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Effect of waste cooking oil biodiesel on the emissions of a diesel engine

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Abstract

This paper is focused on investigating the gaseous and particulate emissions of a 4-cylinder natural-aspirated direct-injection diesel engine fueled with different mixed concentrations of biodiesel and diesel fuel, including pure diesel fuel, B10 (diesel containing 10%vol of biodiesel), B20, B30 and pure biodiesel. Experiments were conducted with five engine loads, corresponding to brake mean effective pressures of 0.165, 0.33, 0.496, 0.661 and 0.753MPa at a constant speed of 1800rpm. The results show that biodiesel leads to reduction of HC, CO and particulate mass concentrations and number concentrations but an increase in NO_x. In addition, particulate samples were collected from the diluted exhaust and analyzed using thermogravimetric analyzer/differential scanning calorimetry (TGA/DSC). The TGA results show that with increasing biodiesel in the fuel or decreasing engine load, the volatile mass fraction of the particulate increases and the ignition temperature of the soot decreases.

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Introduction

Increasing energy consumption and environmental deterioration drive human to finding out alternatives fuels for replacing petroleum fuels, especially for replacing diesel fuel which is widely used by commercial vehicles. Biodiesel is one of the alternative fuels for diesel engines due to its renewability, potential of reducing greenhouse gas emissions, and inhibition of PAH and soot formation [1]. Since biodiesel has many similarities to diesel fuel, it can be directly used in diesel engine without any modification. Biodiesel, consisting of alkyl monoesters of fatty acids, can be derived from vegetable oil or animal fats. There is increasing interest in applying biodiesel converted from waste cooking oil for its lower cost and added advantage of reducing waste oil disposal [2]. Significant amount of research has been carried out on the combustion and emission characteristics of diesel engines fueled with biodiesel/diesel blends [3-5]. However, very few [6-8] have been carried out on quantifying the internal nanostructure and oxidation of biodiesel soot or biodiesel/diesel blends soot, especially using waste cooking oil biodiesel.

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As a result, the aim of this investigation is to study the effect of diesel blended with different proportions of biodiesel from waste cooking oil on the emission of a diesel engine. Regulated gaseous emissions and particle size distribution and particulate mass concentration were investigated under five engine loads at a constant engine speed of 1800rpm. For further understanding to the effect of biodiesel on the soot oxidation properties, particulate samples were collected from the diluted exhaust and analyzed using thermogravimetric analyzer/differential scanning calorimetry (TGA/DSC).

Experimental approach

Experiments were carried out on a 4-cylinder natural-aspirated direct-injection diesel engine fueled with different mixed concentrations of biodiesel and diesel fuel, including pure diesel fuel, B10 (diesel containing 10%vol of biodiesel), B20, B30 and pure biodiesel. The biodiesel used in present study was manufactured from waste cooking oil by Dynamic Progress Ltd., complying with EN14214. Table 1 gives the specifications of the engine and the main properties of pure biodiesel and diesel.

Table 1. Engine specifications and main properties of pure biodiesel and diesel fuel.

Mode	Isuzu 4HF1	Property	Biodiesel	Diesel
Type	In-line 4-cylinder	Low heating value (MJ/kg)	37.5	42.5
Maximum power	88 kW/3200 rev/min	Cetane number	51	52
Maximum torque	285 Nm/1800 rev/min	Density (kg/m ³ at 20 °C)	871	840
Bore × stroke	112 mm × 110 mm	Viscosity (mPa s at 40 °C)	4.6	2.4
Displacement	4334/cc	Carbon content (% wt)	77.1	86.6
Compression ratio	19.0:1	Oxygen content (% wt)	10.8	0
Injection pump type	Bosch in-line type	Hydrogen content (% wt)	12.1	13.4
Injection nozzle	Hole type (with 5 orifices)	Sulfur content (mg/kg)	<10	<10

The engine was operated under five engine loads, corresponding to brake mean effective pressures of 0.165, 0.33, 0.496, 0.661 and 0.753MPa at a constant speed of 1800rpm. The regulated emissions were measured using gas analyzers, which were calibrated with standard gases and zero gas before each experiment. HC was measured with heated flame ionization detector (HFID), NO_x was measured with heated chemiluminicent analyzer (HCLA) and CO/CO₂ were measured with non-dispersive infra-red analyzers (NDIR). Particulate size distribution and number concentration was measured with a scanning mobility particle sizer (SMPS, TSI, Inc) and particulate mass concentration was measured with a tapered element oscillating microbalance (R&P TEOM 1105). After the exhaust gas temperature, the cooling water temperature and the lubricating oil temperature attained steady-state values, experimental data were collected. All gas concentrations and particulate mass concentration were continuously recorded for more than 5 minutes and the average results were presented in this paper. Each experiment was repeated twice and the results were found to agree with each other at 95% confidence level. Additionally, the oxidation properties was analysed with TGA/DSC following the procedures described in [9].

3. Results and discussions

3.1 gaseous emission

The regulated gaseous emissions including total hydrocarbon (THC), carbon monoxide (CO) and nitrogen oxide (NO_x) were measured and compared when the engine was fuelled with various test fuels at different engine loads. It is observed that the addition of biodiesel would lead to the decrease of THC and CO but an increase of NO_x. The results are similar to those reported in the literature and hence not presented in details in this paper.

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