Wear 332-333 (2015) 1256–1261

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Effect of CuO and Al_2O_3 nanoparticle additives on the tribological behavior of fully formulated oils

Laura Peña-Parás [a,*,1], Jaime Taha-Tijerina [a,1], Lorena Garza [a,1], Demófilo Maldonado-Cortés [a], Remigiusz Michalczewski [b], Carolina Lapray [a]

[a] Universidad de Monterrey, Departamento de Ingeniería, Av. Morones Prieto 4500 Pte. San Pedro Garza García, N. L. 66238, Mexico
[b] Instytut Technologii Eksploatacji, Department of Tribology, Ul. K. Pulaskiego 6/10, 26-600 Radom, Poland

ARTICLE INFO

Article history:
Received 1 September 2014
Received in revised form
19 January 2015
Accepted 4 February 2015

Keywords:
Lubricant additives
Lubricated wear including scuffing
Wear testing
Nanotribology

ABSTRACT

Lubrication is essential for the advancement of energy efficient modern industries. Lubricants are widely used in industry to minimize friction and wear between tools and moving components. Additives are utilized as common lubricants reinforcement in order to achieve overall improved tribological properties. This study presents and discusses the tribological properties of friction, wear, and extreme pressure of two synthetic lubricants: GL-4 (SAE 75 W-85), a fully-formulated oil; and Poly-alpha olefin 8 (PAO 8) base oil. These lubricants were doped at various filler concentrations (0.5, 1.0, and 2.0 wt%) of CuO and Al_2O_3 nanoparticle additives. Anti-wear tests were performed with an Optimol SRV 4 tester, according to ASTM D5707; extreme pressure tests were performed with a T-02 four-ball tribotester. Wear scar diameters (WSD) were characterized by optical microscopy, scanning electron microscopy (SEM), and energy dispersive spectrometry (EDS). Anti-wear results showed a decrease of up to 18% and 14%, on coefficient of friction (COF) and WSD with 2 wt% CuO/PAO 8. The load carrying capacity (p_{oz}) of GL-4 and PAO 8 increased by ~14% and ~273%, respectively, with the addition of CuO nanoparticles. However, the incorporation of Al_2O_3 nanoparticles was not as effective, showing an increase of up to 18% and 12% on p_{oz} for GL-4 and PAO 8, respectively.

1. Introduction

Lower friction among mechanical components is one of the most critical properties in industrial components and tools; one possible solution for this issue is lubrication. Lubricants are used to minimize friction and wear among components, increasing tooling savings [1]. It has been observed from various studies [2–11] that in order to improve tribological properties diverse additives have been homogeneously dispersed within conventional lubricants. Additive performance greatly influences the quality of a lubricant [12]; traditional lubricants contain sulfur and phosphorus as additives, which are highly contaminant and require high temperatures in order to be effective [3].

Recently, nanoparticles have been investigated as additives for lubricants in order to improve extreme pressure properties, reducing friction and wear, dissipating heat generation and extending tool life [2–6,12–15]. For example, Taha-Tijerina et al. [12] observed an enhancement in thermal and tribological performance of common lubricants by adding very small filler fraction (<0.10 wt%) of 2D-nanosheets of h-BN and graphene (500 by 500 nm, with ~5 and ~8 atomic layer thickness, respectively). Results showed a decrease on COF and wear scar diameter (WSD) of 19% and 11%, respectively, with addition of 0.01 wt% graphene. Load carrying capacity was increased up to 155% with 0.10 wt% graphene.

The effectiveness of nanoparticles strongly depends on the type of fluid used, nanoparticles size and geometry, as well as filler concentration. The advantages of nanoparticles within lubricants are that nanoparticles act as a third body or nano-bearing, creating a rolling effect between surfaces mechanism [4]; filling valleys, thus forming a protective film on the surface [4,16]; or may be tribo-sintered to the surface [3,7], showing the contribution of friction and wear reduction by dispersed nanoparticles.

For instance, nanoparticles of CuO, ZrO_2, and ZnO dispersed in PAO 6 showed an overall decrease in friction and wear, where CuO proved to be more effective due to its tribo-sintering to the worn surface, reducing metal-to-metal contact [7]. Wu et al. [4] incorporated 1.0 wt% of sphere-like CuO nanoparticles with a diameter of 5 nm within a pure and a fully formulated oil; results showed a decrease on the coefficient of friction (COF) of ~6% and 18%, respectively, attributed to the rolling effect. Similarly, Jiao et al. [5] reported a decrease on the COF of 22% at 0.5 wt% Al_2O_3/SiO_2 composite nanoparticles in a pure lubricant oil, also due to rolling-friction.

In this work, the effect of addition of spherical-shaped CuO and tubular-shaped Al_2O_3 nanoparticles on the tribological properties, namely COF, wear resistance, and load carrying capacity (p_{oz}) of poly-alpha olefin (PAO) 8 oil and a fully-formulated gear oil GL-4 (SAE 75 W-85) was determined. These nanoparticles were selected

* Corresponding author.
E-mail address: laura.pena@udem.edu (L. Peña-Parás).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.wear.2015.02.038
0043-1648/

due to their small size, which may fill valleys, as well as their geometry in order to promote and take advantage of the rolling effect and achieve a reduction on friction and wear.

2. Materials and methods

Synthetic oils; PAO 8, a base oil without additives; and GL-4 (SAE 75 W-85), a fully-formulated oil, were reinforced with varying concentrations by weight of CuO and Al_2O_3 nanoparticles, supplied by Sigma-Aldrich. Basic characteristics of these fluids and nanoparticles are shown in Table 1. Nanoparticles at various concentrations

Table 1
Material properties.

Materials ***Base fluids***	Properties ***Density*** **(20 °C)**
PAO 8	0.83 g/cm^3
GL-4	0.88 g/cm^3
Nanoparticles	
CuO	Morphology: spherical Size: < 50 nm, hardness: 3.5 Mohs
Al_2O_3	Morphology: tubular Size: < 50 nm, hardness: 8–9 Mohs

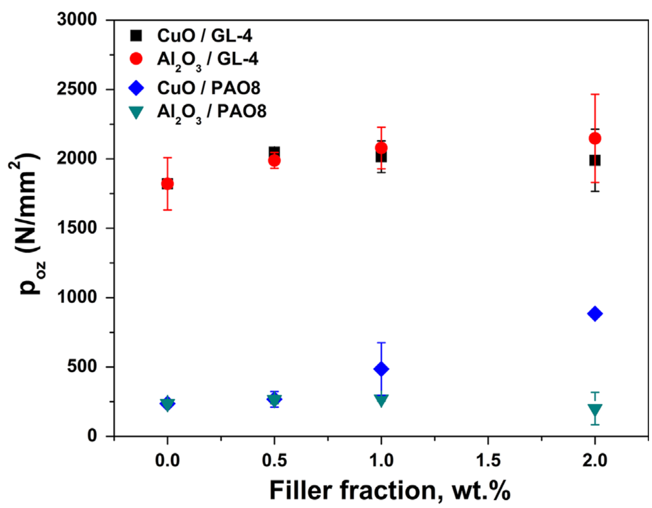

Fig. 3. Pressure loss limit results (p_{oz}) of nanofluids obtained by the ITEePib Polish method.

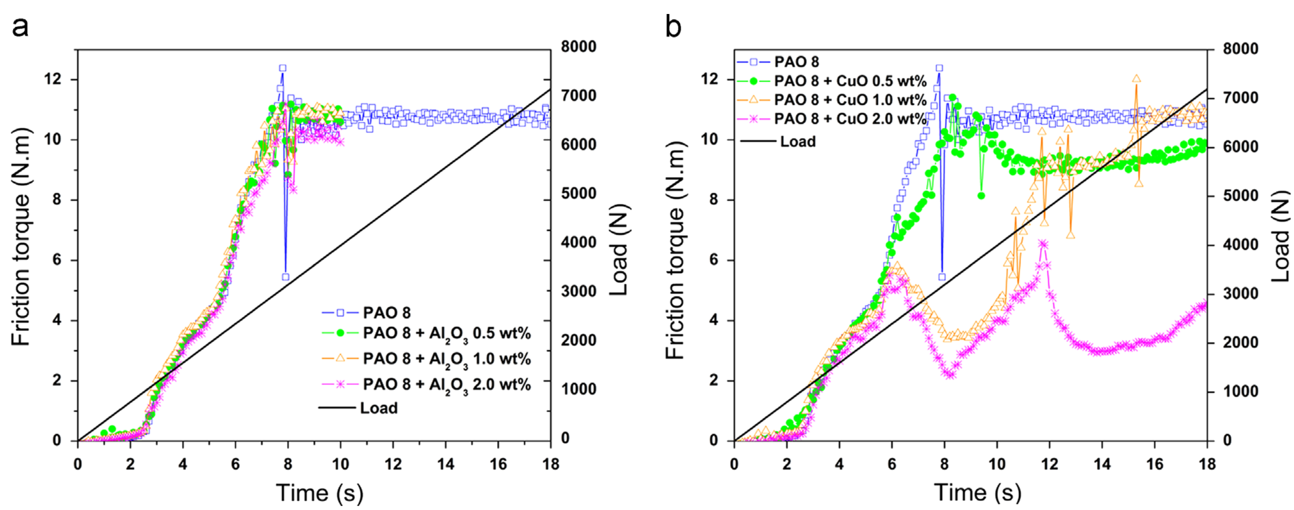

Fig. 1. Friction torque curves at continuously increasing load over time for (a) Al_2O_3/PAO 8 nanofluids, and (b) CuO/PAO 8 nanofluids.

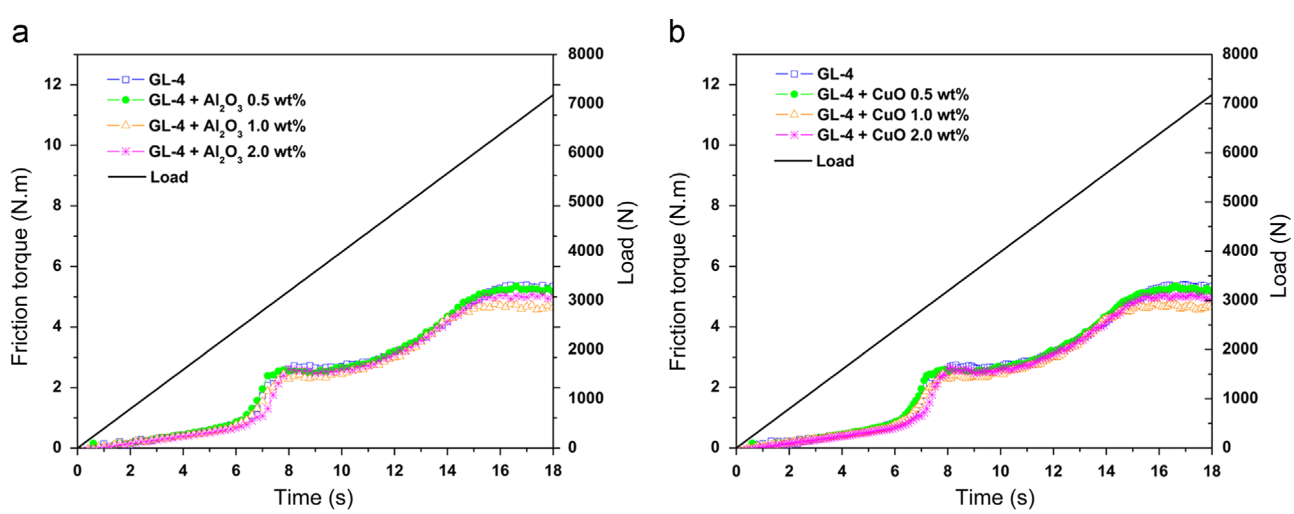

Fig. 2. Friction torque curves at continuously increasing load over time for (a) Al_2O_3/GL-4 nanofluids, and (b) CuO/GL-4 nanofluids.