hydrauli oil with kinematic viscosity at 40℃ and 100℃,68 and 8.8 Respectively. The concentration of CuO nanoparticle additive in nano lubricant were 0.2 wt%, 0.5 wt% and 1 wt%. nanoparticle were separately dispersed with an ultrasonic probe during two step for 5 min with an output power of 300W and 400W respectively. The main properties of the nanoparticle and lubricant are listed in table 1.

A pin-on-disk tribometer was used to determine the tribological properties of nano lubricant. In this tribometer the sliding contact consist of a hard steel pinof 4mm diameter reciprocate on an AISI 316 steel at certain vertical sliding force under fully submerged oil. The test condition were run for a total distance of 1200m at a rotational speed of 2400 rpm. The load is 15kg and operation time is 6 hour. Prior to the friction and wear test the disk and pin were cleaned by ultrasonication in acetone and dried with hot air before and at the end of each test. Wear was quantified by weight loss($\pm$0.1mg). the friction coefficient was recorded by computer attached to

the tribometer. All tests under each present condition were repeated three times. The average of the repeat were reported in this paper. After the lubrication test to determine the extent of the reduction in wear, wear surfaces on disk were characterized using SEM.

Table 1- material properties

Materials	Properties			
Nanoparticle	Morphology	Purity(%)	Size(nm)	specific surface area (/g)
CuO	Nearly spherical	99.5	<50	>80
Base oil	Physical properties			
Hydraulic oil	Density: 0.88 g/ Viscosity: 68.0 cSt(40℃) 8.8 cSt(100℃) VI: 102			

Research findings:

Figure1 shows the behavior of friction coefficient as function of sliding distance during the anti wear test at load 15 kg. As can be seen the friction coefficient of the hydraulic oil with all CuO nanoparticle content is lower that of pure hydraulic oil. The lowest friction coefficient was obtained for concentration of 0.5 wt% CuO nanoparticle.

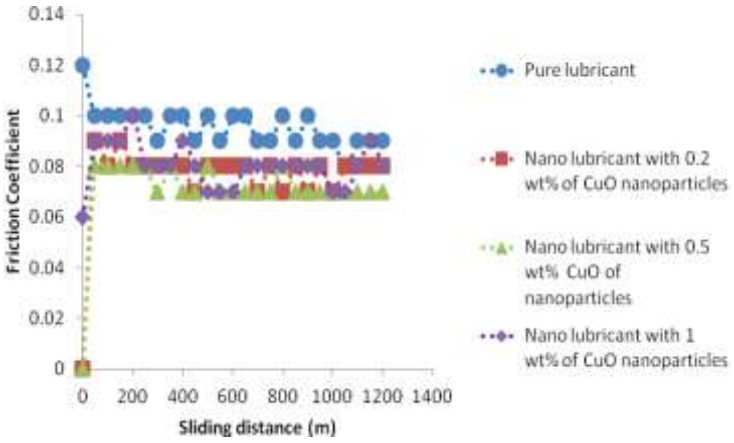


Figure 1. Friction coefficient as function of sliding distance at load of 15 kg

Figure2 shows the wear behavior as function of sliding distance. The results were showed the addition of CuO nanoparticles in hydraulic oil reduced wear as compare pure hydraulic oil. The highest wear resistance was found for hydraulic oil with a nanoparticles concentration of 0.5 wt% and the worst for 1 wt%. CuO nanoparticles can easy deposit at normal load that other aso have good anti-wear behavoir. Previous studies have

indicated that the concentration of nanoparticles within base-oil strongly influences the tribological properties of such lubrication systems (Akbulut, et al.,2006).

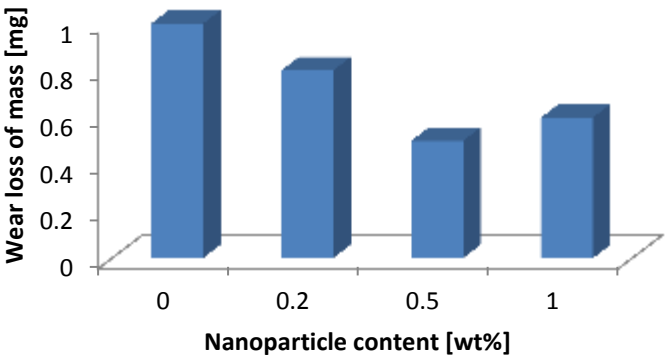
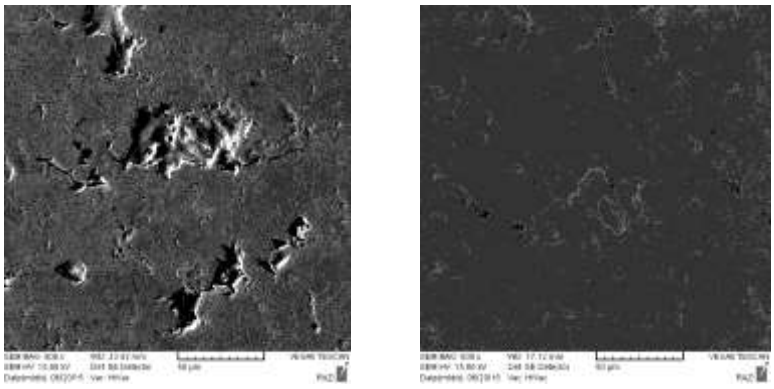


Figure 2. Wear loss as function of sliding distance at load of 15 kg

In general, there is an optimum concentration at which the coefficient of friction is at a minimum. It is seen that the friction coefficient decreases by increasing concentration of nanopartciles in the lubricant, shows the lowest value for a concentration of 0.34% and then increases. This trend may be attributed to the fact that the nanoparticles in the lubricant at lower concentration levels develop a third body rolling effect between the sliding surfaces causing a reduction in friction, whereas larger concentrations causes interaction between the solid particles themselves, thus increasing friction. Figure3 showed the SEM micrograph of the worn surface of the steel disk after wear tests testing with hydraulic oil containing 0.5 wt% CuO nanoparticles and pure hydraulic oil. It can be seen the type of wear in both surface was adhesive. The worn surface that lubricated with hydraulic oil containing 0.5 wt% CuO was smoother than pure hydraulic oil. It can be deduced that the nanoparticles additive reduced wear.



(a) (b)

Figure 3. SEM image of the worn surface lubricated with (a) pure hydraulic oil (×50) (b) hydraulic oil with 0.5 wt% CuO nanoparticle (×50)

Conclusions:

This paper reported the anti-wear behavior of different concentration of CuO nanoparticles used as additive to hydraulic oil by using pin on disk tribometer. The following conclusion can be drawn:

- All concentration of CuO nanoparticles in hydraulic oil exhibited friction coefficient and wear reduction compared to pure hydraulic oil.
- hydraulic oil containing 0.5 wt % CuO nanoparticles had the best tribological behavior exhibiting reduction coefficient and wear
- the result of morphology analyses showed addition of CuO nanoparticles decresed wear and perecense of CuO indicate that nanoparticles significantly reduced surface steel contact.

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