



# Performance, combustion and emission characteristics of n-butanol additive in methanol–gasoline blend fired in a naturally-aspirated spark ignition engine



Lennox Siwale<sup>a,\*</sup>, Lukács Kristóf<sup>b</sup>, Akos Bereczky<sup>b</sup>, Makame Mbarawa<sup>c</sup>, Andrei Kolesnikov<sup>a</sup>

<sup>a</sup> Department of Mechanical Engineering, Tshwane University of Technology, Private Bag X680, Pretoria 0001, South Africa

<sup>b</sup> Department of Energy Engineering, Budapest University of Technology and Economics, H-1111 Budapest, Bertalan Lajos u. 4-6, D208, Hungary

<sup>c</sup> Ministry of Communication, Science and Technology, Jamhuri Street, P.O. Box 2645, Dar es Salaam, United Republic of Tanzania

## ARTICLE INFO

### Article history:

Received 19 April 2013

Received in revised form 14 October 2013

Accepted 14 October 2013

Available online 8 November 2013

### Keywords:

Brake specific fuel consumption

Brake thermal efficiency

Emission

Bioalcohols

Spark ignition

## ABSTRACT

The aim of the study was to compare the effects of dual alcohols (n-butanol and methanol) with single alcohol (methanol) blended in gasoline fuel (GF) against performance, combustion and emission characteristics. Problems arise in the fuel delivery system when using the highly volatile methanol–gasoline blends. This problem is reduced by adding n-butanol to methanol–gasoline blends. However, the satisfactory engine performance of the dual alcohol–gasoline blends need to be proved. The test fuels were GF, blend M53b17 (53 % methanol, 17 % n-butanol and 30% GF by volume), M20, and M70. The blend M53b17 was selected to match the vapor pressure (VP) of GF, whereas M70 to match the total alcohol content in the blend. The test fuels were a lean mixture with excess-air ratio of  $\lambda = 1.1$ . The experiments were conducted on a naturally-aspirated, spark ignition engine. The brake thermal efficiency (BTE) improved whereas the exhaust gas temperature (EGT) of the blends reduced, which is a benefit that reduces compression work. The regulated emissions were also reported. The blend M53b17 was recommended in preference to M70 because the former had shortened combustion duration, high-energy content and its VP was selectively matched to that of GF's.

© 2013 Elsevier B.V. All rights reserved.

## 1. Introduction

Environmentally friendly alternative or renewable fuels are taking the center stage globally in the search for greener combustible fuels for use in internal combustion engines [1]. The renewable fuels such as biofuels, which include bioalcohols, vegetable oils and biodiesel, biocrude and synthetic oils, are biodegradable and reduce air pollution [1,2].

The bioalcohols used in internal combustion engines can reduce emission of greenhouse gas and toxic exhaust components, enhance overall energy efficiency and reduce fuel costs [1,3–6].

The biobutanol used as a fuel in internal combustion engine is a second generation biofuel that can be produced from lignocellulose using biotechnological methods such as hydrolyzing lignocellulose to C<sub>5</sub> and C<sub>6</sub> sugars. The other method used to produce biobutanol is the gasification of biomass to synthetic gas, a precursor for the catalytic conversion of syngas to higher alcohols [7]. The synthesis of alcohols from synthesis gas remains an economically attractive method for making fuels and primary materials from chemical industries. The synthesis gas can be produced by natural gas reforming, coal gasification, or biomass gasification. The production of synthesis gas from biomass is advantageous

because of the following: (a) the flexibility regarding feedstocks used and (b) it is renewable. The catalytic conversion of synthesis gas to alcohols is advantageous as it uses forest or agricultural surplus or household wastes and does not compete with the food grain available for human need [1]. Therefore, the process such as the acetone–butanol–ethanol (ABE) fermentation is less competitive than the catalytic conversion route. Methanol is generated through the catalytic process of the synthesis of CO, CO<sub>2</sub>, and H<sub>2</sub> [4]. A very competitive biofuel for use in engines is butanol. It is a biomass-based renewable fuel, like ethanol, that can be produced by alcoholic fermentation of biomass feedstocks [8].

The advantages of butanol include: high tolerance to water contamination, use of existing distribution pipelines, lower vapor pressure (reducing vapor lock occurrence and evaporative emissions), miscible with gasoline without modifying vehicles, better fuel economy due to higher energy content, less knock tendency and reduces carbon monoxide (CO) and unburned hydrocarbon (UHC) [9–14]. The laminar burning velocities decrease [9] in the order of n-butanol, sec-butanol, iso-butanol and tert-butanol. Some of the chemical and physical properties of methanol, ethanol and gasoline are presented in Table 1 [15].

Several researchers have conducted experiments to establish the effects that butanol blends as alternative biofuels in spark ignition (SI) engines have on regulated emissions and engine performance characteristics. They compared their findings with the results obtained using gasoline fuel (GF).

\* Corresponding author. Tel.: +27 76 442 2347, +27 12 382 5164; fax: +27 12 382 5602.

E-mail address: [zambe.siw@gmail.com](mailto:zambe.siw@gmail.com) (L. Siwale).

**Table 1**  
Properties of methanol, ethanol, n-butanol and gasoline fuel.

	Methanol	Ethanol	Gasoline	n-Butanol <sup>a</sup>
Molecular formula	CH <sub>3</sub> OH	C <sub>2</sub> H <sub>5</sub> OH	–	C <sub>4</sub> H <sub>9</sub> OH
Oxygen content (%)	50	46	95–120	22
Density kg/m <sup>3</sup>	792	785	740	810
LHV MJ/kg	20	26.9	44.3	33.3
Octane number	111	108	>90	113
Auto-ignition temp (°C)	465	425	228–470	385
Stoichiometric A/F (λ) ratio[kg/kg]	6.47	9.0	14.8	11.1
Latent heat kJ/kg	1103	840	305	581.4
Vapor pressure at 23.5 °C (kPa)	3.2	–	60–90	32

<sup>a</sup> Source: [15,16].

Szwaja and Naber [16] found that the peak pressure is highest for 100% n-butanol. The fuel–mass flow rate increases with the fraction of n-butanol used in the blend: such as blend B30 (30% n-butanol and 70% gasoline fuel) and B50 [7]. The brake specific fuel consumption (BSFC) increases with increased ethanol fraction in GF (E5, E10, E15 and E20) [17]. Similar results were obtained when using pure-butanol, B20, B40 and B60 [18], when using B30, B50 and B100, n-butanol blends [7] and when using E60 [19]. Yusuf et al. [20] reported that brake thermal efficiency (BTE) increases more with ethanol blends than with GF.

Dernotte et al. [18] found that NO<sub>x</sub> emission concentration when measured against the equivalence ratio  $\Phi$  reduced with increased fraction of n-butanol in GF. The CO emission concentration when the SI engine was fired with n-butanol was higher than with GF. The UHC emission concentration was identical for B0, (GF), B20 and B40 at stoichiometric mixture. Increasing the fraction of butanol blend to B60 and B80 resulted in an increase in the UHC emission regarding B0. The blends used in the experiment were B20, B40, B60 and B80. Blends of methanol experimented on yielded similar results [21]. The blend ISB30 (30% of isobutanol) in spark engine promotes the oxidation of nitrogen to NO<sub>x</sub> emission in high temperatures [22–24]. Gu et al. [25] obtained similar results. Despite the research studies so far published in literature on n-butanol–gasoline, the potential of the bio-fuel of n-butanol still remains to be determined [18].

Andersen et al. [26] demonstrated that mixing a lower alcohol (methanol) to a higher alcohol (n-butanol) in gasoline (dual alcohols) reduces the vapor pressure (VP) and evaporative emission on the fuel delivery system. Therefore, a mixture can be prepared having the same VP as that of GF. However, they did not test any actual dual alcohol–gasoline blends to determine whether these blends can be applied satisfactorily to spark ignition engines, complying with the most recent emission regulations as well as the engine performance requirement.

In this study the purpose was to compare the engine performance, combustion and regulated emission characteristics of a dual alcohol–gasoline blend with those of the single alcohol–gasoline blends.

## 2. Methods and materials

The experiments were performed using the dual alcohol–gasoline and single alcohol–gasoline blends in turn at steady state (see Table 2). The dual alcohol–gasoline blends were specially selected to reduce the problems of high volatility caused by single alcohol–gasoline

**Table 2**  
Gasoline-methanol or/and n-butanol fuel blends.

Blend #	Methanol (%)	n-Butanol (%)	Gasoline (%)	Alco./total (%)	Identification
1	–	–	100	0	M0 and B0
2	20	0	80	20	M20
3	70	0	30	70	M70
4	53	17	30	70	M53b17

blends [26]. In this study, the performance and combustion characteristics and regulated emissions, for methanol–n-butanol–gasoline blend designated as M53b17 (53% methanol, 17% n-butanol and 30% GF by volume (v/v)), were experimentally evaluated. The other blends tested were: M20 (20% methanol and 80% GF by volume) and M70.

The engine used for the experiments was a Suzuki RS-416 engine with sixteen valves, in-line, and four-stroke and multi-point fuel injection system. The engine was warmed up until the cooling-water temperature was raised to 90 °C. The detailed engine parameters and specification are listed in Table 3.

### 2.1. Control system of the engines

The Suzuki engine was equipped with an electronic control module, (ECM), actuators, and sensors to control fuel–mass flow and an exhaust gas recirculation, (EGR). The optimum engine operation was reached using all these control units or variables with the help of sensors that measure manifold air temperature, (MAT), manifold air pressure, (MAP), crank oil pressure, and knock.

### 2.2. Measuring equipment

The sampling gas was pumped through the pre-sampler, which was connected to the gas analyzers. A Horiba 8120F analyzer module included hardware components (two Horiba Model AIA-23 infrared gas analyzers) to measure the CO and CO<sub>2</sub>. The process of calibration of the gas analyzers involved passing two known certified concentration ( $\pm 2\%$  accuracy) of the target gas, one for low/zero point and the other for high/span point, and finding the difference between the concentrations of the calibration gas and the analyzer response. The unburned hydrocarbon content was measured by the Horiba FID-FIA-22 hydrocarbon analyzer, using heated flame ionization sensor type. Nitrogen oxides were measured by a chemiluminescence detector (CLD) of the type CLD-53M [27]. The fuel–mass flow was measured by the dynamic fuel consumption measuring equipment type AVL 7131-12. The fuel balance works on the gravimetric measuring principle. Fuel is supplied to the engine from a measuring vessel, the weight of which is continuously measured with an accuracy of 0.12%. Torque was measured by an eddy current dynamometer of the type Carl Schenck W260. The engine control unit (ECU) used was the versatile engine management system, Vems 3.3. The accuracies of the measuring instruments are listed in Table 4.

### 2.3. Indication system

Indicated pressure was measured by a piezo-electric transducer of the type: Kistler 6051B-Kistler-6517BCD-KIAG 5001 incorporated in the miniature pressure sensor with a spark plug adaptor. The measurement was carried out using a 1024 triggered signal/round of the crankshaft by an encoder (Hengstler RI 32-0/1024.ER.14kA). The piezo-electric transducer was calibrated using a calibration cylinder filled

**Table 3**  
Engine specification and parameters.

Engine type	Suzuki RS-416 1.6L
Model	T10M16A (2006)
Bore [mm]	78
Stroke [mm]	83
Swept volume [l]	1.586
Compression ratio [–]	11.1
Power (kW)	92 (@ 6800 RPM)
Max torque (Nm)	148 (@ 4800 RPM)
Number of cylinders	4
Camshaft	DOHC with VVT
Number of valves	4
Fuel type	Petrol-P
Fuel aspiration	Naturally aspirated
Fuel delivery	Multi-point injection

Download English Version:

<https://daneshyari.com/en/article/6657319>

Download Persian Version:

<https://daneshyari.com/article/6657319>

[Daneshyari.com](https://daneshyari.com)