

A Study of Effect of Biodiesel on Common-Rail Injection Nozzle

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ABSTRACT

Due to the need to reduce the use of fossil fuels, renewable fuels such as biodiesels are of interest. Biodiesels have different properties to pure diesel especially higher viscosity. This research studied the effect of using biodiesel on common-rail injection nozzles. Pure diesel and two biodiesel blends were supplied to the nozzles using a 1,800 bar injection pump with the same rotational speed of 2,200 rpm for 1,000 hours. The biodiesel blends were 5% palm oil based fatty acid methyl esters (FAME) biodiesel blended with 95% diesel (B5), and 10% palm oil based FAME biodiesel blended with 90% diesel (B10). Comparing with the petroleum-derived diesel (petrodiesel) fuel, the use of higher viscosity fuels such as B5 or B10 did not show the possibility to cause wearing around the injection nozzle holes. On the other hand, the results obtained by the Scanning Electron Microscope (SEM) demonstrated that the contaminations were observed around the holes when the nozzle were tested with B5 and B10. Using the Energy Dispersive X-ray (EDX) analyzer, we expect the contaminations to be black carbon particulate, iron oxide and the tested fuels.

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INTRODUCTION

The number of automobiles has been increasing constantly in many parts of the world over the past years, giving rise to ever increasing demand for fuels. At present, the majority of fuels used in the transportation sector are fossil fuels, the supply of which decreases with time. Many concerns have been raised surrounding the use of such limited fossil fuels including rising fuel price, dependency, energy security and, very importantly, greenhouse gas emission which has been linked to devastating climate change. The only solution to reduce the use of fossil fuels is to increase the use of alternative renewable resources [1].

In pursuit of reducing the use of petroleum and hence reducing carbon dioxide emission, biodiesel has been developed and produced commercially to replace conventional diesel used in diesel engines [2, 3, 4, 5, 6]. The figures from the Biofuels Association of Australia show that since 2006, biodiesel capacity has more than doubled with the EU producing more than 10 million tonnes in 2013. In the United States and Asia, biodiesel markets are experiencing rapid growths [7].

Biodiesels are fatty acid methyl esters which are made from transesterification reaction of vegetable oils (or animal fats) and alcohols. When comparing with conventional diesel fuel, the resulting biodiesel is similar to conventional diesel in its main characteristics. Biodiesel contains no petroleum contents but it is compatible with

fossil diesel, allowing it to be blended with normal diesel in any proportion to create a stable biodiesel blend. For instance, the blending level of 5% biodiesel and 95% diesel is referred to as B5 whereas B10 being 10% biodiesel and 90% diesel. Biodiesel blend can be used in compression ignition engines without major hardware modification [8]. However, there are many advantages of biodiesels such as their non-toxicity, lower sulphur levels and higher cetane numbers [9, 10, 11]. On the other hand, the disadvantages are higher viscosity, lower heating values and lower volatility [12-13].

A common-rail injection system generates a high pressure (more than 1500 bar [14]), thereby producing fine fuel atomization for the engine and ensuring that combustion is as complete as possible. The common-rail injection diesel engines are installed in all types of road cars especially in pick-up trucks which gain more than 50% market share in Thailand [15]. Previous research has been conducted on the common-rail injection systems applied to the use of biodiesels [16, 17, 18, 19, 20, 21, 22, 23]. However, previous published works related to the investigation of wears in common-rail injection system, especially injection nozzle, is limited [24].

This research aims to study the effect of the high viscosity of biodiesels on the high pressure common-rail injection nozzle. Materials, methods, experimental setup are presented in the paper. Results and analyses of the investigation are subsequently illustrated.

MATERIAL AND METHODS

Fuel to be Tested

Three types of fuel were studied in this paper which were (1) 100% petroleum-derived diesel (petrodiesel), (2) 5% palm oil based fatty acid methyl esters (FAME) biodiesel blended with 95% diesel (B5) and (3) 10% palm oil based FAME biodiesel blended with 90% diesel (B10). Their properties are shown in Table 1.

Table 1. Fuel properties [25]

Parameter	Diesel	B5	B10
Specific gravity at 15.6/15.6°C	0.8271	0.8295	0.8338
Density @40°C [kg/m ³]	0.8094	0.8117	0.8159
Viscosity @40°C [mm ² /s]	3.222	3.264	3.353
Lubricity by HFRR [μm]	445	216	237
Cetane number	63.5	64.2	65.9
Pour point (°C)	-3	-3	-3
Flash point [°C]	65.0	66.0	68.5
Gross heating value [kJ/kg]	46.178	45.888	45.347
Oxidation stability [g/m ³]	2.3	3.1	4.9
Methyl ester for fatty acid, (%vol)	0.0	5.4	15.8
Water content [%Wt]	0.007	0.009	0.012
Sulfur content [%Wt]	0.0049	0.0048	0.0043
% C	85.99	85.39	84.79
% H	14.01	13.91	13.81
% O	0.00	0.65	1.30

The viscosities of the B5 and B10 are slightly higher than that of the petrodiesel. However they meet the specifications contained in the standards (1.9-4.1 mm²/s). [26]

Experimental Setup and Conditions

The experimental setup used in the experiment consisted of fuel tank, oil filter, supply pump, electronics control unit (ECU) and common-rail with four nozzles as shown in Figure 1. The high pressure pump, the common-rail and injector nozzles used in this study were made by DENSO Co. Ltd. They were parts of an Isuzu D-Max 4JK1-TCX diesel engine which was an example of widely used engines in Thailand.

All parts used in the experiment were new, and all nozzles were inspected by the Scanning Electron Microscope (SEM) before the tests to confirm that there were no cracks or dust around the nozzles holes. Three fuel, i.e. petrodiesel, B5 and B10 were tested with the same rotational speed of 2,200 rpm for 1,000 hours, as shown in Table 2. After finishing each experiment, one injector nozzle was selected to investigate wears occurred on its surfaces using the SEM, while the other 3 nozzles remained unchanged. After replacing a new nozzle into the system, the next experiment with a different fuel was performed.

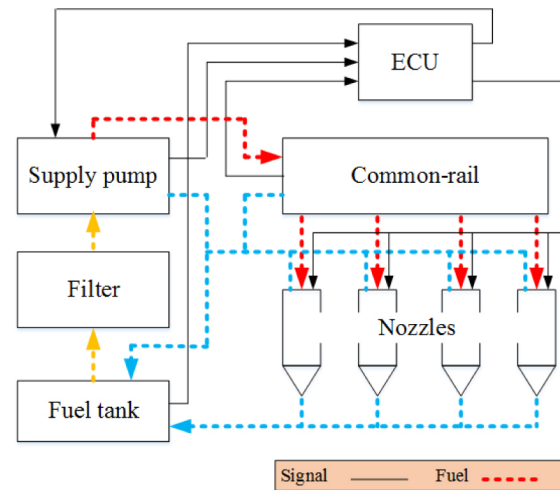


Figure 1. Experimental setup

Table 2. Test conditions

Parameter	Value	Unit
Rotational speed	2,200	rpm
Injection pressure	1,800	bar
Operation time	20	hours/day
Total test time	1,000	hours

RESULTS AND DISCUSSIONS

Observation of Nozzle Hole Using Scanning Electron Microscope (SEM)

After testing for 1,000 hours, one nozzle used in each experiment was detached from the experimental system. The nozzle was simply cleaned by washing in the tested fuel and blowing by an air gun. Then the wears were observed using the LEO 1450 Scanning Electron Microscope (SEM). Figure 2 and 3 show an example of a nozzle to be observed and the pictures of the injection nozzle hole obtained by the SEM, respectively.



Figure 2. Injection nozzle