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Comparison of the frictional properties of nano-oil and SAE 15W40 oil diluted with biodiesel fuel

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ABSTRACT – The aim of this study is to investigate the friction properties of nano-oil and SAE 15W40 oil diluted with biodiesel fuel. An optimal composition of 0.5 vol.% 70nm hexagonal boron nitride (hBN) nanoparticles was dispersed into SAE15W40 oil and diluted by four difference percentages of B100 biodiesel fuel in the range of 5 to 20 vol.%. As a comparison, the SAE 15W40 oil was diluted by the same composition. The tribological test was performed using a four-ball tribometer. The Scanning Electron Microscope (SEM) was used to determine the prominent wear mechanisms on the worn surfaces. It was found that the addition of biodiesel fuel increases both coefficient of friction (COF) of nano-oil and SAE 15W40 oil. However, the COF of SAE 15W40 oil is drastically increasing after diluting with 15 vol.% of biodiesel fuel, resulting in mild-to severe wear transition.

1. INTRODUCTION

Diluted engine oil can be very detrimental to an engine and its components. Under normal operating conditions, the engine oil film is keeping metal surfaces and their asperities separated to prevent it from wear [1]. There are many symptoms when the fuel enters the crankcase and contaminates the engine oil, especially it will reduce the oil viscosity [2], disrupts the oil film strength causing metal asperities to contact each other promoting engine wear, particularly in the cylinder/ring area [3]. It also may weaken lubricant detergency and increases volatility, which in very extreme cases it can lead to a crankcase explosion. There are several cases where this dilution also accelerates the lubricant oxidations which lead to acid formation/corrosion. Usually, the diluted oil present in low oil pressure and entrapped the varnish formation.

The causes of this phenomena can be result of many things such as leaking on injectors, excessive of idle time, incomplete combustion, cool engine operating conditions, frequent short trip driving, engine modification, restricted air filter/bad air to fuel ratio, worn piston rings/excessive blow-by, incorrect choke settings, over fuelling and also may be due to improper injector timing. According to Amsoil [4], depending on the application and operating conditions, a cautionary limit of up to 2% fuel dilution may be allowed provided viscosity has not changed. However, it may be recommended to examine the engine and analyze operating conditions. Dilution ranging between 2.5% to 5.0% is considered excessive and requires immediate maintenance action.

Nano-oil [5] or modern oil enhanced by nanoparticles additives currently being discussed a lot on their performance as friction modifier and anti-wear additive, but less studies discuss about the tribological effects of this diluted oil. Thus, this study focus on the frictional properties of the diluted nano-oil as compared with the SAE 15W40 oil.

2. METHODOLOGY

The nano-oil was prepared by dispersing an optimal composition of 0.5 vol.% 70nm hBN nanoparticles into 15W40 oil using ultrasonic homogenizer (Sartorius Labsonic P). The optimal value of hBN nanoparticles was determined from the previous study [6]. The nano-oil and SAE 15W40 oil were then diluted separately by four difference percentages of B100 biodiesel fuel of 5, 10, 15 and 20 vol.%. The tribological test was performed using a four-ball tribometer (TR20) according to the ASTM D4172 (Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid). The speed, load, time, and temperature, were 1200rpm, 392.4N, 3600sec, and 75ºC, respectively. The four-ball tribometer incorporated three 12.7mm diameter carbon chromium steel balls, clamped together, and covered with lubricant for evaluation. A fourth steel ball of the same diameter (referred to as the top ball), held in a special collet inside a spindle, was rotated by an AC motor. The top ball was rotated in contact with the three fixed balls that were immersed in the oil sample. The coefficient of friction was recorded using a data terminal processing system. Table 1 shows the mechanical properties of the ball bearing material. The surface morphology of the ball bearing was observed using SEM.

3. RESULTS AND DISCUSSION

Figure 1 shows that the steady state COF for both diluted nano-oil and SAE15W40 oil increases with increasing biodiesel fuel amount. However, the COF of SAE 15W40 oil increases drastically from 0.1 to 0.4 after diluting with 15 vol.% biodiesel fuel. According to Bartels et al. [7], the more diluted engine oil the higher reduction in oil viscosity which can weaken the lubricant detergency; lubricant thickness become thinner which can cause increases of friction between asperities and resulting in increases of COF and wear.

Table 1 Mechanical properties of ball bearing material

[a]**Properties**	**Ball bearing material**
Hardness (*H*), HRC	61
Density (ρ), g/cm^3	7.79
Surface roughness (R_a), µm	0.022

[a]From laboratory measurements

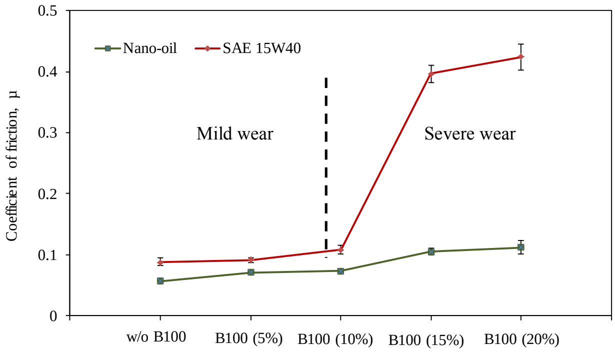

Figure 1 Steady state COF of nano-oil and SAE 15W40 oil diluted with B100 biodiesel.

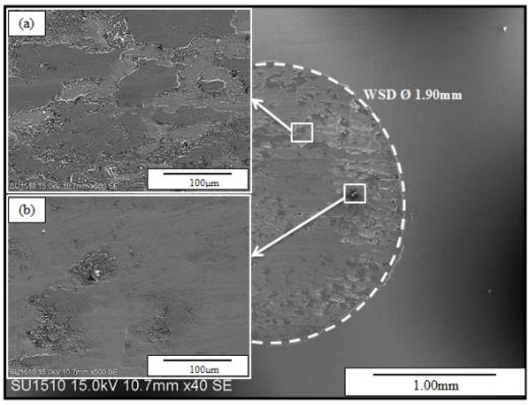

Figure 2 SEM images of the worn surfaces of the ball bearing tested by SAE 15W40 oil with 15 vol.% B100 biodiesel fuel with (a) adhesive wear and, (b) pitting and scuffing surfaces.

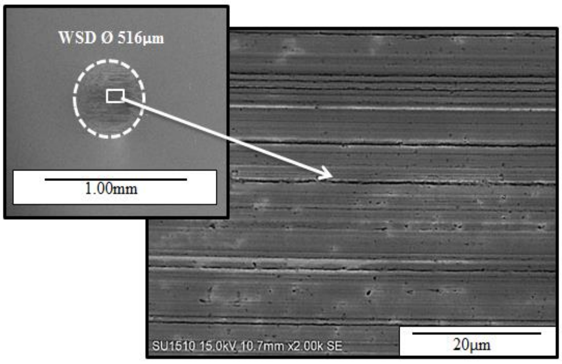

Figure 3 SEM images of the worn surfaces of the ball bearing tested by nano-oil with 15 vol.% B100 biodiesel fuel with clear grooves formed by abrasive wear.

Adhesive wear with some pitting and scuffing was clearly observed on the worn surfaces of ball bearing tested by SAE 15W40 oil with 15 vol.% of biodiesel fuel, as shown in Figure 2. This feature is characteristic of a mild-to-severe wear transition as proven in Figure 1. However, from Figure 3, only parallel grooves are formed by abrasive wear when tested with nano-oil diluted by the same amount of biodiesel fuel.

These results show the potential of hBN nanoparticles as an effective friction reduction additive to address the challenge of oil dilution even though being diluted by 20 vol.%.

4. CONCLUSIONS

In conclusions, both COF of diluted nano-oil and SAE 15W40 oil increases with increasing biodiesel fuel amount. However, at 15 vol.%, the COF of diluted SAE 15W40 oil starts to increase drastically from 0.1 to 0.4, resulting to mild-to-severe wear transition. Adhesive wear with some pitting and scuffing was indicated as the prominent wear mechanism of the ball bearing material tested with diluted SAE 15W40 oil, while for diluted nano-oil, only abrasive wear was observed on the worn surfaces. The results presented here may facilitate improvements in the friction properties of diluted oil by hBN nanoparticle additive.

5. ACKNOWLEDGEMENT

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