# EDS analysis of tribofilm formed on self-mated stainless steel lubricated by palm biodiesel

Z. Fuadi<sup>1,\*</sup>, T. Takeno<sup>2</sup>, K. Adachi<sup>2</sup>, M. Tadjuddin<sup>1</sup>

\*Corresponding e-mail: zahrul.fuadi@unsyiah.ac.id

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ABSTRACT – A ball on disk tribometer was used to investigate the wear of self-mated stainless steel lubricated by palm methyl ester (PME) mixed diesel oil. It is found that the wear resistance of the material is improved with the presence of palm methyl ester content in the diesel oil. EDS analyses were conducted to analyze the tribofilm formed on the contact interface of the ball. The results indicate the existence of metallic film mainly consisted of Mn on the worn surface of the ball lubricated by diesel oil without PME. On the other hand, the trace of Mn on the worn surface is much smaller in the case where palm methyl ester is mixed in the diesel oil.

#### 1. INTRODUCTION

The use of biodiesel in automotive industry has been increasing nowadays due to sustainability and environmental issues. In particular, diesel engine can have efficiency up to 40% with the use of high pressure fuel injection system [1]. Palm methyl ester is the main biodiesel resources in South East Asia with the product of 273 million liters in 2012 [2]. The methyl ester is mixed with petro diesel oil and sold as biodiesel fuel. For example, starting 2013, the biodiesel fuel sold in Indonesia is a mixture of 10% palm methyl ester in petro diesel oil [3].

Biodiesel has several technical advantages compared to petro diesel fuel. Among those are higher flash point, higher cetane number, higher lubricity, and lower exhaust emissions [4]. Moreover, it has an ability to improve the friction and wear of the components [5]. For example, a mixture of palm methyl ester in petrodiesel oil reduces wear of steel ball up to 20% [6].

In this paper, the wear of self-mated stainless steel lubricated by palm methyl ester contained diesel oil is investigated. The tribofilm formed on the surface of the ball were analyzed using Energy-Dispersive X-Ray Spectroscopy (EDS) to reveal the chemical composition of the tribofilm. Based on the results, a hypothesis on the wear mechanism is proposed.

## 2. METHODOLOGY

A ball on disk tribometer was employed (Fig. 1). The radius of the ball used was 4 mm and the diameter of the disk was 30 mm. Both the disk and the ball are made of stainless steel SUS 304. The surfaces of both the ball and the disk were mirror polished. A profilometer evaluation indicated that the surface

roughness of the disk is Ra=0.03 μm.

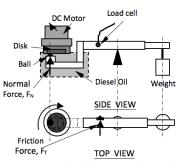


Figure 1 Schematic diagram of the tribometer.

The friction tests were conducted inside an oil chamber. Two different compositions of diesel oil were used. The first is the diesel oil without containing palm methyl ester and the second is the diesel oil containing palm methyl ester; the biodiesel. Both oils were obtained from commercial fuel station in Indonesia. The bio-diesel oil contain 10% palm methyl ester.

The test were conducted at normal load of 13 N at 250 rpm for 20000 cycles. The oil temperature was 20°C. The worn surface of the balls were analyzed using the Energy-Dispersive X-Ray Spectroscopy (EDS).

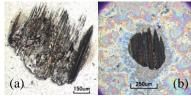


Figure 2 Worn surfaces of the balls in diesel oil (a) without palm methyl ester content and (b) with palm methyl ester content.

#### 3. RESULTS AND DISCUSSION

The worn surfaces of the ball obtained from the friction tests in the two different oil conditions are given in Fig. 2. It can be seen in the figure that the worn area is significantly larger in the case of the diesel oil without palm methyl ester content than that in the case of the diesel oil with palm methyl ester content. In the first case, the width of the wear is 750  $\mu$ m and in the second one it is 300  $\mu$ m. However, the friction coefficients of the two conditions were not very much different. In the first case, it was 0.25 and in the second case it was 0.2. The numbers are taken average across

<sup>&</sup>lt;sup>1)</sup> Mechanical Department, Syiah Kuala University, Jl. Tgk. Syech Abdul Rauf No. 7 Banda Aceh 23111, Indonesia.

<sup>&</sup>lt;sup>2)</sup> Graduate School of Engineering, Tohoku University, 6-6-01 Aramaki-aza Aoba, Aoba, Sendai 980-8579, Japan.

the 20000 cycles of friction test.

Fig. 3 and Fig. 4 give the results of EDS analysis of the balls. The analyses were conducted to investigate the trace of materials on the contact interface, which are Fe, Cr, O, Mn, C, and Ni.

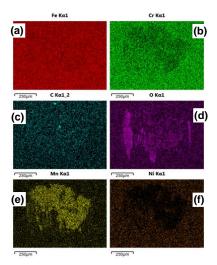


Figure 3. EDS image of wear track of ball under 0% PME diesel oil. Brighter part of the image shows the trace of Fe (a), Cr (b), C (c), O (d), Mn (e), and Ni (f). Indicated scale is 250 μm.

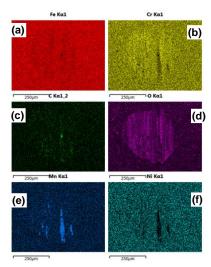


Figure 4. EDS image of wear track of ball under 7.5% PME diesel oil. Brighter part of the image shows the trace of Fe (a), Cr (b), C (c), O (d), Mn (e), and Ni (f). Indicated scale is 250 µm.

The trace of Fe and C are relatively similar in both conditions (Fig. 3(a)(c) and Fig. 4(a)(c)). Cr is traced more evenly in the worn surface of the ball in the case of PME contained oil (Fig. 4(b)) compared to that in the other case (Fig. 3(b)). In the case of PME contained oil, Ni is traced evenly on the surface (Fig. 4(f)) while in the case of the oil without PME, Ni trace is smaller in the wear track area, as shown in Fig. 3(f). Mn traces is found more significant on the worn surface of Fig. 3(e) rather than that of Fig. 4(e). O is found dominant on the worn surfaces, as shown in Fig. 3(d) and Fig. 4(d).

The trace on Mn and O in the wear track can be related to the wear mechanism. The wear was larger in the case shown in Fig. 3 in which Mn trace is found dominant on the worn area. On the contrary, Mn exists only in clustered area in the case shown in Fig. 4e. Based on these results, one of the reasons of high wear is the formation of metallic film consisted of Mn and O, possibly Mn oxide. Thus, it can be hypothesized that the presence of PME in the oil is could prevent the formation of Mn metallic film causing high wear.

#### 4. CONCLUSIONS

Based on the analysis, the followings are concluded;

- The wear of the stainless steel is smaller when the test is conducted in the palm methyl ester contained diesel oil. This indicated that palm methyl ester is favorable in wear reduction of the material.
- 2) EDS analysis indicated that the wear is cause by the formation of metallic film consist of Mn and O, possibly Mn-oxide. The amount of Mn and O is much smaller in the case where the diesel oil is mixed with palm methyl ester.

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