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Use of post flame metal-based and oxygenated additive combination for biodiesel-diesel blends

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This paper presents effects of using vegetable oil-based additive combined with metal-based additive on exhaust emissions of 4-stroke diesel engine fueled with biodiesel. Tests were conducted using biodiesel from palm blended with diesel, palm polyol and MgO as a post-flame additive. A test with 100% conventional diesel fuel was also conducted for comparison purposes. Palm-biodiesel blended fuel with and without additive generally produced less emission compared to ordinary diesel. Moreover, post flame additives was found successfully diminishing poisonous exhaust gases from diesel engine combustion, eliminating stringent environmental issues on atmospheric pollution.

Keywords: Biodiesel, Emissions, Metal-based additive, Palm oil, Post-flame additive

Introduction

Vegetable oil based fuel such as palm oil contributes less carbon dioxide into atmosphere[1-3]. However, higher viscosity of vegetable oils contributes to poor atomization during engine combustion, thus use of transesterified vegetable oil (methyl esters of palm oil, jatropha oil, karanja oil, rice bran oil, etc) is more preferable[3,4]. Additives as chemical material added to base fuel enhance desirable chemical properties to modify existing properties. Additive also functions as a detergent and dispersant. Diesel fuel additives solve problems occurring prior to burning fuels, and promote complete burning of fuel in combustion chamber and after combustion to reduce engine deposits, smoke, and emission[5]. Several studies have been conducted on oxygenated additive and metal-based additive[6-9].

This study presents combination of MgO as metal-based additive with palm-polyol as oxygenated additive for production of metal-based combustion catalysts. Combined additive was also used as biodiesel-diesel blended fuel additive in order to study its effect on diesel engine emission.

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Experimental

Experiments were conducted at the Engine and Tribology Laboratory of Mechanical Engineering Department, University of Malaya. An Isuzu 4FBI four-cylinder direct injection diesel engine was fully connected with 250 kW Eddy-Current Froude Consine dynamometer and data acquisition system was used[10]. Test procedure was in accordance with SAE-recommended practice J1349 JUN90[11].

Engine was operated with variable speed (1000-2400rpm) with full-throttle opened setting for every test fuel. Tests were done at full load (approx. 900 Nm) without any modifications on injection pressure or timing, etc. SAE grade 40 was used as lubricating oil for engine. Engine specifications were as follows: ISUZU 4-FBI direct injection; water cooled; 4-cylinder horizontally arranged displacement; 1817cc; compression ratio, 17.5:1; rated power output, 128 kW@2800 rpm; max. speed, 4000 rpm; injection pressure/timing, 200 bar/24 BTDC; and maximum valve lift, 10.5 mm. Testing conditions were as follows: full throttle opening; full load, 900 Nm; speed, 1000-2400 rpm; room temperature, 29°C; and emission measurement, every 10 min of engine operation. Same test procedure and practice were followed for all test fuels. Exhaust emissions [oxides of

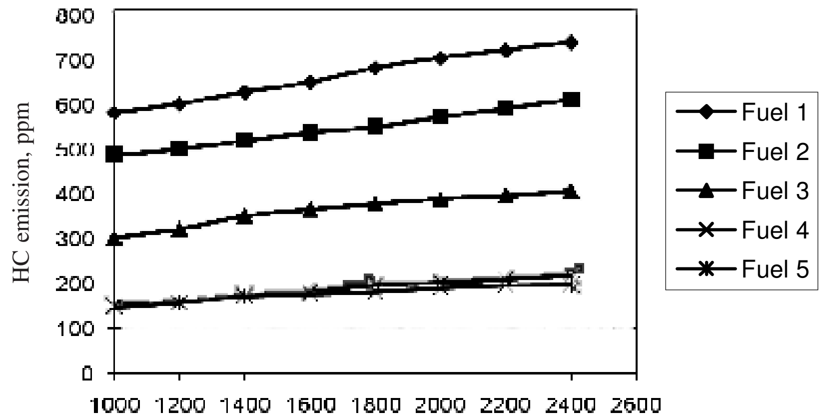

Fig. 1— HC concentration vs engine speed

Table 1— Palm-biodiesel and diesel fuel properties

Properties	Palm-biodiesel	Diesel
Viscosity$^{40°C}$, cSt	3.96	3.6
Calorific value, MJ/kg	42.7	46.8
Sulphur content, %wt	n/a	0.1
Cetane number	54	53
Flash point, °C	152	110
Density$^{15°C}$, g/cm^3	0.87	0.832

Table 2 — Fuel properties of blended fuels

Properties	5% B+ 95% D	10% B + 90% D	2% A + 5% B + 93% D	2% A + 10% B + 88% D
Calorific value, MJ/kg	44.35	44.2	44.88	45.25
Specific density, g/cm^3	0.868	0.873	0.846	0.858
Viscosity$^{40°C}$, cSt	4.20	4.40	3.95	4.10
Cetane number	51	51	53	52
Flash point, °C	150	144	115	106
Density$^{15°C}$, kg/m^3	0.85	0.842	0.838	0.83

A, additive; B, Palm biodiesel; D, diesel

nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), and hydrocarbons (HC) were measured by using HORIBA MEXA 9100D compact cabinet gas analyzer.

Palm-biodiesel and palm-polyol was collected from Malaysia Palm Oil Board (MPOB) and diesel fuel from PETRONAS. Properties are given of palm-biodiesel and diesel (Table 1) and that of all blended fuels (Table 2). MgO as metal based-additive was blended with palm-polyol stoichimetrically using mechanical stirrer (500 rpm) at 70°C. Additive was blended with palm-biodiesel and diesel using homogenizer system under room temperature. Tested fuel configuration and percentages were as follows: Fuel 1 (100% conventional diesel No.2); Fuel 2 (5% palm-biodiesel + 95% diesel); Fuel 3 (10% palm-biodiesel + 90% diesel); Fuel 4 (2% additive + 5% palm-biodiesel + 93% diesel); Fuel 5 (2% additive + 10% palm-biodiesel + 88% diesel).

Results and Discussion

Exhaust Emissions Analysis

Hydrocarbons (HC)

Unburned HC emission reduces with increasing blended fuels (Fig. 1). Fuel-5 shows successful reduction of HC emission. Blended fuel with additive can ignite at a proper time, because more oxygen content in blended

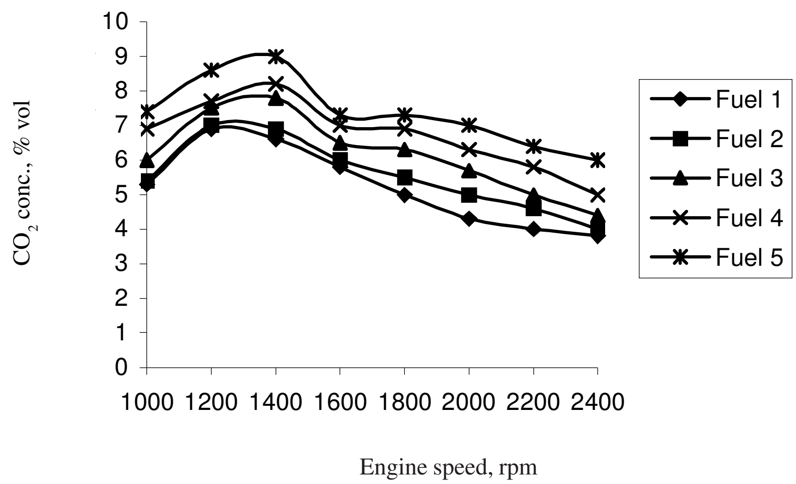

Fig. 2 —CO_2 concentration vs engine speed

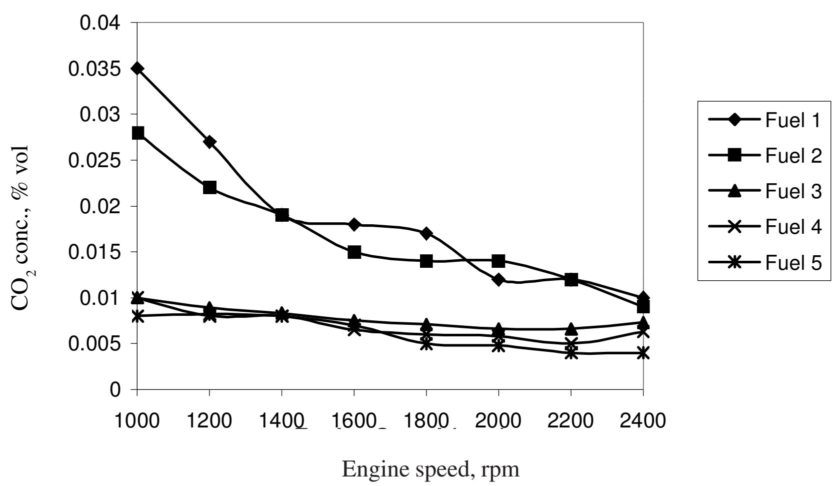

Fig. 3— CO concentration vs engine speed

fuel helps to complete combustion. Additive as a catalyst reduce unburned HC formation.

Carbon Dioxide (CO_2)

All blended fuels and blended fuels with additive demonstrated higher CO_2 than ordinary diesel (Fig. 2). Formation of CO_2 indicates efficiency of combustion because blended fuels with and without additive burn completely with proper air-fuel mixture ratio. Concentration of CO_2 from biodiesel-blended fuel with additive is higher than conventional diesel fuel due to improving combustion efficiency of engine.

Carbon Monoxide (CO)

CO is formed during combustion process with rich air-fuel mixtures. Diesel engines are not a significant source of CO, because they use excess air (around 1.8 x stoichiometric) to combust supplied fuel. Concentration of CO for blended fuels using additive greatly decreased and remained constant with increasing engine speed (Fig. 3). Thus, additive helps engine to burn fuel better.

Oxides of Nitrogen (NO_x)

NO_x decreases with increasing blended fuel due to the production of a low combustion temperature in comparison with ordinary diesel (Fig. 4). Reduction of NO_x was also found for every tested fuel while running at higher speed. NO_x emission was produced from high temperature of fuel combustion. However, due to the presence of additive into blended fuel, this helps to reduce temperature inside cylinder during combustion[4]. Moreover, metal-based additive produced lower NO_x while running with biodiesel blends[9].

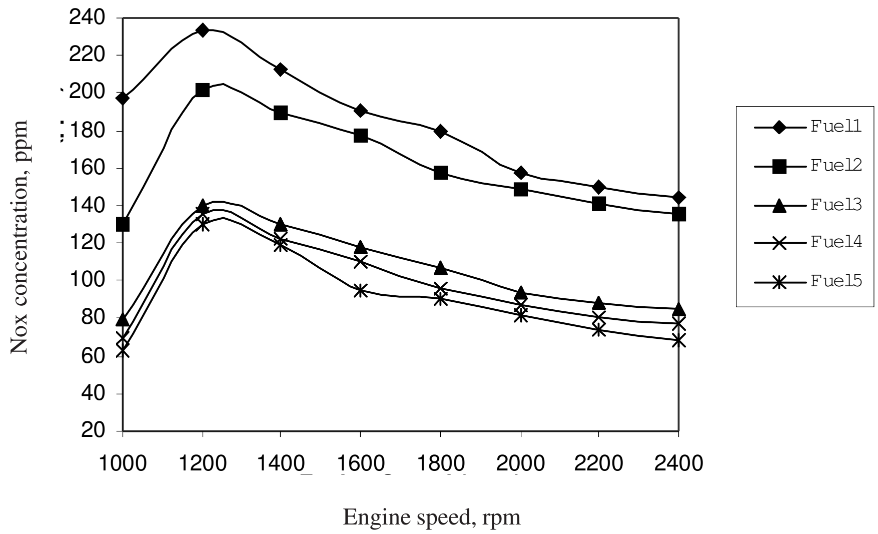

Fig. 4— NO_x concentration vs engine speed

Conclusions

Palm-biodiesel blended fuel generally has low exhaust emission compared to conventional diesel. Blended fuels with additive shows a good result for exhaust emissions (HC, NO_x and CO) as compared with conventional diesel fuel and biodiesel-diesel blends without additive. Palm-biodiesel blended fuel with and without additive has higher CO_2 emission as compared to ordinary diesel[2,9,10]. Use of metal-based additive such as MgO combined with oxygenated additive (palm-polyol) found reducing exhaust emissions especially for NO_x from biodiesel-diesel blended fuel combustion. Use of palm-polyol as additive for biodiesel fuel also contributes in renewable-based application in agriculture.

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