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# Tribology characteristic of hBN particle as an additive in modified jatropha oil as a sustainable metalworking fluids

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**ABSTRACT** – Sustainable metalworking fluids have been used in the manufacturing industry due to the environmental concern and health impact. Bio-based oil is the suitable to replace petroleum-based oil in order to reduce the aforementioned problems. This study was focus on the investigation of wear and friction characteristics of modified jatropha oil (MJO). MJO was formulated at different molar ratio of trimethylolpropane and jatropha methyl ester to produce MJO1, MJO3 and MJO5. Next, a hexagonal boron nitride (hBN) was mixed with MJOs at different concentration. The samples were tested by using four ball tribotester machine and compared with synthetic ester (SE). The result shows that the concentration of 0.05wt. % of hBN particles in MJO5 enhances the tribological performances. The mixture of hBN particles influenced the sliding effect by reducing the wear and friction. This study shows that MJO has a potential to replace SE as a sustainable metalworking fluid.

## 1. INTRODUCTION

Generally, lubricant was formulated with 70-90% of based oil with the addition of various additives. The oil based can be mineral, vegetable and synthetic oil. Sustainable metalworking fluids (MWFs) from bio-based oils has been considered in the manufacturing industry to replace the usage of mineral oils. Mineral oils are normally from petroleum-based oil and additives that contribute to the water contamination and health impact. However, bio-based oil from the crude vegetable has low oxidation and thermal stability. Thus, the crude oil performances can be enhanced by additive mixtures and chemical modification.

Additive consists of boron and nitrite was explored as a solid lubricant additive. Bouville and Deville [1] identifies that hexagonal boron nitrite (hBN) has high thermal conductivity, high thermal stability and low surface energy. Besides, Ji et al. investigated that the hBN poses excellent anti-wear and anti-friction behavior [2].

Therefore, this research was aimed to determine the interaction between modified jatropha oil (MJO) with different percentage of hBN additives. The tribology characteristics in term of wear and friction were investigated in order to recognize the potential of MJO as a sustainable MWF.

## 2. METHODOLOGY

### 2.1 Preparation of Metalworking Fluids

MWFs samples from crude jatropha oil (CJO) were formulated via chemical modification process in order to improve its properties. Prior to this, jatropha methyl ester (JME) was prepared from CJO with two steps acid-based catalyst transesterification process. Then, JME was reacted with trimethylolpropane (TMP) by transesterification process. The modified jatropha oil (MJO) was formulated with various molar ratio of JME:TMP as shown in Table 1. Once completed, the MJOs were then mixed with hBN at different percentage (0.05wt. %; 0.1wt. % and 0.5 wt. %, based on oil weight percentage). The size of hBN particles was in the range of 2 to 5 µm. The entire samples were compared with commercially synthetic ester as the reference oil.

Table 1 Modified jatropha oils.

| Descriptions | Molar ratio |
|---|---|
| MJO1 | JME:TMP; 3.1:1 |
| MJO3 | JME:TMP; 3.3:1 |
| MJO5 | JME:TMP; 3.5:1 |

### 2.2 Metalworking Fluids Characteristics

The tribology test was conducted using tribotester according to four ball wear test method according to ASTM D4172. This experiment was conducted by using four stainless steel balls as shown in Figure 1. The lubricant sample was poured approximately 10 ml into the ballpot. Furthermore, the operating temperature was regulated at 75± 2ºC for one hour operation time. The top ball which attached to the ball holder was rotated at 1200±60rpm. The bottom three balls were pressed with the applied load force at 392N. From the testing, the coefficient of friction (COF) was determined by the Winducom 2010 software. Meanwhile, the average mean wear scar diameter (WSD) was measured by using image acquisition system. This testing was repeated for two times and the average value of COF and WSD was recorded.

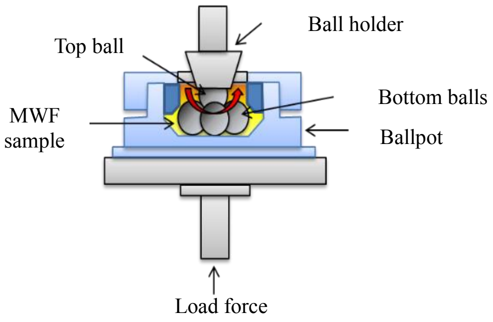


Figure1 Four ball test set up.

## 3. RESULTS AND DISCUSSION

The tribology value was an important characteristic that affect the machining performances [3]. Figure 2 (a), (b) and (c) illustrates the results of different percentages of hBN as an additive in the MJOs. MJOs act as the carrier fluids that allow the additive particles to remain in between the sliding contact surfaces. It can be seen in the graph that MJO5 outperformed MJO1 and MJO3 in terms of WSD. The average value of WSD in between the range of 1.2 to1.7 mm. In addition, the value of WSD for all MJOs was decreased when it mixed with 0.05% of hBN. MJO5 with 0.05%wt. hBN has reduced 23.6% when compared with SE respectively. The additive particles susceptible to form a thin lubrication film subsequently prevent an adhesion wear mechanism at the contact surfaces [2].

It can be observed that the COF of MJOs mixed with the hBN was lower than SE. The values of COF were ranging from 0.02 to 0.04. MJO5 with 0.05wt. % of hBN recorded the lowest value of COF compared to all samples. The COF reduces 2% and 75% when compared with MJO5 and SE respectively. The thin lubrication film established by the additive prone to reduce the friction between the sliding surfaces subsequently contributes to an anti-friction characteristic. The sliding friction was changed to the rolling effect, resulting in a reduction of friction at the contact area [4].

However, the increment of percentage of hBN imparted the WSD and COF values. The excessive amount of additive caused negative impact to the sliding area and severe the contact surfaces. These can be seen from higher increased of WSD values.

## 4. CONCLUSIONS

The following conclusions can be drawn from the current study;

1) The 0.05wt. % of hBN particles as an additive in the MJOs enhanced the tribology characteristic in terms of wear and friction.
2) The higher percentages hBN detrimental the tribology characteristic and damage the contacts area.

## 5. ACKNOWLEDGEMENT

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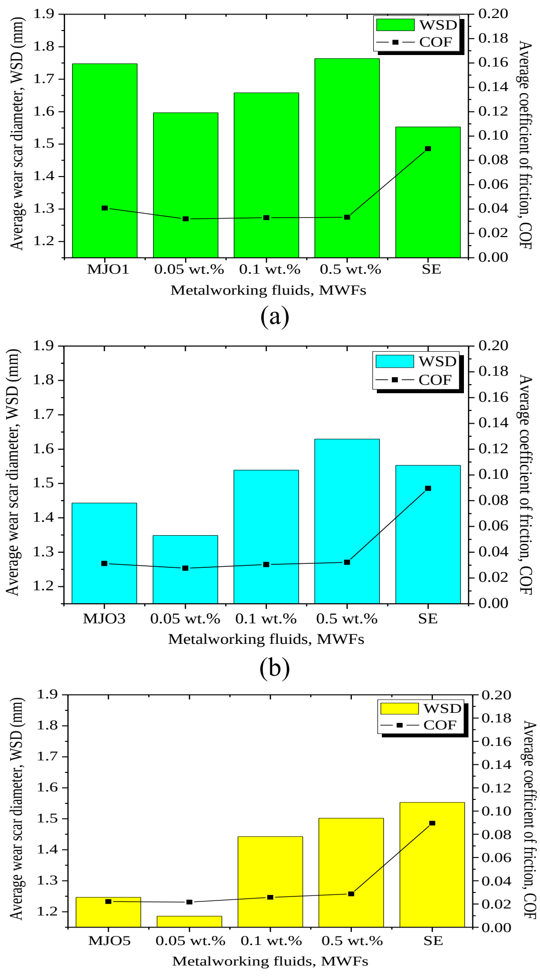


Figure 2 Average wear scar diameter (WSD) and coefficient of friction (COF) for different MWFs.

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