

Influence of Bio Diesel Fuel on Engine Oil Performance

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ABSTRACT

To evaluate the influence of FAME, which has poor oxidation stability, on engine oil performance, an engine test was conducted under large volumes of fuel dilution by post-injection. The test showed that detergent consumption and polymerization of FAME were accelerated in engine oil, causing a severe deterioration in piston cleanliness and sludge protection performance of engine oil.

1. INTRODUCTION

To help reduce CO₂ and alleviate the problem of energy security, larger amounts of bio diesel are being blended into diesel fuel. Most of this bio diesel is fatty acid methyl ester (FAME) produced from biomass oils. Low-concentration fuels labeled B5 (blended diesel fuel containing 5% bio diesel) or less are the main fuels in current use. However, parts of Europe introduced B7 in 2008, and it is likely that higher concentrations of FAME will be introduced in the future.

As shown in Fig. 1, FAME contains unsaturated bonds, which gives it lower oxidation stability than conventional diesel. Since fuel quality varies in accordance with the raw materials and production methods used, various research has been conducted to investigate the influence of bio diesel fuel on injection and exhaust systems and so on, in preparation for the wider use of fuels containing higher concentrations of FAME⁽¹⁾.

Post injection in a diesel vehicle is performed to remove particulate matter (PM) in the diesel particulate filter (DPF) by combustion. Fuel in the piston chamber does not combust

during post injection, causing larger amounts of fuel mixing into engine oil. Since this is a likely cause of fluctuations in engine oil performance, engine oil degradation due to the addition of various types of FAME has been researched^{(2), 3, 4 (5)}.

The research described in this paper focused on identifying the influence of continually mixing engine oil with fuel affected by combustion radicals and heat.

Post-injection was repeated using an actual engine to evaluate the degradation of engine oil under accelerated fuel dilution. Using a commercially available diesel fuel and SME B30 (a blended diesel fuel containing 30% soybean methyl ester, abbreviated to B30 below) as the evaluation fuels, accelerated degradation tests were performed under larger assumed volumes of fuel dilution than would be found in an actual vehicle.

The results of the tests showed that with B30, the piston cleanliness and sludge protection performance of engine oil deteriorated rapidly. Additionally, the degradation mechanism of FAME in engine oil was verified, and it was found that the deterioration in engine oil performance was caused by accumulation of FAME-derived polymers.

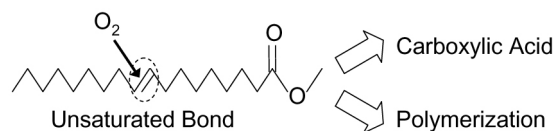


Fig. 1. Scheme of FAME Oxidation

2. EXPERIMENT

2.1. ENGINE TEST

Using a 3.0-liter turbocharged 1KD-FTV diesel engine, engine oil was intentionally diluted with fuel by post injection and its degradation was evaluated. To maintain the fuel dilution volume at approximately 15%, the following engine controls were alternately repeated as shown in Fig. 2: (1) fuel dilution acceleration process (controlled by post injection) and (2) oil degradation process (controlled at the maximum power point). The test duration was 120 hours under the maximum power point operation described in (2).

The fuel dilution volume was controlled quantitatively using gas chromatography in accordance with the JPI-5S-23-05 standard. The engine oil used in the test was JASO DL-1 5W-30 oil. The fuels used were a commercially available diesel fuel (abbreviated as “diesel fuel” below) and SME B30. The properties of the oil and fuels are shown in Tables 1 and 2.

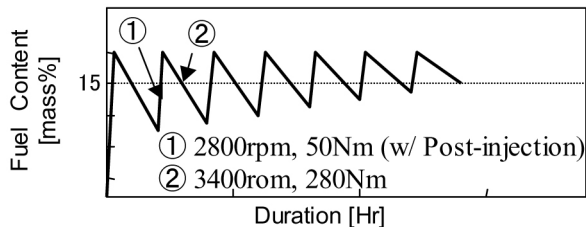


Fig. 2. Fuel Content Control During Test

Table. 1. Properties of Engine Oil Used in Test

Quality	JASO DL-1
SAE Viscosity Grade	5W-30
Kinematic Viscosity@40°C [mm ² /s]	54.5
Kinematic Viscosity@100°C [mm ² /s]	9.61
Sulfated Ash [mass%]	0.57
Acid Number [mgKOH/g]	1.20
Base Number* [mgKOH/g]	3.13

* JIS K2501 (HCl method)

Table. 2. Properties of Fuels Used in the Test

Fuel	Diesel Fuel	SME B30
Density [g/mL]	0.827	0.843
Kinematic Viscosity@30°C [mm ² /s]	3.33	3.60
T90 [°C]	336.0	341.0
Water Content [ppm]	24	109
Acid Number [mgKOH/g]	0.02	0.05
FAME Content [mass%]	-	31.3
Sulfur Content [ppm]	6	7
Lower heating value [J/g]	44540	42280
Oxidation stability [h] (EN14112)	-	3.1(neat)

2.2. ENGINE OIL PROPERTY TESTS

- Base number (HCl method)/acid number: JIS K2501
- n-Pentane Insoluble: Ultracentrifugation, method B
- Hot tube test (evaluated by the deposit weight adhering to the heated glass tube, 240°C × 16 hr)

3. TEST RESULTS

3.1. OPERATION RESULTS

The fuel dilution volume during the test was measured based on the Japan Petroleum Institute (JPI) test method. This test method assumes C19 hydrocarbons and below as the fuel components and maintains a target fuel dilution volume of approximately 15% as shown in Fig. 3. In the evaluation test for B30, the test was stopped at 75 hours because the engine oil was judged to have lost dispersion performance (determined by visual inspection).

Since FAME is outside the parameters of the JPI method and due to the accumulation of high-boiling components equivalent to C20 or higher, the actual fuel dilution volume was probably higher than the measured value in the JPI method. Figure 4 shows the estimated fuel dilution volume based on the reduction in Ca concentration. It was estimated that approximately 40% fuel dilution occurred, creating a more severe evaluation than the conditions found in an actual vehicle. However, the evaluation described below was performed in order to verify the influence of FAME under accelerated conditions.

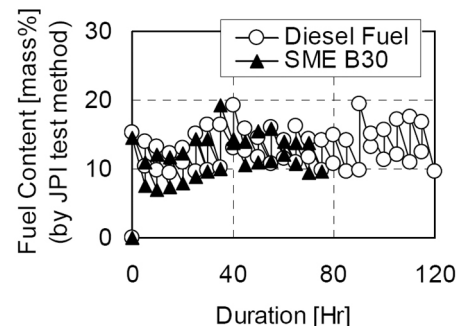


Fig. 3. Fuel Content During Test (Measured by JPI Test Method)

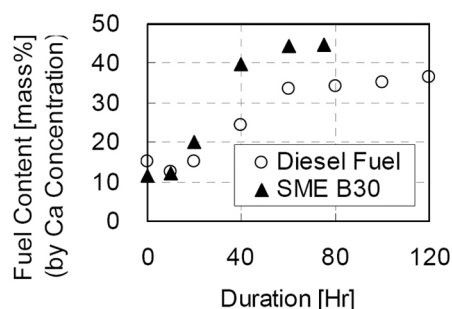


Fig. 4. Fuel Content During Test (Estimated by Ca Concentration)

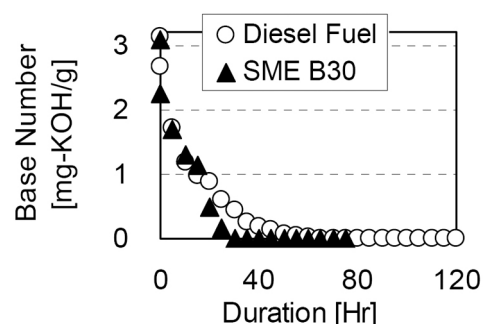


Fig. 7. Base Number Change During Test

3.2. INFLUENCES ON ENGINE

As shown in Fig. 5, in the B30 evaluation, carbon deposits were observed in the piston ring grooves (2nd ring and oil ring), and piston ring stick was confirmed (not confirmed in the diesel fuel evaluation). In addition, large amounts of sludge were observed adhered to the cylinder heads as shown in Fig. 6.

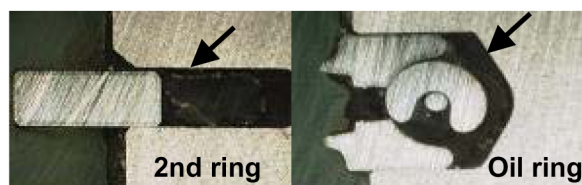


Fig. 5. Piston Ring Grooves of B30-tested Engine

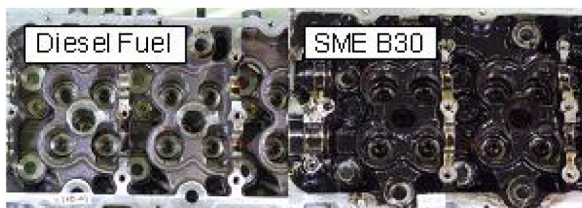


Fig. 6. Overview of Cylinder Heads

3.3. INFLUENCE ON ENGINE OIL PROPERTY

(1). Base number and acid number

Figures 7 and 8 show the changes in the base number and acid number of the recovered fuel. In the B30 evaluation, reduction of the base number was accelerated and the acid number increased rapidly once the base number reached zero (after 30 hours). This is thought to be due to oxidation degradation of SME, which accelerated antioxidant consumption and the formation of acid components, thereby leading to early consumption of the detergents in the engine oil.

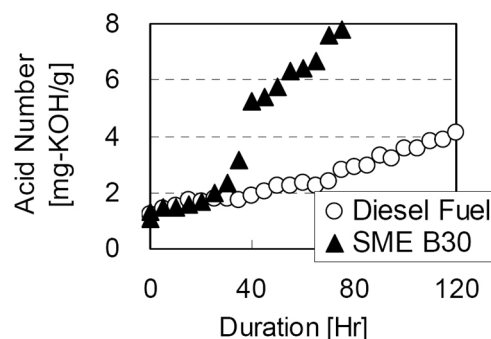


Fig. 8. Acid Number Change During Test

(2). n-pentane insolubles

The amounts of insoluble components after ultracentrifugation (abbreviated to “insolubles” below) were measured quantitatively. The results are shown in Fig. 9. Insolubles increased rapidly in the B30 evaluation after 30 hours when the base number reached zero.

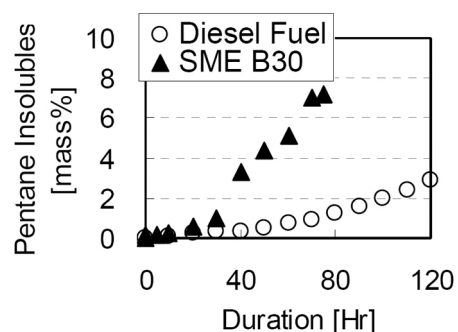


Fig. 9. n-Pentane Insolubles During Test

(3). Deposit resistance

In order to identify the timing of the deterioration in engine oil detergency performance (i.e., deposit resistance), a hot tube test was performed on the recovered oil to investigate the changes in deposit weight. The results are shown in Fig. 10. In the B30 evaluation, the deposit weight increased substantially after 30 hours. In other words, the deposit