

Study of the Impact of High Biodiesel Blends on Engine Oil Performance

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ABSTRACT

In Biodiesel Fuel Research Working Group(WG) of Japan Auto-Oil Program(JATOP), some impacts of high biodiesel blends have been investigated from the viewpoints of fuel properties, stability, emissions, exhaust aftertreatment systems, cold driveability, mixing in engine oils, durability/reliability and so on. This report is designed to determine how high biodiesel blends affect oil quality through testing on 2005 regulations engines with DPFs. When blends of 10-20% rapeseed methyl ester (RME) with diesel fuel are employed with 10W-30 engine oil, the oil change interval is reduced to about a half due to a drop in oil pressure. The oil pressure drop occurs because of the reduced kinematic viscosity of engine oil, which resulting from dilution of poorly evaporated RME with engine oil and its accumulation, however, leading to increased wear of piston top rings and cylinder liners. When a blend of 10% hydrogenated biodiesel (HBD) with diesel fuel is employed with 10W-30 engine oil, the pressure drop is smaller than that of 10-20% RME blends, because HBD has less heavy fraction compared to RME, and thus, even when diluting with engine oil, HBD can evaporate and is not apt to accumulate. Another study has been conducted to determine how 10% RME blends affect oil quality. 15W-40 engine oil is employed due to high initial oil pressure to avoid oil changes during the test period, resulting from dilution of RME with engine oil and its accumulation. The oil changes are avoided as planned; however, engine oil shows indications of degradation, such as increased total acid number and lead elution from the bearing material and components.

INTRODUCTION

In recent years, there are requirements for development of automotive fuel technologies that may contribute to reducing environmental load, such as diversification of primary energy sources and reduction in carbon dioxide emissions as well as reduction in motor vehicle emissions. And, as one of the measures to reduce environmental load, concern has been raised about the use of biofuels.

In fiscal 2007, Japan Petroleum Energy Center started a research on the use of biofuels in diesel vehicles under the Japan Auto-Oil Program (JATOP), which is a collaborative research program between auto and oil industries and subsidized by the Ministry of Economy, Trade and Industry. This research is focusing on the use of high biodiesel blends (the blending ratio exceeding the mandatory specifications of the Law on the quality control of Gasoline and Other Fuels (Quality assurance law) [5%]), and aims to gain technological knowledge that may contribute to studies that have been conducted towards market introduction of high biodiesel blends, which covers standardization of such high biodiesel blends, by identifying technical issues that could arise in the use of high biodiesel blends in diesel vehicles, and conducting an analytical study of the issues to develop measures to be taken by vehicle manufacturers and oil refiners, and so on.

In Biodiesel Fuel Research Working Group(WG) of Japan Auto-Oil Program(JATOP), some impacts of high biodiesel blends have been investigated from the viewpoints of fuel properties, stability, emissions^[1], exhaust aftertreatment systems^[2], cold driveability, mixing in engine oils, durability/reliability and so on.

Among biodiesel feedstocks, fatty acid methyl ester (FAME) is widely distributed in Europe and the U.S. However, FAME differs in quality from diesel fuel; FAME has poor oxidative stability due to the presence of unsaturated bond and heavier distillation range.

Diesel particulate filters (DPFs) are equipped on the latest diesel vehicles to reduce PM emissions; however, there are concerns about the increased amount of fuel contaminating the engine oil, which is caused by post injection of fuel for burning and removing PM deposits in DPF. When FAME having poor oxidative stability and heavier distillation range is blended into diesel fuel, there is also a concern about performance degradation of the engine oil.^{[3] - [11]}

Based on the above circumstances, researches have been conducted to determine the impact of biomass feedstocks on engine oil performance, durability and other properties of engine in the case of contamination of the engine oil by a blend of over 5% biodiesel and diesel fuel.

EXPERIMENTAL

TEST METHOD

Tests have been conducted on a 4.0L, inline 4-cylinder, turbo-intercooled DI diesel engine equipped with an oxidation catalyst and DPF unit as exhaust aftertreatment systems. The test engine specifications are shown in Table 1.

Table 1 Test engine specification

Engine type	In-line 4
Displacement, L	4.0
Emission regulation	Japanese 2005 regulation
Emission reduction technology	Turbo-intercooler Common-rail injection system Cooled-EGR DOC+DPF

TEST CONDITIONS

Figure 1 illustrates an image of durability test conditions. Test pattern includes full load operation, DPF regeneration, idle, stop and so on. The event of DPF regeneration simulates the relationship between mileage and DPF regeneration during city driving. For the durability test time, the total duration of full load operation is set to 200 hrs. This test pattern includes the post injection event which is designed to regenerate the DPF, so that the engine oil can be diluted with test fuel.

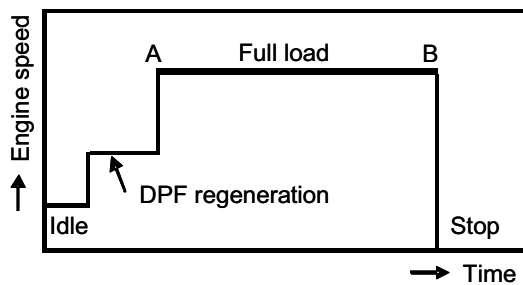


Fig.1 Image of durability test pattern

TEST ENGINE OIL/ TEST FUEL

Fig.2 illustrates an investigation of the engine oil viscosity grade distribution for the truck in Japan^[12]. The ratio of multi-grade engine oil is higher than single grade one, specially, the ratio of 10W-30 oil is highest among all.

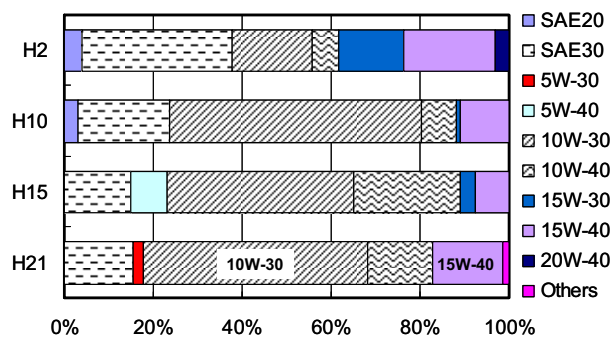


Fig.2 Viscosity grade distribution of engine oil (Truck)^[12]

Table 2 lists the properties of test engine oils. The test was conducted mainly using 10W-30 engine oil, which meets JASO DH-2 and is known as the mainstream used in the domestic truck fleet^[3]. 15W-40 engine oil, the second top of engine oil used in the domestic truck fleet, was also used for comparison purpose. The 15W-40 engine oil was prepared using the same additive formulation as that of 10W-30 engine oil except for viscosity grade.

Table 2 Properties of Engine Oil

			10W-30	15W-40
Density	@15degC	g/cm3	0.868	0.877
Kinematic viscosity	@40degC	mm2/s	68.07	107.9
	@100degC	mm2/s	10.51	14.2
Viscosity index			142	134
Acid number		mgKOH/g	2.05	2.14
Base number (HCl method)		mgKOH/g	6.53	6.21
Carbon residue		mass%	1.01	1.00
Sulfated ash		mass%	0.97	1.00

Rapeseed oil methyl ester (RME) was chosen as the representative of fatty acid methyl esters (FAMES) based on the followings; when RME is contaminated into the engine oil, the acid number increases relatively greatly, so that the contamination is inferred to have a significant impact on engine oil performance, and in addition to that, RME is widely used in Europe and the production quality is relatively stable.

Test fuels were prepared by blending 10 / 20 mass% of RME with commercial JIS #2 diesel fuel: RME B10 and RME B20. Meanwhile, a blend of 10% bio hydrogenated diesel (HBD) with diesel fuel was also prepared to determine whether biomass-derived hydrocarbon feedstocks have superiority over FAMES. Properties of the test fuels are listed in Table 3.

Table 3 Properties of test fuels

Fuel		Diesel Fuel	RME B10	RME B20	HBD B10	RME B10
Density@15degC	g/cm3	0.827	0.832	0.837	0.823	0.833
Kinematic Viscosity@30degC	mm2/s	4.061	4.074	4.227	3.887	4.114
T50	degC	287.5	295.5	318.5	285.5	293.5
T90	degC	336.0	344.0	356.5	334.5	338.0
Engine Oil (SAE Viscosity Grade)		10W-30	←	←	←	15W-40

RESULTS AND DISCUSSION

IMPACT ON ENGINE OIL PRESSURE

Figure 3 shows changes in oil pressure during operation at full load in the durability testing with various test fuels. When the test was conducted with 10W-30 engine oil and RME B10/ B20, oil pressure continuously showed a decreasing tendency with increasing the duration of durability testing. The decrease in oil pressure to the specified value (the application limit value set in terms of durability) was observed after 100 hrs of operation for RME B10, and after 120 hrs for RME B20, respectively, so that the oil changes were done (at the symbol “*” in the figure).

Meanwhile, when the test was conducted with diesel fuel, oil pressure showed a decreasing tendency, however, decreased relatively slightly, so that no oil change was needed. When the test was conducted using 10W-30 engine oil and RME B10/ B20, the oil change interval was roughly halved because of the decrease in oil pressure, which has never been experienced with diesel fuel.

The decrease in oil pressure was inferred to be caused by the decreased kinematic viscosity of engine oil, which was resulted from the contamination of engine oil with fuel (affected by the dilution of engine oil with fuel).

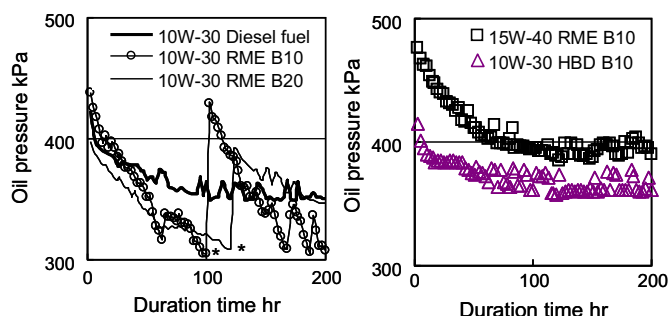


Fig.3 Change of oil pressure during durability test