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AW/EP behavior of WS_2 nanoparticles added to vegetable oil-based lubricant

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ABSTRACT – Improvement in the anti-wear (AW) and extreme pressure (EP) ability of chemically modified jatropha oil (CMJO) by adding nanoparticles was experimentally evaluated. Nano-lubricants were synthesized by adding 1 wt% tungsten disulfide (WS_2) nanoparticles to CMJO. The AW/EP ability of trial oils were evaluated using four-ball wear tests. Wear surfaces were analyzed by scanning electron microscopy (SEM) along with energy-dispersive X-ray (EDX). The addition of 1 wt% oleic acid as surfactant (S) assisted in reducing the agglomerates. The addition of WS_2 nanoparticles improved AW/EP properties of CMJO.

1. INTRODUCTION

With the recent advances in renewable energy alternatives, development of vegetable oil based biodegradable lubricant is of great interest for tribologists and researchers. The related advantages are energy security, biodegradability, nontoxicity, and recyclability. However, low thermal stability and low oxidation stability obstructs the direct use of vegetable oils as lubricants. Over the years the researchers worked for the better oxidation and thermal stability of the vegetable based oils to be used as lubricants. Different chemical changes to crude vegetable oil have been performed to improve the oxidation stability and thermal stability [1, 2]. However for the lubrication purposes, chemically modified vegetable based oils become significantly less effective at extreme loads between the interacting surfaces [3]. To address the AW/EP related limitations of chemically modified vegetable oils the mechanism of nanotribology can be helpful. The nanoparticles improve AW/EP ability by a number of mechanisms which involve, the ball bearing, polishing, mending, and protective film formation effects [4]. The major focus of nanoparticle enriched lubricants has been related to mineral and synthetic base oil while a few studies have been reported for vegetable oil-based nano-lubricants [5]. Researchers have investigated that chalcogenides such as molybdenum disulfide (MoS_2) [6] and tungsten disulfide (WS_2) [7] have shown better EP and wear prevention characteristics. As only a few studies have been reported for nanoparticle enriched bio based lubricants, the present research develops and uses chemically modified jatropha oil (CMJO) as a base lubricant. Nanoparticles of 1 wt% WS_2 are used to formulate the trail oil. Formulations with 1 wt% WS_2 and 1 wt% oleic acid are also synthesized to observe the effect of surfactant on the dispersion and AW/EP mechanism of nanoparticles. The standard four-ball test is used to evaluate the anti-wear (AW)/extreme pressure (EP) characteristics of the oil samples. The wear surfaces are analyzed for nanoparticle deposition using SEM and EDX.

2. METHODOLOGY

2.1 *Preparation of Nano Bio-Lubricant*

The transesterification process was used in the presence of Trimethylolpropane (TMP) to modify the jatropha methyl ester chemically for better oxidation and thermal stability. The detailed procedure and mechanism for producing chemically modified vegetable oil were adapted from an earlier investigation of this research [2]. The WS_2 nanoparticles were added in CMJO in 1 wt% concentration. Table 1 shows the properties of the nanoparticles and base oil (CMJO) used in this study. The size and structure of nanoparticles were verified using SEM as shown in Figure 1.

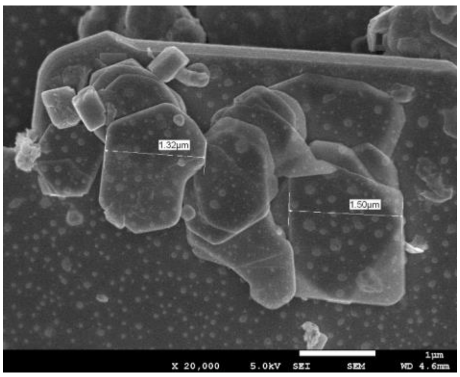

Figure 1 SEM micrograph of WS_2 nanoparticles.

2.2 *AW/EP Tests*

For the four-ball configurations, the AW/EP test was performed using the ASTM standard D2783. AISI 52100 steel balls with 12.7 mm diameter and HRC 64–

66 hardness were used. Parameters like, load–wear index (LWI), last non-seizure load (LNSL), initial seizure load (ISL), and weld point (WP) were evaluated for all lubricant samples.

Table 1 Material properties.

Materials	Properties		
Nanoparticles	Purity (%)	Size (nm)	Molecular wt (g/mol)
WS_2	99	50 - 2000	247.97
Base Oil	Physical Properties		
	Viscosity 10.21 cSt (100 ºC) Density 0.912 Kg/m^3 (15 ºC)		

2.3 *Worn Surfaces Analysis*

The worn scar surface were analyzed using SEM. The EDX spectrum was used to identify the elements on worn surfaces.

3. RESULTS AND DISCUSSION

The WS_2 nanoparticles show better AW/EP characteristics. Table 2 shows the results of the considered wear parameters of all samples. The LWI values clearly show that CMJO dispersed with the WS_2 nanoparticles show better wear protection than blank CMJO. Similarly, the parameter values are equally good for CMJO+1% WS_2+1%S. The comparison of the WP values for all the trial oils shows that the WS_2 nanoparticle-enriched lubricants show an improvement in EP ability of CMJO. SEM micrograph (Figure 2) shows tribo-sintering of WS_2 nanoparticles on the worn surfaces at ISL. The tribo-sintering mechanism helped in providing wear protection and improved the load carrying capacity of CMJO.

Table 2 LNSL, ISL and LWI and WP values.

	CMJO	CMJO+1% WS_2	CMJO+1% WS_2+1% S
LNSL/N	686	784	784
ISL/N	784	980	980
LWI/N	192.6	217.1	217.1
WP/N	1568	1764	1764

4. CONCLUSION

The WS_2 nanoparticles were found to be effective AW/EP additives to CMJO. The nanolubricants provided high load carrying capacity by tribo-sintering mechanism.

5. ACKNOWLEDGEMENTS

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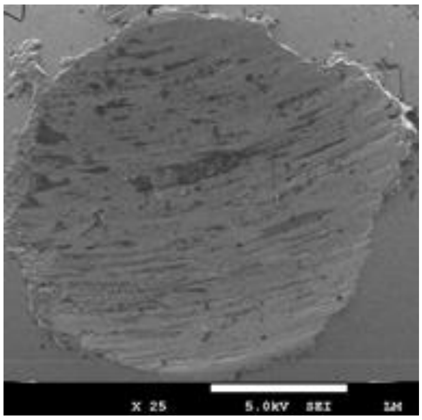

Figure 2 SEM micrograph (25x) at ISL.

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