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Comparison of the effect of gasoline – ethanol E85 – butanol on the performance and emission characteristics of the engine Saab 9-5 2.3 l turbo

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Abstract. Due to the increasing environmental demands of the European Union for reducing emissions, it is necessary to utilize biofuels at the expense of the conventional fossil fuel BA95. Biofuels in spark-ignition engines usually use ethanol at a ratio of up to 85% to 15% of the conventional fuel BA95. Such a fuel is known as E85. Butanol also has very similar properties to ethanol. Ethanol is a higher alcohol. For comparison, ethanol and butanol fuels with conventional fuels were chosen for the vehicle Saab 9-5, turbo-charged 2.3l. This vehicle is completely adapted to operation on ethanol fuel (broad adaptation control unit, suitable sealing elements, fuel pump, etc.). The engine performance and emissions were monitored when operating on these fuels as compared to the conventional fuels BA95. It can be stated that the engine reached higher performance parameters when operating on ethanol and butanol fuels. This is due to the fact that the control unit increases the fuel supply during operation on biofuels (lower calorific value of fuel). There is no lean combustion and the possible damage to the engine during long-term operation. From the perspective of bootable showing, butanol fuel has worse parameters compared to ethanol fuel and conventional fuels.

Key words: biofuels, butanol, ethanol, performance parameters, emissions.

INTRODUCTION

In recent years, the European Union has devoted increasing attention to the possibility of using biofuels to power mobile machinery. The main requirement for the biofuel demand is the similarity of its chemical and physical properties to the conventional fuel.

One of the most suitable biofuels usable in internal combustion engines is bioethanol (in the Czech Republic, mainly produced from sugar beet and corn). The use of bioethanol in gasoline engines is not a significant problem and is also significantly more widespread than in diesel engines (Paul et al., 2013; Su et al., 2013). This is mainly due to the big difference between the parameters of ethanol and diesel. The main problem is the especially low ignitability (the cetane number is only 8), which must be increased with special additives. Despite significant additive dosing, it is necessary to conduct adjustments in diesel engines. First of all, increased compression ratio, used as a bi-fuel system with separate tanks and mixing bioethanol directly into diesel (which complicates the difficult miscibility of both fuels and reduces fuel lubricity) (Křepelka, 1988; Křepelka, 1997; Hromádko et al., 2010; Hromádko et al., 2011; Küüt et al., 2011; Olt & Mikita et al., 2011; Khalil & Gupta et al., 2013).

The use of bioethanol as a fuel is not 100% normal (Shifter et al., 2013). In practice, there are usually two possibilities for adding a small amount of ethanol to gasoline (usually below 5% – the amount required for adjustment of motor management – or more typically about 85% – the number required for already adjusted motor management). The required properties of the ethanol added to motor fuels are specified in the quality standard DIN EN 65 6511 – Automotive fuels – Ethanol as a blending component for petrol – Requirements and test methods. The characteristics and requirements for E85 are given in the standard EN 65 6512 (Automotive fuels – Ethanol E85 – Requirements and test methods, 2006). Selected quality indicators of ethanol mixed in gasoline and E85 are shown in Table 1 (Šebor et al., 2006; Olt & Mikita et al., 2011).

The aim of this paper is to compare the effect of fuel on the operational characteristics of the spark ignition internal combustion engine of a vehicle Saab 9–5. It is a vehicle that is adapted to operate on biofuels, and therefore there are no technical problems arising from the aggressive nature of these fuels on the sealing elements. The chosen fuels are petrol Natural 95 (N95), 85% ethanol mixed with gasoline (E85), and butanol as a higher hydrocarbon (But). The engine control unit has a wide range of adaptation values to be able to compensate for the reduced calorific value of biofuels. The operational parameters focused on are measuring the torque, performance and emissions produced by the combustion engine.

Table 1. Comparison of the basic properties of ethanol, butanol and gasoline (Šebor et al., 2006; Mužíková et al., 2009; Hromádko et al., 2011)

Fuel	Ethanol	Butanol	Gasoline
Density at 15 °C (kg m^{-3})	795	810	750
Viscosity at 20 °C (mm^2 s^{-1})	1.52	3.64	0.4–0.8
Calorific value (MJ kg^{-1})	26.4	32.5	43.3
Octane number VM	108	96	95
Boiling point (°C)	78	118	30–190
Vapour pressure by Reida (kPa)	16.5	18.6	75
Oxygen content (% vol)	34.7	21.6	< 2.7

MATERIAL AND METHODS

Measurements were conducted on the vehicle Saab 9-5 (Fig. 1) with a turbocharged engine of 2.3 dm^3. This vehicle is already adapted to run on E85 (85% ethanol and 15% natural 95). It contains sealing elements that degrade E85 fuel and an adaptive controller was used which, when using any fuel ratio of N95 E85 fuel (95 octane), sets increased supply of fuel to compensate for the difference in the calorific value of the fuel used.

The performance and emissions were measured by a cylindrical test (Fig. 2) under free acceleration. The cylindrical testing was also connected to flywheels, which slow down the dynamic process and allow the turbocharger boost pressure to develop sufficiently even at lower operating speeds.

Figure 1. Saab 9-5.

Figure 2. Cylindrical test room.

The emission measurement used was the Brain Bee emission analyzer. The main technical parameters are given in Table 2.

Table 2. The parameters of the emission analyser Brain Bee

Component	Distinction	Accuracy
CO	0.01% vol.	0.03% vol. or 5% RV (read value)
CO_2	0.1% vol.	0.5% vol. or 5% RV
HC	1 ppm vol.	10 ppm vol. or 5% RV
O_2	0.01% vol.	0.1% vol. or 5% RV
NO	1 ppm	10 ppm vol. or 5% RV
Opacity	0.1%	2%
Temperature	1°C	2.5°C

Performance measurement is performed so that corresponding pulses are sensed in engine rotational speed (incremental encoders were read with speed rollers with an accuracy of 20 nanoseconds) and from them, after taking into account the transmission ratio, the angular velocity and angular acceleration of the engine crankshaft are calculated by the relationships 1 and 2.

$$\varpi_j = \frac{4 \cdot \pi}{t_j + t_{j+1}} \qquad (1)$$

$$\varepsilon_j = 4 \cdot \pi \cdot \frac{\frac{1}{t_{j+1}} - \frac{1}{t_j}}{t_j + t_{j+1}} \qquad (2)$$

ϖ_j (rad·s^{-1}) – central angular speed of the engine crankshaft between j-th well plus the first turn;

ε_j (rad·s^{-2}) – angular acceleration of the engine crankshaft at an angular speed ϖ_j; t_j (s) – the duration of the j-th revolution of the engine crankshaft; t_{j+1} (s) – j plus the duration of the first turn of the engine crankshaft.

The measurement begins by setting the full dose of fuel when the engine starts and quickly accelerates from idle to maximum speed. The calculation of torque and power are given by the relationships 3 and 4.

$$M = I \cdot \varepsilon \tag{3}$$

$$P = M \cdot \varpi = I \cdot \varepsilon \cdot \varpi \tag{4}$$

P (W) – useful engine power to the crankshaft; M (N·m^{-1}) – engine torque; ϖ (rad·s^{-1}) – angular speed of the engine crankshaft; I (kg·m^2) – moment of inertia of the moving masses at reduced engine crankshaft; ε (rad·s^{-2}) – angular acceleration of the engine crankshaft.

A comparison of the operating parameters of the internal combustion engine vehicles Saab 9-5 were used for the fuels N95 (natural) 95 E85 (85% ethanol and 15% N95) and But (butanol).

RESULTS

From the measurement of the performance parameters, it is evident that the highest torque and power was reached with E85. It was followed by But fuel. The worst performance parameters were achieved with the fuel N95 (Table 3, Figs. 3 and 4). This is due to the fact that the control unit increases the fuel supply during operation on biofuel (lower calorific value of fuel) to prevent lean combustion and hence possible damage to the engine during extended operation. The given results are always the moving average of 3 measurements, only in the case of the fuel But, of two measurements.

Table 3. Maximum engine performance parameters of Saab 9-5

	Max. torque (Nm)	Engine Speed (1 min^{-1})	Max. power (kW)	Engine speed (1 min^{-1})
N95	377	2,875	134	4,600
E85	413	2,825	141	4,575
But	412	2,800	137	4,325

Evaluation of the emission was conducted at the same stage of the test as the measurement of the performance parameters during the acceleration tests on a cylindrical test. The emission parameters of the internal combustion engine were recorded in a text file with a frequency of 2 Hz. Evaluation then proceeded to find the emissions produced above the maximum. The minimum value was only registered in the case of CO_2. Thus, the values obtained are given in Table 4 below. Table 4 also gives the maximum speed measured by a very accurate sensor that is part of the emission analyser Brain Bee.

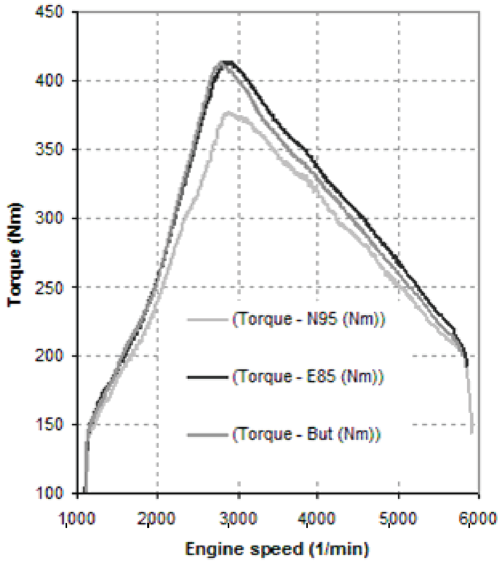

Figure 3. Course of engine torque.

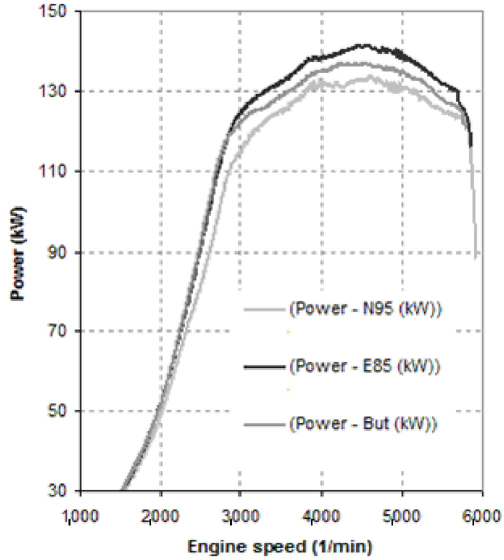

Figure 4. Course of engine power.

Table 4. Emission parameters of the engine Saab 9-5

		Speed (1/min)	CO_2 (%)	NO_x (ppm)	HC (ppm)	CO (%)
E85	1	5,950	12.0	496	25	4.87
	2	6,230	12.1	537	22	4.88
	3	6,120	12.1	515	67	4.87
	4	6,150	12.3	559	39	4.16
	Ø	**6,113**	**12.13**	**527**	**38.25**	**4.70**
N95	1	6,140	9.4	414	96	8.47
	2	6,210	9.5	254	77	8.52
	3	6,270	9.6	205	78	8.98
	Ø	**6,207**	**9.50**	**291**	**83.67**	**8.66**
But	1	6,280	10.6	345	181	6.9
	2	6,410	10.6	804	308	6.91
	Ø	**6,345**	**10.60**	**575**	**244.50**	**6.91**

Grey colour in Table 4 underlines the average value of the fuel with which the best emission parameters are achieved. Hydrocarbons HC and carbon monoxide CO in E85 and oxides of nitrogen in the fuel N95. The graphic design of this comparison is shown in Figs. 5 and 6.

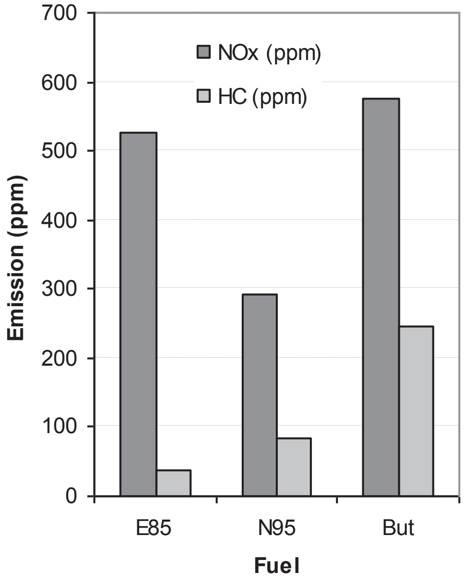

Figure 5. Course of emission – NO_x a HC (ppm).

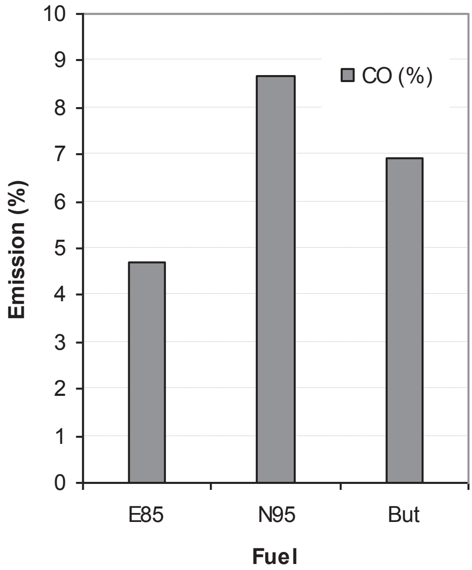

Figure 6. Course of emission – CO (%).

The total comparison is then shown in Fig. 7, which shows the individual components of the emission, and the summary displays the fuel in units of ppm. E85 has the best emission parameters, followed by But. The conventional fuel N95 had the worst parameters.

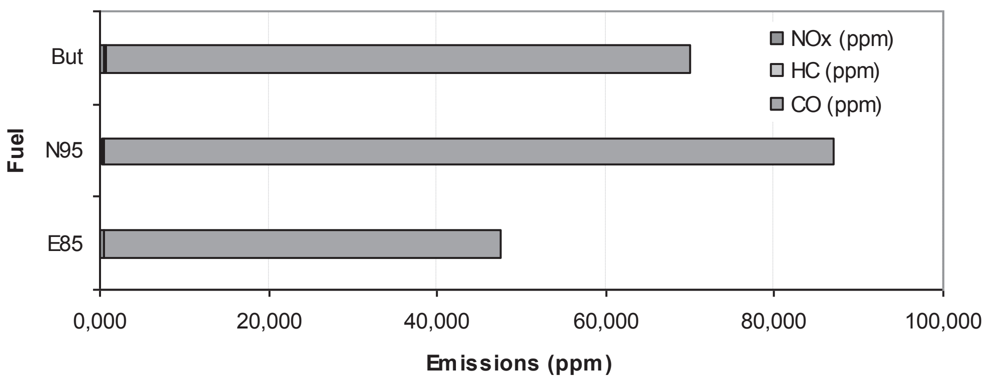

Figure 7. Cumulative emission – $NO_{x,}$ HC a CO (ppm).

CONCLUSION

Measurements were performed on a vehicle with the Saab 9–5 turbo engine capacity of 2.3 dm^3. It is a vehicle that allows burning of standard fuel N95, E85 biofuels, but also with increased fuel supply, so as to offset the lower calorific value of the fuel E85 to fuel N95.

The measurement used was the dynamic performance measurement while recording the emission parameters of the engine. The dynamic measurement method was implemented in the cylindrical testing, flywheels, so that the effect of the turbocharger was reached operating at low engine speeds. The analyser Brain Bee was chosen to evaluate the emission parameters.

In terms of the performance parameters, it can be stated that the abovementioned supercharged internal combustion engine achieves the best performance on the E85 fuel. The lowest performance parameters were achieved by combustion engine on the fuel N95. In terms of emissions, the order is not quite same order. The best emission parameters of the internal combustion engine were achieved when operating on E85 and worst when running on N95.

Overall, the conclusion is that the turbocharged internal combustion engine 2.3 dm^3 of vehicles Saab 9-5 achieved the best performance and emission parameters on the E85 fuel. The second best fuel was the fuel But, before the conventional fuel N95, which finished the testing in the third and last position.

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