

## Wear performance of TMP ester as bio-based 2T lubricant

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**ABSTRACT** – Bio-based lubricant has long known for its superior lubricity. Through the process called transesterification the vegetable oil and animal fats can be transformed into lubricant or polyol ester. For two-stroke petrol lubrication, mineral-based lubricant is still widely used. This gap must be filled so that the two-stroke engine could be lubricated with the same high-quality bio-based lubricant as the four-stroke, leads to better fuel economy and cleaner emission. In this paper a polyol ester called Trimethylol Propane Trioleate (TMP TO) blend has been tested for wear performance. Result shows COF reduction of 7.3% as well as 47.8% less wear scar diameter compares to mineral-based lubricant.

### 1. INTRODUCTION

Vegetable oils and animal fats contain natural triglycerides. According to Gryglewicz et al. [1], these natural fatty acids with glycerol component (Figure 1) is readily destructible at high temperature. Replacing the hydrogen atoms in position beta with another polyhydric alcohol which does not contain beta-hydrogen atoms will solve this problem. The candidates include neopentyl glycol (NPG), pentaerythritol (PE) and trimethylol propane (TMP). These alcohols although exhibit decomposition at high temperatures, their thermal decomposition has a radical character thus slowing the process.

For this report, Trimethylol Propane Trioleate (TMP TO) was used. This fatty acid methyl ester is normally used in metalworking and stamping industries. Its superior character includes good cold stability, high flash point and excellent lubricity. TMP TO use in this report is Radialube 7561 manufactured by Oleon [2].

The motivation of this experiment is to explore the relatively cheap and environmental friendly TMP polyol ester for the possibility of using it as lubricant in a two-stroke petrol engine. This project is also supported by the key industrial player in bio-lubricant sector.

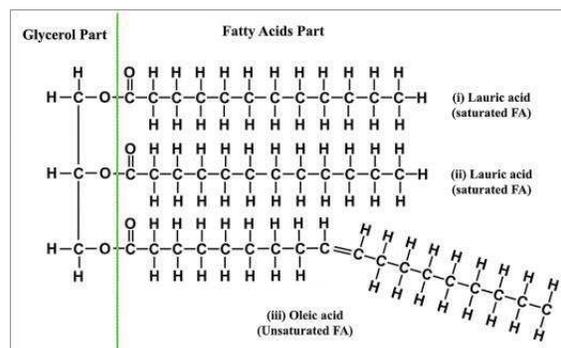


Figure 1 Glycerol part (on the left) in a triglyceride molecule [3].

### 2. METHODOLOGY

#### 2.1 Samples preparation

There are four samples prepared for this experiment from three base materials namely 1. TMP TO, 2. Quickstar 2T, and 3. Quicksilver 2T. Sample 3 is a commercial 2T lubricant which complies international 2T lubricant standard (TC-W3<sup>®</sup> by National Marine Manufacturers Association) thus it will act as reference for this experiment.

Samples 1,2 and 3 are used in pure and undiluted form. The fourth sample is prepared from a mixture of 10%v/v TMP TO (sample 1) with Quickstar (sample 2). The mixture was put on a magnetic stirrer for 10 minutes at 500rpm to ensure good mixing and was immediately brought to the four-ball test machine. 10% ratio for sample 4 was not randomly selected but instead was done after discussion with the manufacturer considering the cost, available facilities and other marketing factors.

The ASTM D4172 B four-ball test was conducted at 400N, 1200rpm for 3600s at slightly higher temperature of 100°C instead of 75°C. 100°C was selected to test the extreme temperature of samples following the flash temperature of Quicksilver sample of 107°C (refer Table 2). More than 100°C would expose the Quicksilver 2T lubricant to catch fire during four-ball procedure thus the temperature was closely monitored during the process to eliminate unwanted occasion.

## 2.2 Physicochemical properties

For the physicochemical properties of the samples, all samples except TMP TO were tested for flash temperature via Pensky Martens closed cup following ASTM D93 A standard. The device used was NormaLab Flash Point Tester. TMP TO flash temperature was retrieved directly from datasheet published by the manufacturer [2].

M7 Viscosity index for all samples was checked using Anton Paar SVM 3000. The physical as well as the chemical properties of all four samples are tabulated in Table 1.

## 3. RESULTS AND DISCUSSION

Pure TMP TO shows the highest viscosity index (VI) of 191 compares to the other three samples. Addition of TMP TO to the Quickstar lubricant was expected to increase the VI of the Quickstar (139.3) but it reduced the VI instead. 10% blend also exhibits almost identical physicochemical properties with Quickstar except the kinematic viscosity at 40°C. Other parameters can be referred in Table 1.

Table 1 Physicochemical properties of samples

Properties	TMP TO	Quickstar (mineral)	10% TMP TO (blend)	Reference (mineral)
Kinematic Viscosity 40°C [mm <sup>2</sup> /s]	49.431	44.061	<b>50.074</b>	37.802
Kinematic Viscosity 100°C [mm <sup>2</sup> /s]	<b>9.8759</b>	7.5724	8.5468	6.2275
Viscosity Index	<b>191.0</b>	139.3	136.5	112.3
Density [g/cm <sup>3</sup> ]	0.9171	0.8657	0.8739	0.8634
Flash temperature [°C]	>280*	129	125	107

\*from Oleon [2]

Wear scar diameter (WSD) shows an unexpected result with Quickstar brought the less WSD on the steel ball. COF of pure TMP TO is the least with 0.06690. Lubricants made of 100% mineral-based oil i.e. Quicksilver and Quickstar are proven to inherit high COF. However, the lowest WSD was recorded by Quickstar (see Table 2).

Table 2 Tribological performance.

Properties	TMP TO	Quickstar (mineral)	10% TMP TO (blend)	Reference (mineral)
Wear scar diameter [mm]	0.4955	<b>0.3191</b>	0.3695	0.7082
COF	<b>0.06690</b>	0.07999	0.06931	0.07479

## 4. CONCLUSIONS

Mineral-based oil is proven to exhibit low wear performance compares to bio-based lubricant. Trimethylol Propane ester in this case is in wear perspective, suitable for being use in a mineral-based lubricant blend as the two-stroke lubricant. This can be verified by the following findings:

- Polyol ester (TMP TO) in pure form has the best COF compares to 1. pure mineral lubricant and 2. bio-based and mineral-based blend.
- Polyol ester drastically improves the COF of mineral-based lubricant (13.35%) even at low dilution percentage (10%).
- Kinematic viscosity of sample 3 (blend) was increased instead of decreased. Rheological properties of this mixture should be further researched.

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