Agronomy Research **12**(2), 315–322, 2014

Effect of E85 Fuel on Harmful Emissions – Škoda Fabia 1.2 HTP

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Abstract: This article deals with harmful emissions production by a spark ignition engine Škoda Fabia 1.2 HTP operating on E85 fuel. The measurement was performed on a test bench using a test cycle that simulates real traffic conditions. Three variants were chosen for burning E85 fuel and the first one was the usage of the E85 fuel without modifications of the engine control unit (variant 1 – E85), the second one was the usage of the E85 fuel with prolonged time of the injection by 28% (variant 2 – E85+) and the last third variant was reference fuel petrol Natural BA95 (variant 3 – N95) for comparison. The results of the measurement have shown that for the variant 1 – E85 there was a significant decrease in the emissions of CO and HC while increasing emissions of NO_X especially at high load. For the variant 2 – E85+ there was a significant increase of the emissions of CO and HC, again especially at high load. Emissions of NO_X have shown a decrease for this variant. CO_2 emissions were approximately on the same level for both variants (E85, E85+) in comparison with the variant 3 – N95.

Keywords: ethanol, E85 fuel, emissions production.

INTRODUCTION

The increase in the usage of bioethanol as a fuel in Europe is significant (up to 15% annually) (Beran, 2011). The reason could be the European Parliament and the European Council, which adopted the so called action plan concerning with the issue of biofuels in transport. In the action plan the strategy for achieving the planed 20% substitution of conventional liquid motor fuels with alternative fuels by 2020 is defined (Šebor et al., 2006). Furthermore, according to the European Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC the target is a 20% share of energy from renewable sources and a 10% share of energy from renewable sources in transport (EU Directive 2009/28/EC; Beran, 2011;). The second reason could be the dependence of Europe on the imported crude oil products. European OECD countries were dependant on the imported crude oil in the year 2007 from about 65% and by 2030 the dependence could increase up to 83%. The transport in Europe is dependant on the crude oil products from about 98% (Šebor et al., 2006; IEA, 2009; Gnansounou, 2010). France is the major consumer of bioethanol in Europe with a 5.41% share of bioethanol on the market (in Sweden it is 5.14%) (Gnansounou, 2010).

The most used fuel with higher share of bioethanol is the E85 fuel, which is made from 85% bioethanol and from 15% petrol. In comparison with the petrol the E85 fuel has lower energy content and higher density, it also has higher share of oxygen and therefore lower stoichiometric ratio. Furthermore it has lower Reid vapour pressure, higher octane number and therefore an option of using higher compression ratio than petrol Natural 95 and higher heat of evaporation (Pumphrey et al., 2000; da Silva et al., 2005; Laurin, 2006a; Laurin, 2006b; Šebor et al., 2006; Mužíková et al., 2010; Hromádko et al., 2011; Küüt et al., 2011). Taking into account new technologies for its production (second and third generation bioethanol) it could be a perspective alternative fuel which reduces the content of released greenhouse gases and the dependence on the crude oil (Wendhausen et al., 2001; Varga et al., 2003; Sánchez & Cardona, 2008; Goh & Lee, 2010; Hromádko et al., 2010; Eisenhuber et al., 2013; Tutt et al., 2013).

It's well known, that using biofuels such as E85 reduces production of the current most watched greenhouse gas the carbon dioxide. If we neglect CO_2 emitted during processing of primary raw materials, bioethanol is actually CO_2 neutral (Hromádko et al., 2009; Hromádko et al., 2011; Winthera et al., 2012). This article also describes how this fuel affects other harmful emissions such as carbon monoxide, oxides of nitrogen and unburned hydrocarbons. According to the other experiments in this field (Graham et al., 2008; Graham et al., 2009; Vojtíšek-Lom & Mazač, 2011; de Meloa, 2012) we can expect that emissions of CO and HC will be lower compared to petrol, emissions of NO_X could be higher and emissions of CO_2 could be approximately on the same level.

As it was already mentioned, the purpose of the experiment was to measure emissions of CO_2, CO, NO_X and HC, produced by light duty petrol vehicle, operated on E85 fuel without engine modifications of the engine control unit and with prolonged time of the injection in simulated real traffic conditions and to compare with operation on petrol Natural 95.

MATERIALS AND METHODS

The whole experiment was performed on the test bench of the Department of Vehicles and Ground Transport at the CULS Prague.

For the experiment an electric-swirl dynamometer V125 with construction IP23/ICW37 was used. The reaction from the dynamometer was captured via a tensometric sensor with nominal load 2kN and merged mistake 0.5% of the nominal load.

The measurements were performed on the engine Škoda Fabia 1.2 HTP. This engine is a three-cylinder atmospheric in-line four stroke engine, it has overhead cams with 2 valves per cylinder. Max. power is 40 kW at 4,750 rpm, max. torque is 106 Nm at 3,000 rpm and compression ratio is 10.3:1.

The emissions were measured by an emission analyser VMK. This analyser was made by the VMK s.r.o. according to the needs of the Department of Vehicles and Ground Transport at the CULS Prague. The parameters of the analyser are listed in Table 1.

This analyser is using the Non Dispersive InfraRed method (NDIR). This method utilizes the fact, that every gas, which has at least two atoms in its molecule, has unique dependence of the absorption coefficient on the wavelength of the radiation.

As it was already mentioned, the experiment was performed for E85 fuel without modifications of the engine control unit (variant 1 – E85), E85 with prolonging of the time of the injection (variant 2 – E85+) and Natural BA95 (variant 3 – N95). For prolonging of the time of the injection for the second mentioned variant additional control unit plugged between ECU and injectors was used. That means that the input for this unit are the impulses for the injectors sent by ECU and the additional unit is extending them by preset period in percentage and is sending them to injectors. In the case of the variant 2 – E85+, the prolonging of the time of the injection was by 28%.

Table 1. Parameters of the emission analyser

Measured component	Scope	Resolution	Accuracy
CO	0–10% vol.	0.001% vol.	0–0.67%: 0.02% 0.67–10%: 3% from measured value
CO_2	0–16% vol.	0.1% vol.	0–10%: 0.3% 10–16%: 3% from measured value
HC	0–20,000 ppm	1 ppm	10 ppm or 5% from measured value
NO_X	0–5,000 ppm	1 ppm	0–1000 ppm: 25 ppm 1,000–4,000 ppm: 4% from measured value
O_2	0–22% vol.	0.1% vol.	0–3%: 0.1% 3–21%: 3% from measured value

For communication with ECU the diagnostics system VAG-COM was used. This system was primary used for reading values from ECU, such as rotations, load of the engine (in percentage) and the air-fuel equivalence ratio.

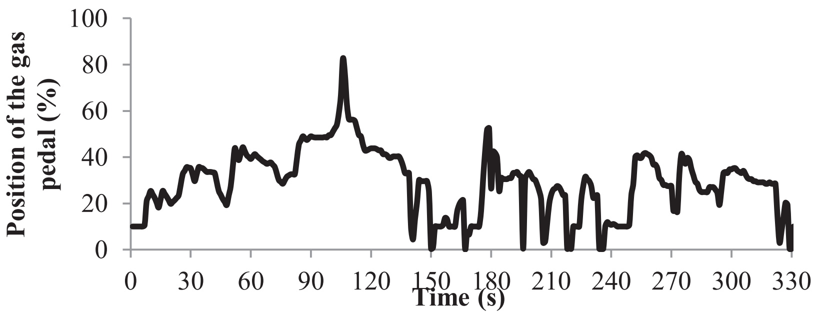

Figure 1. Progression of the position of the gas pedal during the test cycle.

The test cycle was acquired, as mentioned above, from real traffic by recording values from the OBD diagnostics system of the vehicle and the length of the cycle is 330 sec (Fig. 1). The whole cycle is characterized by the dependence of the position of the gas pedal on the time of the driving cycle. During the cycle the values of the torque and rotations of the engine are not the same for all variants as a result of the different performance parameters for the used variants (Table 2).

All measured parameters are logged with frequency of 1 Hz into a DBF file on the hard drive of the computer. These measured data were further processed using MS Excel.

Table 2. Performance parameters

	Torque		Power	
Variant	(Nm)	(%)	(kW)	(%)
E85	107	92.2	40,7	89.3
E85+	111	95.7	41,2	90.4
N95	116	100	45,6	100

RESULTS

In Fig. 2 the progression of the concentration of carbon dioxide emissions during the driving test cycle is shown. As can be seen, the concentration of CO_2 is for all variants approximately on the same level for most of the time of the cycle. The biggest difference is achieved between 90. and 120. sec. of the cycle, where the concentration is decreasing. For variant 3 (N95) and variant 2 (E85+) that decrease of concentration could be caused by worse combustion as a result of the rich mixture at high engine load. This can be also seen in the progression of CO concentration in Fig. 3 and the progression of the air-fuel equivalence ratio in Fig. 4. For variant 1 (E85) is the progression of CO_2 between 90. and 120. sec. probably caused by poor mixture, as can be seen in Fig. 4. Decreases in the concentration of CO_2 which can be seen for all three variants between 150. and 240. sec. of the cycle are connected with shortening of the time of the injection due to the sudden reduction of the fuel supply (Fig. 1) and thereby with sudden reduction of the engine load. This also shows the value of the air-fuel equivalence ratio in Fig. 4, which significantly increases in these places.

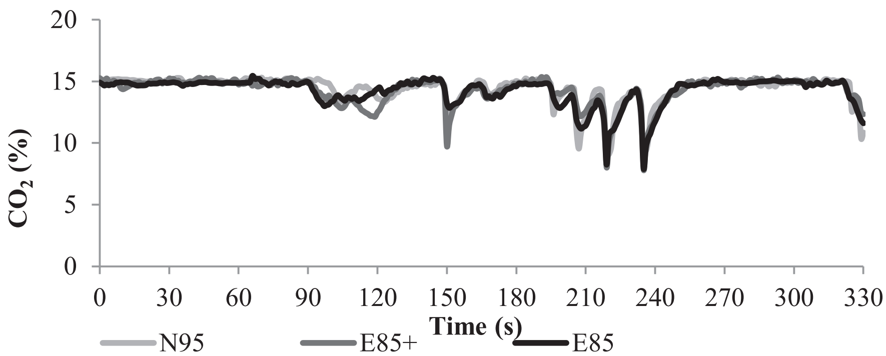

Figure 2. Progression of CO_2 during the test cycle.

From Fig. 3 it is evident that the concentration of CO was significantly higher for variant 2 (E85+) than for variant 3 (N95), this is caused by the fact that between 90. and 120. sec. of the cycle for variant 2 a richer mixture was burned than for variant 3 (Fig. 4). For variant 1 (E85) a significant decrease in concentration of CO compared to variant 3 (N95) can be seen. That is most probably caused by better combustion efficiency as a result of a poor mixture.

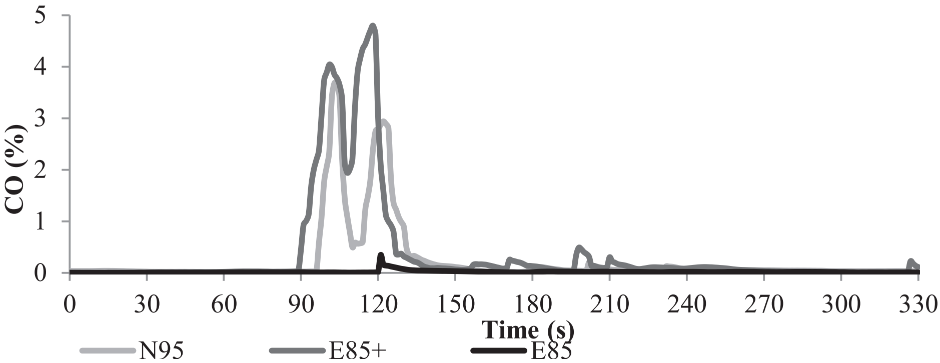

Figure 3. Progression of CO during the test cycle.

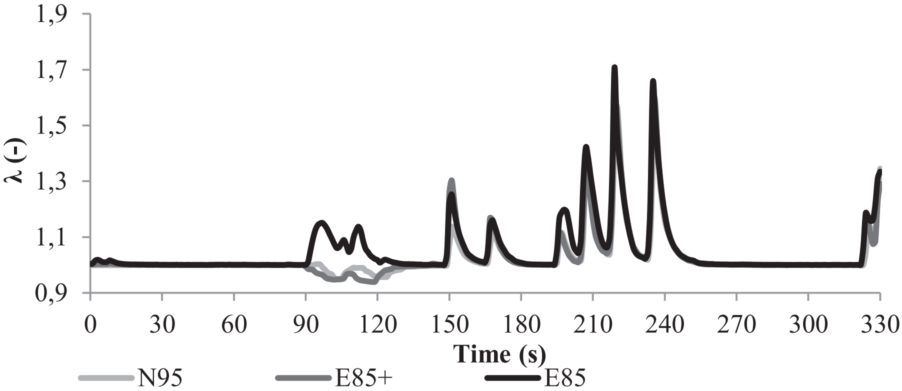

Figure 4. Progression of λ during the test cycle.

In Fig. 5 the progression of the concentration of NO_X during the test cycle is shown. As can be seen for variant 1 (E85) the concentration is order of magnitude higher than for variant 3 (N95). That is probably caused by higher temperature as a result of combusting of the poor mixture. Another reason may be poor three–way catalyst efficiency for oxides of nitrogen as a result of lack of CO and unburned hydrocarbons to oxidation. For variant 2 (E85+) it can be seen that the concentration of NO_X between 90. and 120. sec. of the cycle is lower than for variant 3 (N95). That can be explained by combusting of richer mixture that creates higher concentration of CO, which ensures good efficiency to the three-way catalyst for oxides of nitrogen.

The progression of HC emissions is shown in Fig. 6. The biggest difference between variants 2 and 3 is again in the places with the highest engine load. As a product of prematurely stopped oxidation reactions, HC are usually located in the exhaust gases along with CO, which can be seen in variant 2 (E85+) in Fig. 3. On the contrary, for variant 1 (E85), where almost no CO was, lower concentration of HC can be also seen.

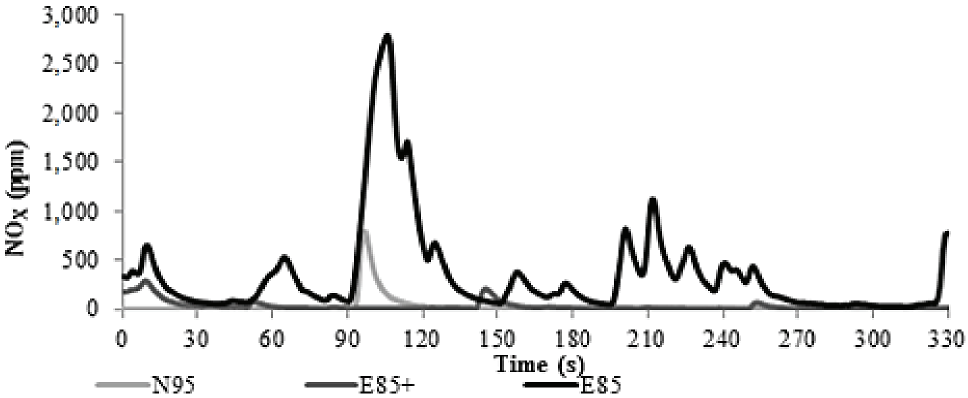

Figure 5. Progression of NO_X during the test cycle.

Even after repeated measurements using driving cycle for variant 1 (E85) without conversion, the ECU was reporting an error message indicating too poor mixture. Therefore the engine is not able to fully adapt to operation on E85 fuel without customization of fuel amount supply.

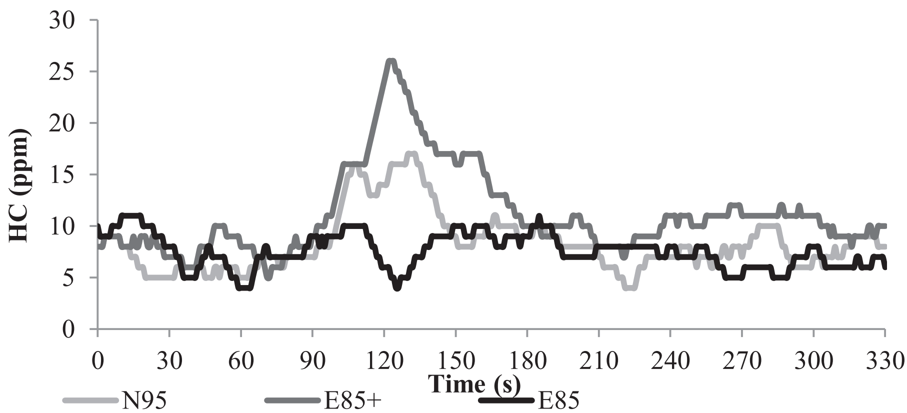

Figure 6. Progression of HC during the test cycle.

CONCLUSION

In Table 3 the mass expression of the emissions, produced during the cycle is listed. These values were counted from knowledge of the mass flow of the fuel, immediate value of the air-fuel equivalence ratio, stoichiometric ratio and concentrations of the individual components of the emissions. For variant 2 (E85+) significant increase of the emissions of CO, almost by 100%, and emissions of HC by 25% compared to variant 3 (N95) occurred. Here the expectations, resulting from the literature research, listed in the introduction, were not verified. The reason is most probably too big prolonging of the time of the injection, which was 28%. In the contrary, emissions of NO_X decreased most likely because of good efficiency of the catalyst as a result of increased concentration of CO emissions in the exhaust gases. Furthermore for variant 1 (E85) a significant decrease of the emissions of CO, almost to zero, and emissions of HC by 25% compared to variant 3 (N95) are indicated. Emissions of NO_X were increased almost eight times. This variant is verifying the expectations because the decrease of CO, HC and the increase of NO_X can be seen.

Table 3. Mass expression of individual components of the emissions

Variant	CO		CO_2		NO_X		HC	
	(g)	(%)	(g)	(%)	(mg)	(%)	(mg)	(%)
N95	21.01	100	879.93	100	270.2	100	51.5	100
E85+	41.33	196.7	800.06	90.9	144.6	53.5	64.4	125
E85	0.98	4.7	754.8	85.8	2,394.3	886.1	39.3	73.3

As can be seen in Table 2, according to the expectations the performance parameters of the engine Škoda Fabia 1.2 HTP were reduced as a result of the lower energy content of the E85 fuel. For variant 1 – E85 was the decrement by 10% and for variant 2 – E85+ it was by about 5–10%.

Although the E85 fuel may seem as a suitable bio-substitution for the fossil fuel BA95, the operation of this fuel is problematic especially concerning most of the current sealing elements, which are damaged by influence of the E85 fuel. Also there is a problem with worse starting qualities of the engine during the lower temperatures as a result of the lower RVP. Non-problematic use of this fuel is then possible only for vehicles where the manufacturer explicitly allows using the fuel E85.

Paper was created with the grant support – 2013:31150/1312/3110 – Innovation of the emissions measuring method during regular control measurements for vehicles in the traffic.

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