Reducing Emissions from Diesel-Butanol-Biodiesel Engines

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Abstract

This paper reports the findings on the performance and emission of a diesel generator using diesel-butanol-biodiesel was examined. The experimental results revealed that formaldehyde, acetaldehyde and acrolein account for more than 75% of aldehydes and ketones emissions. Different blends of diesel-biodiesel-butanol were used to appropriately examine the effects of fuel composition on engine-out emissions. The biodiesel used in this study was derived from waste cooking oil. The reduction is largely evident for nitro oxides, particulate matters and carbon monoxide. On the other hand, increasing the amount of biodiesel in the blends lowers engine out emissions. Amongst the fuel compositions studied, the blends with 70% diesel, 10% butanol and 20% biodiesel resulted in lowest emissions level.

Keywords: Biodiesel, Butanol, Diesel Engine, Aerosol, Aldehyde, Ketone.

1. Introduction

Prior studies have significantly pointed out the adverse effects of engine-out emissions on human health, greenhouse effects and environmental concerns such as toxic smog and acid rain. In order to minimize the impact of exhaust emissions, numerous researches have been conducted to improve the diesel engine such as improving the design, installing catalytic converter, and using alternative fuels from renewable-sources. Bio-fuels, such as biodiesel [1 - 5] and bio-alcohol [6 - 7], seems to be the most promising solution for clean engine operations. Biodiesel is one of the most credible modern day alternatives to petroleum-based diesel as it is renewable, compatible with current economic and technological infrastructures and burnt cleanly. Biodiesel can simultaneously reduce various engine emissions: carbon monoxide (CO), hydrocarbon (HC), particulate matters (PM), polycyclic aromatic hydrocarbon (PAH), polychlorinated dibenzo-p-dioxin/dibenzofuran (PCDD/F), and sulfur oxide (SO2) [8 -11]. Biodiesel is commonly produced from economic plants and among others: soybeans [10], rapeseed [7, 12], canola and sunflower [13], to name a few. One of the major problems of using economic plants as feedstocks is the likelihood of causing food shortages and higher food costs. As for such reason, research focus has been shifted to recycled cooking oil as the feedstock of biodiesel [12 - 15].

The primary objective of this study is to critically examine the effect of engine performance and exhaust emission of a diesel generator, using various diesel-biodiesel-butanol blends. This paper will contribute to the new novelty in the vehicle engines that would result in pollutant reduction, and most importantly reducing emissions from diesel engines.

2. Methods and Materials

2.1 Test fuels and diesel-fueled engine generator

Three different blends as recorded in Table 1. D100 (98% fossil diesel and 2% biodiesel) have been used. The key fuels are produced by the Chinese Petroleum Corporation (CPC), while the biodiesel (from waste cooking oil) used in the experiment is produced by Greatec Green Energy Corporation of Taiwan. The following diesel blend fuels have been used in this study: B10W10 (10 vol% butanol and 10 vol% biodiesel) and B10W20 (10 vol% butanol and 20 vol% biodiesel), respectively.

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Table 1. Composition of blended fuels used in the experiment.

Blend	Composition [% Vol]		
	Diesel	Biodiesel	Butanol
D100 (Base Case)	100%	0%	0%
B10W10	80%	10%	10%
B10W20	70%	20%	10%

2.2 Sample collection

The engine emission was monitored from tail pipe using online portable gaseous pollutant analyzer. Each sample was analyzed specifically for nitrogen oxide using a chemiluminescent detection (CLD). While carbon monoxide (CO) was detected using a nondispersive infrared detector (NDIR). Moreover, a detector flow isokinetic consoles system equipped (PM_{10} & $PM_{2.5}$ cyclone kit) with quartz fiber filters was connected on the downstream side of the diesel generator exhaust for the collection of particulate matters (PM_{10} & $PM_{2.5}$). The system could automatically tune pump flow rate by a set of pitot tube to fit the monitored flow rate of exhaust gas from engines. Then each filter sample was weighed by using an electronic analytical balance with fully automatic calibration technology to determine the net volume of collected PM.

3 Results and Discussions

3.1 Engine Performance

Brake specific fuel consumption (BSFC) and Brake thermal efficiency (BTE) are the most important parameters that measure the performance of diesel engine. Diesel fuel shows the lowest BSFC as compared to butanol–biodiesel blends in every test conducted or run. There was moderate low calorific values, high viscosity and high density in biodiesel-diesel blends which could be accounted for small increase in BSFC value [15]. Nevertheless, this challenge could be rectified with better dehydration of fuel mixtures, engines running at full load or high loads, or intake air preheated [12]. The BSFC had a reduction rate of 0.7% to 7.7% as shown in Figure 1. It was however found that the BTE reduction rate of the engine fell under the range of 6.3% to 9.8%, as shown in Figure 2. Besides that, it was also found that the higher biodiesel content in the blends has reduced the BTE as a result of lower carbon contents in the fuel.

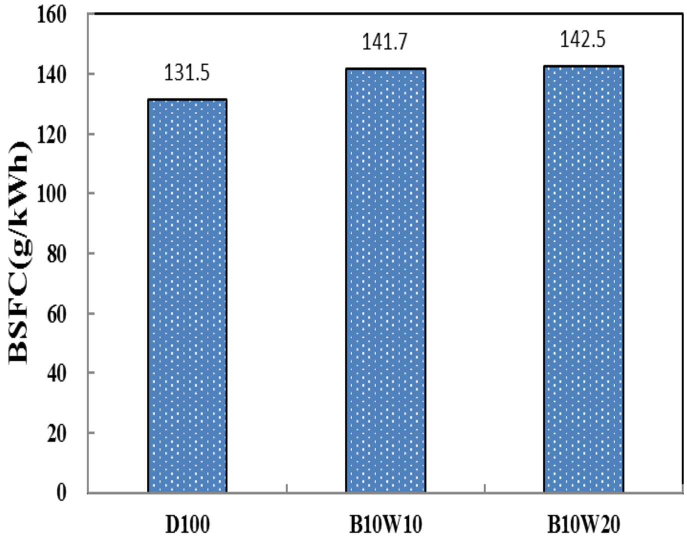

Fig 1. Brake specific fuel consumption (BSFC) for different diesel-butanol-biodiesel blends.

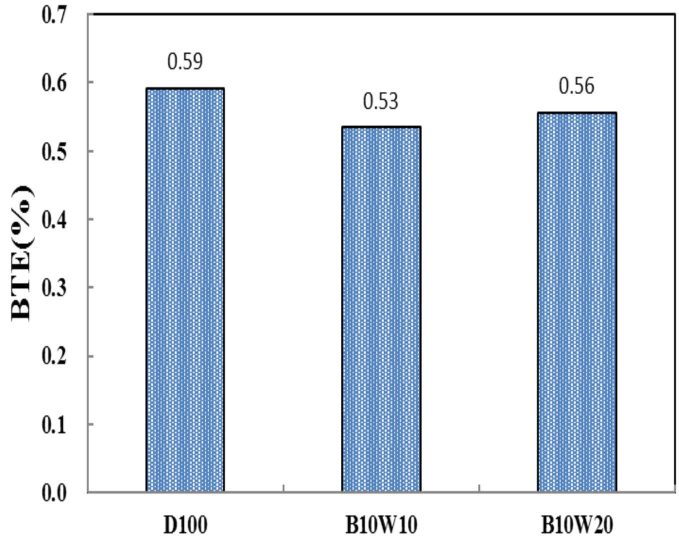

Fig 2. Brake thermal efficiency (BTE) for different diesel-butanol-biodiesel blends.

3.2 NO_x emissions

Figure 3 shows the emissions of NOx (nitrogen oxide) under different operation conditions with the diesel-butanol-biodiesel blends. The reduction of NOx with diesel/biodiesel/butanol blends is clearly observed as decreased by 11.65%-13.59% compared with the petroleum diesel.

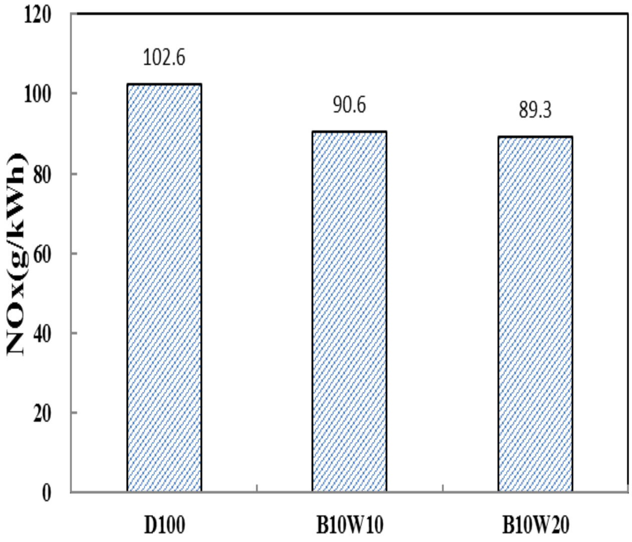

Fig 3. NO_x emission for different diesel-butanol-biodiesel blends.

3.3 Carbon Monoxide Emissions

Figure 4 shows the measured level of carbon monoxide under different operation conditions for the diesel-butanol-biodiesel blends. Carbon monoxide is a product of incomplete combustion. This causes the minor increase of the carbon monoxide emission level as observed in Figure 4. While for the diesel-butanol-biodiesel blend, the lower diesel contents have resulted in reduced carbon monoxide emission, when compared with the emission level of neat diesel with a reduction rate of 8.5% to 10.5%. Yet the emission level was slightly higher for the diesel-butanol blend, when compared against the emission level for pure diesel.

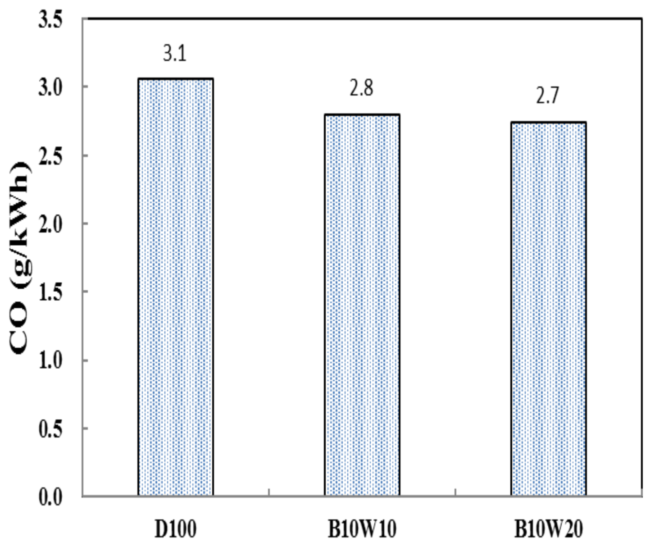

Fig 4. Emission of carbon monoxide for different diesel-butanol-biodiesel blends.

3.4 Emission of Carbonyl (CBC) Compounds

The composition of carbonyl compounds in the exhaust emissions for the diesel-butanol-biodiesel blends and formaldehyde, acetaldehyde and acrolein account for 75 to 90% of total carbonyl emissions, depending on fuel mixture composition. Various carbonyl (CBC) compounds were detected in the experiments, including formaldehyde, acetaldehyde, acrolein, propionaldehyde, crontonaldehyde, butyraldehyde and 2-butanone, benzaldehyde, valeradehtde and hexaldehyde. The three major CBC species in diesel emission were formaldehyde (about 62%), acetaldehyde (about 27.5%), butaldehyde and 2-butanone (about 3%). The three-major species accounted for about 92% of total CBC compounds in the emissions.

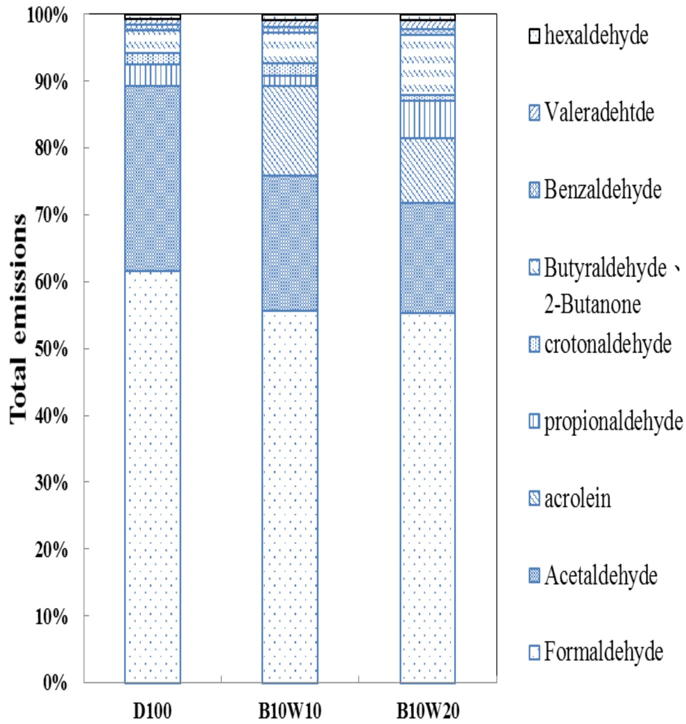

Fig 5. The composition of carbonyl emission from the diesel-butanol-biodiesel blends

Formaldehyde Emissions

The amount of formaldehyde emissions resulted from different diesel-butanol-biodiesel blends. Increasing the amount of biodiesel in the blend reduced the formaldehyde emission significantly [14].

Acetaldehyde Emissions

The amount of acetaldehyde emissions resulted from different diesel-butanol-biodiesel blends and this has increasing the amount of biodiesel in the blend reduced the acetaldehyde emission significantly.

Acrolein Emissions

The amount of acrolein emissions resulted from the diesel-butanol-biodiesel blends. While increasing the amount of biodiesel, up to 30%, in the blend reduced the acrolein emission.

4. Conclusions

The study examined the operation of a diesel generator operating with various blends of diesel-biodiesel-butanol. The biodiesel fuel used in this study was derived from waste cooking oil. Experimental results show that formaldehyde, acetaldehyde and acrolein as the major components of carbonyl compounds (CBCs) emissions. For a given amount of butanol, increasing the amount of biodiesel lowers engine-out emissions. The improvement is most likely due to additional oxygen embedded in biodiesel molecule, which assists the combustion process. The results have further revealed that among the blends examined in this study, lowest emission was observed with the blend containing 40% biodiesel.

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