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The influence of biobutanol on performance parameters of mobile generator

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Abstract. The expansion of biofuel also affects the area of using small internal combustion engines, which are widely used in municipal equipment such as minitractors, chainsaws, mowers and brush cutters. These small engines have their specific operation conditions, especially given by high operating speeds and high loads. Current legislation for fuel BA 95 prescribes the addition of ethanol. The percentage is however very small nearly not affecting the operation of combustion engines. The paper is focused on biobutanol since it is considered as more advanced type of alcohol based fuel than bioethanol. The measurement is focused on a small combustion engine of portable generator with maximum power of 2.5 kW. There is monitored influence of biobutanol on their performance parameters. As the mixing ratios are in the range of 100% fuel BA 95 (without ethanol) to 100% biobutanol.

Key words: combustion engine, bio-fuels, biobutanol, generator, engine parameters, fuel consumption.

INTRODUCTION

In order to reduce the amount of the greenhouse gases released into atmosphere, reduce the dependence on fossil fuels and their import to country, furthermore for support of local production the biofuels are used (Demirbas, 2009). The aim is to achieve a 10% share of energy from renewable sources in transport in 2020 according to EU directive 2009/28/EC. Currently, the ethanol is mostly used as a bio-substitution for gasoline in spark ignition engines. However, the ethanol has many disadvantages such as its affinity to the water, insufficient lubricity, aggression to the most of current sealing elements, low calorific value etc. (Čedík et al., 2014a; Čedík et al., 2014b). Butanol is the second generation biofuel and it is mostly used as admixture in diesel or biodiesel in compression ignition engines (Rakopoulos et al., 2010; Altun et al., 2011; Tüccar et al., 2014; Yilmaz et al., 2014). Production of butanol is similar as ethanol, it can be produced by fermentation or in petrochemical way (Ezeji et al., 2003). It is mainly used in spark ignition engines, requires the modification of the air-fuel mixing ratio, due to lower stoichiometric ratio of butanol, similar as when using ethanol. Butanol has several advantages over ethanol, such as a lower ignition temperature and higher calorific value. Butanol is more mixable with hydrocarbon fuels and the stoichiometric ratio is close to that of gasoline. This ratio allows the use of higher concentrations of butanol in gasoline without engine modification. Butanol is less corrosive due to lower affinity for water.

Properties of butanol are closer to fossil fuels. (Durre, 2007; Shapovalov & Ashkinazi, 2008; Qureshi & Ezeji, 2008; Andersen et al., 2010; Harvey & Meylemans, 2011; Swana et al., 2011; Serras-Pereira et al., 2013; Hönig et al., 2015a,b,c). Gasoline fuel blended with butanol was studied in the ratios from 3% vol. to 100% butanol (Rice et al., 1991; Alasfour, 1997; Yacoub et al., 1998; Gautam & Martin, 2000a; Dagaut & Togbé, 2008; Gautam & Martin, 2000b; Dagaut & Togbé, 2009; Wallne et al., 2009; Williams et al., 2009; Yang et al., 2009; Dernotte et al., 2010; Wigg et al., 2011; Gu et al., 2012; Feng et al., 2013; Elfasakhany, 2014). The results show that addition of butanol reduces exhaust emissions of CO, HC, CO_2, but NO_x emissions are increased depending on concentration and test conditions, as compared with gasoline. The increase in CO and HC and NO_x emissions is reduced at concentrations greater than 60% butanol. Due to lower calorific value than gasoline the specific fuel consumption is higher and the torque and power are lower compared with gasoline. Better combustion efficiency can be achieved due to better anti-detonation characteristics of butanol compared with gasoline and higher oxygen content. Some sources indicate the increased torque and reduced energy consumption at 35% concentration of butanol in gasoline (Feng et al., 2013). Other sources state that the engine power is maintained at proportion of 80% (by volume) gasoline and 20% butanol. (Yang et al., 2009). Most of the above studies were carried out on the engines with fuel injection. Sources indicate small ratios to (3, 7, $10\%_{vol.}$ Butanol) mixture of butanol in gasoline for testing engine carburettor (Elfasakhany, 2014).

Due to the fact that the market for small internal combustion engines is currently based on the delivering fuel through the carburettor, this paper is focused precisely on this issue. Fuel injection on small internal combustion engines is used only rarely at their recent construction.

The aim of this paper is to compare the performance parameters and fuel consumption of the mobile generator with rated power of 2.7 kW powered by small combustion engine while using fuels based on biobutanol and BA 95 petrol. The mixing ratios are selected in the range from 100% BA 95 (without ethanol) up to 100% biobutanol.

MATERIALS AND METHODS

Measurements were carried out on mobile generator ProMax 3500A with a rated power of 2.7 kW powered by small Briggs and Stratton engine type Vanguard 6,5 HP with a rated power of 4.8 kW. Assembly of small combustion engine and the alternator is suitable for the quick and easy driving of load of the engine. In this case value of the output current of the alternator is proportional to combustion engine load.

During loading of the combustion engine there is measured frequency, electrical current and voltage of the output of the generator (elektrometer ZPA ED310 equipped with an RS 485, the accuracy of 0.05%). Simultaneously with the measurement of electrical parameters is also measured fuel mass flow rate using Vibra AJ 6200 standard precision scale (measuring range from 0 to 6,200 grams and the accuracy 0.1 g). In order to monitor the operating parameters of the engine during measurements, the oil temperature sensor, fuel temperature sensor and intake air temperature sensor was mounted on the engine. All data are stored to the PC memory using RS482 to RS232 interface and for this purposes software application was developed.

The principle of measurement is based on the principle of operation of the internal combustion engine and electric generator. The internal combustion engine operates in the range about 3,000 rpm, corresponding to a frequency of 50 Hz of electric generator output. During loading of the internal combustion engine decreases its speed according to the control part of the engine characteristics. However, properly adjusted governor of the engine keep the engine speed steady regardless of engine load. At the moment when is external speed characteristics is achieved, so there is a significant change in engine speed and thus the output frequency of the electric generator.

Measurement is focused on monitoring of the impact of fuel mixture on the fuel consumption during controlled loading of the engine.

Based on engine operation while using pure BA 95 petrol (% BUT) there was selected several measurement points in steps approximately 25%, 50%, 70% and 95% of rated power. Measurement point at a full load (100%) is not selected because of possibility of reaching the external speed characteristic of the engine.

Transmission losses and the change in viscosity of the oil are not considered. The measurement is performed at an operating temperature, which is dependent on the load and the engine oil temperature was kept within the range of from 90 °C to 110 °C.

Used fuels are based on biobutanol and BA 95 petrol. Especially for this measurement there was fitted BA 95 petrol without any bio-components required by the law. In the Czech Republic ethanol is mainly used as this component. There were chosen several ratios of biobutanol and BA 95 petrol:

100% of petrol (0% BUT)
75% of petrol and 25% of biobutanol (25% BUT)
50% of petrol and 50% of biobutanol (50% BUT)
25% of petrol and 75% of biobutanol (75% BUT)
100% of biobutanol (100% BUT).

During the measurement there the air–fuel equivalence ratio was monitored. Consequently, the air-fuel ratio (AFR) was changed using the choke valve. AFR for pure petrol is commonly 14.7:1 and 12:1 for butanol.

RESULTS AND DISCUSSION

Table 1. shows average values of engine torque (calculated), power, speed, mass fuel consumption and specific fuel consumption and standard deviations for each operation mode of an engine.

Fig. 1. shows engine speed and power developed at the respective engine modes. It is obvious, that engine mode is set without significant inaccuracies. Only in the case of engine mode no. 20 there is evident, that 95% engine load results in significant decrease in speed. At this particular point there was transition between control area and external speed characteristics of the engine. Based on this point it can be expected that 95% load of the engine using 0% BUT fuel corresponds with 100% load of the engine running with 100% BUT fuel. Performance parameters of the engine declined about 5% when changing fuel from pure petrol to pure biobutanol.

Table1. Engine mode and measured engine parameters

Fuel	Engine mode	Engine parameters: Torque (Nm)*	Power (kW)	Engine speed (rpm)	Fuel consumption (kg h^{-1})	Specific fuel consumption (g kWh^{-1})	Standard deviation: Power (kW)	Engine speed (rpm)	Fuel consumption (kg h^{-1})
0% BUT	1	2.01	0.666	3,169	0.459	689.1	0.00139	2.78	0.0306
	2	3.96	1.302	3,141	0.712	547.4	0.00112	1.50	0.0813
	3	5.87	1.913	3,113	0.895	468.3	0.00185	3.17	0.0854
	4	8.04	2.554	3,046	1.088	426,3	0.00979	6.61	0.0703
25% BUT	5	2.01	0.666	3,169	0.560	841.2	0.00105	5.00	0.0448
	6	3.93	1.304	3,140	0.728	558.1	0.00287	3.18	0.0865
	7	5.89	1.921	3,113	0.934	486.5	0.00370	2.84	0.0575
	8	8.11	2.580	3,046	1.126	436.4	0.00830	4.23	0.0808
50% BUT	9	2.01	0.665	3,166	0.617	928.1	0.00153	10.26	0.0632
	10	3.96	1.298	3,131	0.724	557.4	0.00356	4.83	0.0992
	11	5.85	1.903	3,106	0.892	468.7	0.00130	4.50	0.0704
	12	8.05	2.560	3,038	1.113	434.7	0.00749	11.93	0.0719
75% BUT	13	2.03	0.672	3,157	0.679	1009.8	0.00211	5.66	0.0958
	15	5.88	1.912	3,106	0.900	470.8	0.00487	3.43	0.0494
	16	8.10	2.557	3,013	1.165	455.7	0.00843	4.80	0.0643
100% BUT	17	2.05	0.677	3,152	0.664	980.0	0.00185	4.80	0.0410
	18	4.03	1.321	3,127	0.832	630.1	0.00170	2.72	0.0429
	19	5.97	1.939	3,080	1.019	525.3	0.00406	3.37	0.0510
	20	8.46	2.589	2,902	1.236	477.6	0.00785	16.46	0.0537

* calculated value

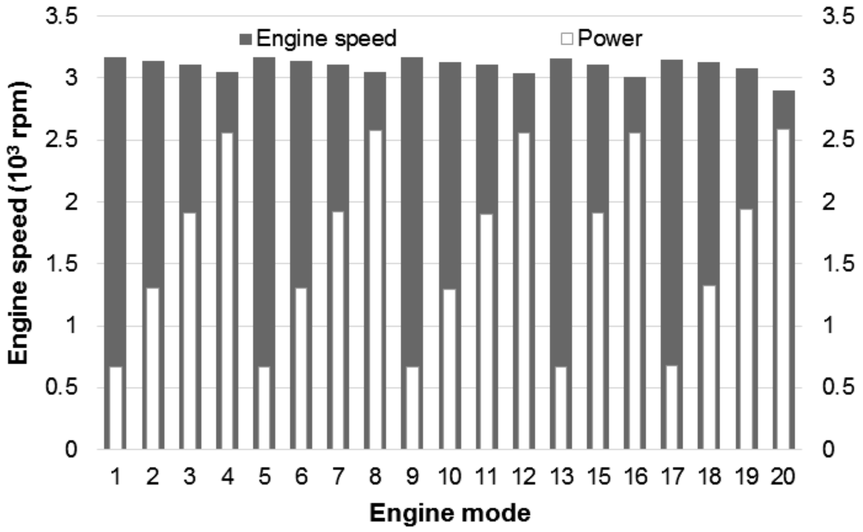

Figure 1. Engine modes selection chart.

The progress of fuel consumption in various operating modes of the engine is shown in Fig. 2. It is evident that a change in fuel consumption due to the changes in air-to-fuel ratio of the fuels' mixture occurred primarily in the engine performance modes corresponding to the lower loads. For loads of 25% was due to addition of biobutanol the increase in specific fuel consumption was 30%, while the fuel consumption did not change by more than 10% when running at a full load. The lowest specific fuel consumption of 426.3 g kWh^{-1} was achieved when using a fuel containing 0% butanol (0% BUT) for full load (about 95%) operation.

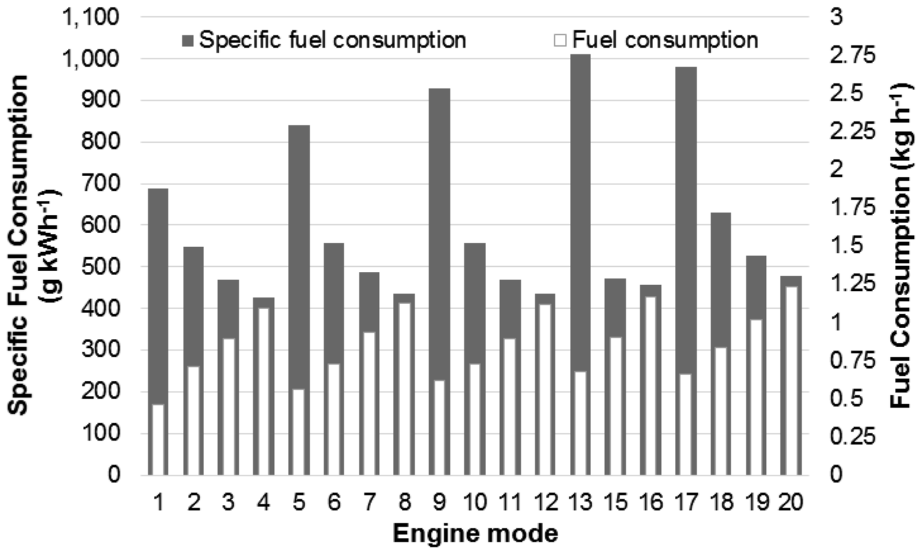

Figure 2. Changes in fuel consumption at specific engine modes.

CONCLUSIONS

When operating with a small internal combustion engine, it was noted that in short terms of combustion any ratio of biobutanol and petrol premixed can be suitable for generation of electrical energy. The higher percentage of biobutanol results in a worse start of cold engine. There were no major changes in other evaluated parameters (Table 1., Fig. 1., Fig. 2.):

- performance parameters (output power) of the engine were not decreased by more than 5%,
- mass fuel consumption and specific fuel consumption varies mainly at lower loads, where the difference is up to 30%,
- the difference in fuel consumption does not exceed 10% at higher loads (The lowest specific fuel consumption 426.3 g kWh^{-1} was achieved at full load (about 95% of rated power) with a fuel containing 0% butanol).

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