Zdzisław CHŁOPEK

ECOLOGICAL ASPECTS OF USING BIOETHANOL FUEL TO POWER COMBUSTION ENGINES

Out of many ways of lowering harmful effects of motorism on the environment, more and more attention is being paid to popularising the use of biofuels. Using bioethanol enables combustion engines to run on fuels containing high content of biocomponent. They are E95 fuels for the self ignition engines, E85 and in the foreseeable future, E100 for the spark ignition engines. Engines running on ethanol fuel are especially adapted for that, with spark ignition engines being multi–fuel ones able to run on a mixture of ethanol fuel with petrol in any proportion. The use of bioethanol fuels makes it possible to lower the emission of harmful pollutants, such as, nitrogen oxides , or – in case of self ignition engines – particulate matter, and also global reduction of carbon dioxide emission. Paper presents results of pollutants emission studies, from the engines powered by bioethanol fuel.

***Keywords**: bioethanol, combustion engines, pollutants emission.*

1. Introduction

From amongst most important criteria of evaluating quality of the combustion engines, particular significance is being attached at present to the ecological characteristics. At first, there have been limitations imposed on combustion engines' harmful pollutants emission. [3, 4]. International legislation has highlighted methods of evaluating harmfulness of substances emitted by combustion engines, to human health and environment. These methods encompass [3, 4]:

- subject range of substances, whose emission is limited, as well as those of restricted impact (exhaust smokiness),
- test methods together with equipment requirements,
- physical values system, characterising harmfulness to health and environment of the substances emitted.

Combustion engines progress is unequivocally connected with limiting emissions harmful to health and environment. Out of many methods, (with which great hopes on decreasing negative impact of the motorism on the environment, are linked), the use of bio fuels is being mentioned [1, 2, 4 – 17, 20, 21]. The use of bio fuels is seen as enabling the decrease of environmental threats on the local and global scales as well as improving fuel balance, together with other consequences of such actions, covering economic and social spheres as well as energy safety of each individual country.

Following ecological threats caused by combustion engines are singled out: local and global [3 – 9].

The greatest local threats caused by motorism are: particulate matter and nitrogen oxides, especially in the great city agglomerations, where the degree of harmfulness is even grater, because it affects larger human population remaining for long periods in the endangered area [3 – 9]. The main emission sources of these substances are first of all self ignition engines. In the case of the spark ignition engines, a significant progress has taken place as far as limiting emission of substances harmful to health and environment is concerned. The development of effective methods of catalytic exhaust purification has contributed to that [3, 4, 6 – 9].

From amongst global threats, caused by combustion engines, one can distinguish first of all greenhouse gasses emission, contributing to the climate warming up [3 – 9]. This is first of all carbon dioxide, and its emission being a direct consequence of using fossil fuels containing carbon.

Using bio fuels enables lowering emission of pollutants harmful to health and global emission of carbon dioxide, connected with carbon circulation in the nature, in the closed cycle of about one year period [4]. Engines running on bio fuels are characterised by lower emission of solid particles (particulates) [5, 9 – 17, 20, 21]. In the case of nitrogen oxides emission, the situation is more complicated. Running self ignition engines on diesel oil with added vegetable oil esters, usually causes slight increase of nitrogen oxides emission [11, 12], while in case of bioethanol additives, particularly with their high content, the emission of nitrogen oxides actually significantly comes down [1, 2, 5, 10, 13 – 21]. Positive effect of limiting greenhouse gasses emission on a global scale is dependent on the use of bio fuels with bio component content [4].

With ecological threats caused by motorism present, particularly great hopes are linked with beneficial results for the environment of the use of bioethanol [1 – 3, 5 – 10, 13 – 18, 20, 21]. This comes from not only from positive experiences of using engines powered that way, but also from the possibility of producing bioethanol in our climatic region and socio–economic realities.

Ethanol is used in the standard combustion engines as a low percentage additive to petrol and diesel oil. The use of bio fuels with high content of bioethanol requires engines specially adapted to that [1, 2, 5, 10, 13 – 18, 20, 21]. In case of spark ignition engines, they are multi–fuel engines, which can run on mixture of petrol and bioethanol, with 0% to about 85% bioethanol content (E85 fuel) [1, 2, 15, 21]. And in the foreseeable future of a few years, even E100, that is almost 100% bioethanol [1, 2, 15, 21]. The only self ignition engine, that can run on high content bioethanol fuels is DSI9E 01 produced by Scania [2, 4, 9, 15, 17, 19, 20]. It is powered by E95 fuel of bioethanol content exceeding 90% [2, 5, 10, 15, 18 – 21].

2. Ecological characteristics of self ignition combustion engines powered by E95 bioethanol fuel

First self ignition engine on high bioethanol content fuel, was designed by Scania corporation in the eighties, last century. It is Scania DSI9E 01 engine, which was a modification of Scania DSC9 11 engine powered by diesel oil [5, 10, 18, 20]. The most important alterations introduced [18]:

- increasing compression ratio from 18 to 24,
- changes in the induction system such as: changes in the fuel metering control, increasing effectiveness of the fuel pump, increasing diameter of the injector or changing gaskets and filters due to their design and materials,

− changes of the intercooler parameters.

Scania DSI9E 01 engine is a six cylinder in–line unit, of 8,7 dm^3 capacity. It develops nominal 169 kW at (1800 ÷ 2000) RPM. DSI9E 01 engine is used to power urban bus Scania Omnicity [18].

E95 fuel contains, according to the specification SEKAB [19] 5% in weight of the additive, so called ignition activator, enabling self ignition of high ethanol fuel – table.

Table. E95 fuel content

Fuel component	Mass content
Ethanol 95% v/v	92,2%
Ignition activator	5%
Ether MTBE	2,3%
Isobuthanol	0,5%
Corrosion Inhibitor	90 ppm

Figures 1 – 4 show specific brake pollutants emission from the Scania DSI9E 01 and DSC9 11 engines in the type approval static test – ESC (European Stationary Cycle) together with EURO 4 and EURO 5 limits [17].

The engine meets the pollutants emission requirements of the EURO 4 level (obligatory since – 2005) without any additional exhaust purification devices, and apart from nitrogen oxides, even of the EURO 5 level (obligatory from – 2008). In the version with EGR (Exhaust Gas Recirculation) and particulate matter filter CRT (Continuously Regenerating Trap), the engine meets EURO 5 and EEV (Enhanced Environmentally Friendly Vehicle) requirements in the dynamic ETC (European Transient Cycle) test [18] – figures 5 – 7.

New Scania engine on E95 fuel, which is to be introduced to the market in the second half of 2007, is a design especially prepared to run on this fuel [18]. This is an in–line, five cylinder

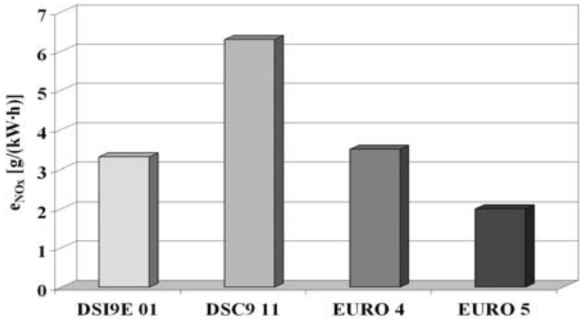

Fig. 3. Nitrogen oxides (NO_x) specific brake emission – in the ESC test from the DSC9E 01 and DSC9 11 engines with EURO 4 and EURO 5 limits

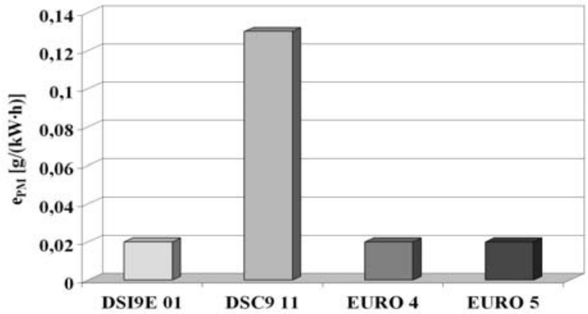

Fig. 4. Particulate matter (PM) specific brake emission – in the ESC test from the DSC9E 01 and DSC9 11 engines with EURO 4 and EURO 5 limits

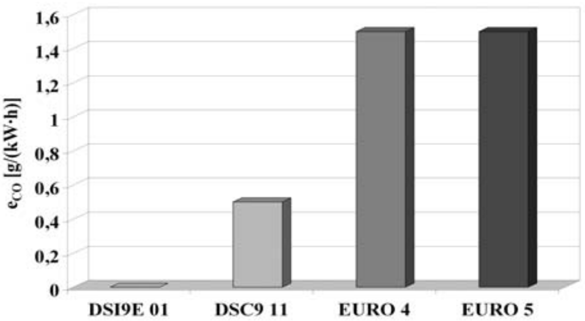

Fig. 1. Carbon monoxide (CO) specific brake emission – in the ESC test, from the DSC9E 01 and DSC9 11 engines with EURO 4 and EURO 5 limits

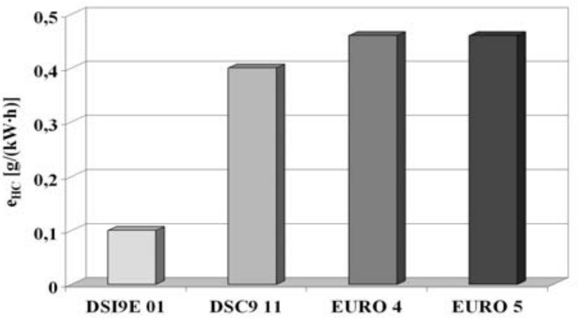

Fig. 2. Hydrocarbons (HC) specific brake emission – in the ESC test, from the DSC9E 01 and DSC9 11 engines with EURO 4 and EURO 5 limits

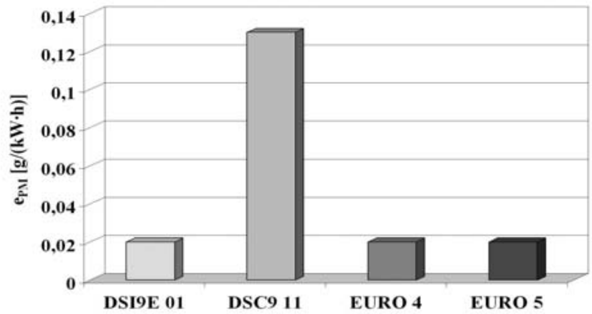

Fig. 5. Non methane hydrocarbons (NMHC) specific brake emission – in the ETC test, from the DSC9E 01 engine with EURO 4, EURO 5 and EEV limits

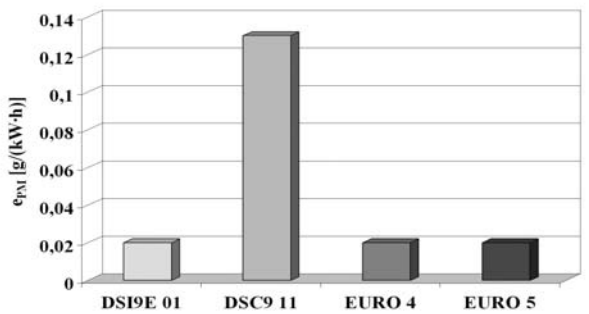

Fig. 6. Nitrogen oxides (NO_x) specific brake emission – in the ETC test, from the DSC9E 01 engine with EURO 4, EURO 5 and EEV limits

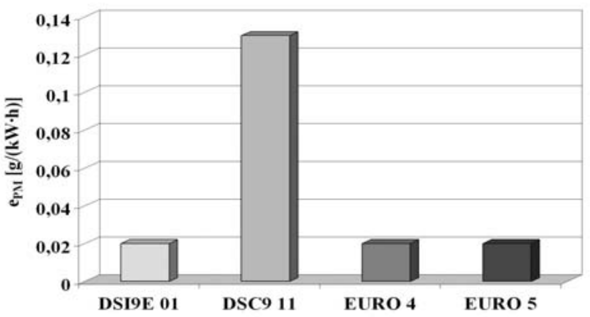

Fig. 7. Particulate matter (PM) specific brake emission – in the ETC test, from the DSC9E 01 engine with EURO 4, EURO 5 and EEV limits

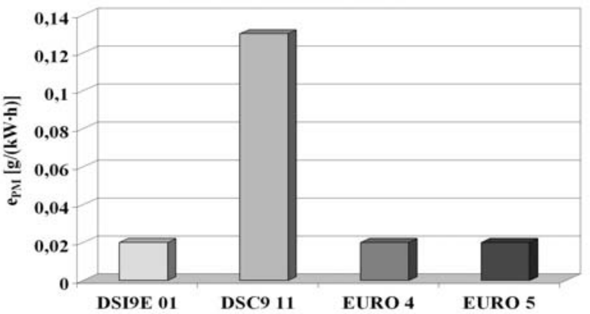

Fig. 8. Relative difference between EURO 4 limits and specific pollutants emission of: carbon monoxide – CO, hydrocarbons – HC, nitrogen oxides – NO_x and particulate matter – PM in the ESC test of a new Scania engine

unit of 8,9 dm³ capacity and compression ratio ε = 28. The engine develops nominal useful power N_{eN} = 199 kW (270 KM) at n_N = 1900 RPM. There are four valves per cylinder. The engine has EGR system (Exhaust Gas Recirculation), but no catalytic converters have been used. The engine comfortably meets and even accedes the EURO 5 and EEV requirements – Figure 8.

Very good ecological characteristics of the engines running on biofuels with high bioethanol content, justify hopes connected with these fuels. Based on the data presented above and contained in the literature as well as Scania materials [11, 12, 18], it is possible to compare ecological characteristics of self ignition engines running on the following fuels:

- diesel oil,
- B20 fuel, being a mixture of diesel oil and 20% rape oil methyl esters,
- B100 fuel, – rape oil methyl esters,

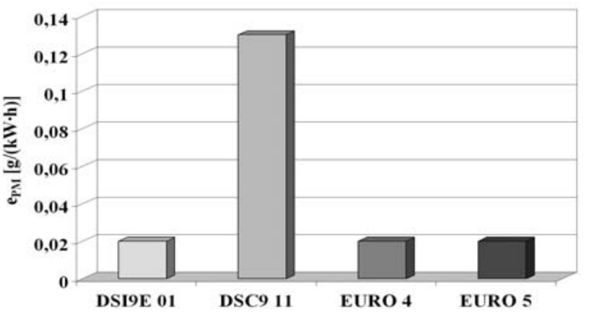

Fig. 9. Relative specific carbon monoxide brake emission – CO in the ESC test

- bioethanol E95 fuel.

Figures 9 – 12 show the specific brake pollutants emission in the ESC test for the engines running on biofuels against specific brake pollutants emission for pure diesel oil.

Pollutants emission analysis, presented in figures 9 – 12, clearly shows ecological benefits from using E95 fuel to power self ignition engines.

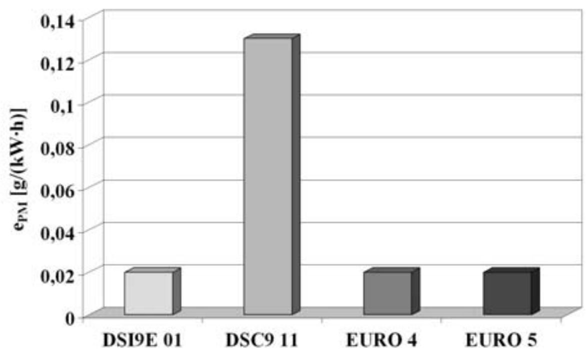

Fig. 10. Relative specific hydrocarbons emission – HC in the ESC test

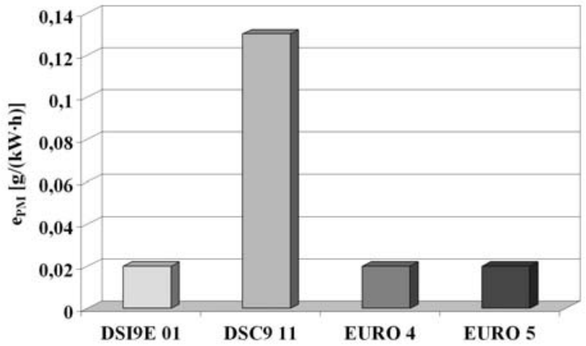

Fig. 11. Relative specific nitrogen oxides brake emission – NO_x in the ESC test

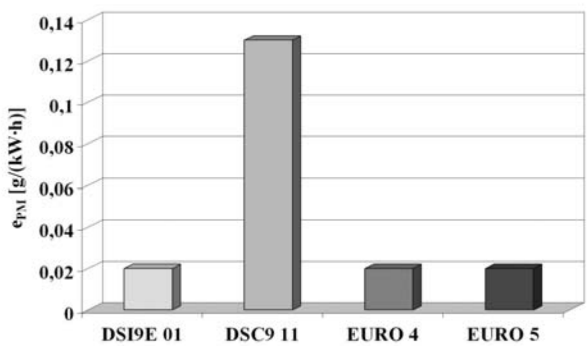

Fig. 12. Relative specific particulate matter brake emission – PM in the ESC test

3. Summary

The use of bioethanol based fuels requires – in case of high bio component content – specially prepared engines. Spark ignition engines are developed as multi–fuel ones, enabling running on the mixture of bioethanol fuel and petrol in any proportion, while self ignition engines are adapted to run only on E95 fuel. Thus, possibilities of propagating bioethanol fuels are smaller than in case of vegetable oil esters. Also costs of propagating bioethanol fuels are higher. However, there are very serious arguments in favour of developing bioethanol fuels.

The most important being the fact that popularising bioethanol fuels, requiring the use of new designs, is a professional solution advocating modernity. It is impossible to use bioethanol fuels for the old designs, as it is the case with fuels based on vegetable oil esters. This fact thus favours natural forcing of modernity, although entails higher costs.

The second argument is – exceptionally beneficial ecological effects of using bioethanol fuels, particularly possibilities of lowering – unlike in the case of vegetable oil esters – nitrogen oxides emission.

The third one is – significantly more advantageous operating properties of bioethanol fuels in relation to fuels with added vegetable oil esters. Particularly better starting properties in low temperatures and better resistance to induction system contamination in connection with possible growth of biological flora in the fuel.

4. References

[1] Brusstar M.: *Ethanol–Gasoline Blends: Fuel Economy and Emissions Benefits*. The SAE Government and Industry Meeting. Washington D.C., May 13, 2003.

[2] Carstedt P.: *End of Oil! Future of What? Just Do It! Bioethanol and the road to sustainable transport*. Imperial College. London March 22, 2006. BAFF – BioAlcohol Fuel Foundation.http://www.baff.info/Filer/BioEthanolLondon/.

[3] Chłopek Z.: *A simulation researches of a pollution emission in a vehicle traffic*. 3rd International Conference Maintenance 2004. Praha 2004.

[4] Chłopek Z.: *Motor vehicles. Natural environment protection*. WKŁ. Warsaw 2002.

[5] Chłopek Z.: *Pollutants emission tests of the compression ignition engine powered by ethanol fuel E95*. Combustion Engines Nr 2007–SC3.

[6] Chłopek Z.: *Development problems of urban buses' engines*. Zeszyty Naukowe Wyższej Szkoły Ekonomii i Innowacji. Nr 2. Lublin 2005.

[7] Chłopek Z.: *Urban buses' engines development solutions*. Road Transport. 3 – 2005. 29 – 46.

[8] Chłopek Z.: *Development tendencies in urban buses' power plants*. Eksploatacja i Niezawodność Nr 1/2006. 3 – 9.

[9] Chłopek Z.: *Tendencies of urban buses' engines development*. Konferencja Komisji Autobusowej Izby Gospodarczej Komunikacji Miejskiej. Szklarska Poręba 2005.

[10] Chłopek Z.: *The use of ethanol fuel to power self ignition engines*. Zeszyty Naukowe Instytutu Pojazdów Politechniki Warszawskiej. (Praca w druku).

[11] Chłopek Z., Bardziński W., Jarczewski M, Sar H.: *The influence of FAME vegetable oil methyl ester additive to the diesel oil, on ecology, fuel consumption and car dynamic properties*. Journal of KONES 2006.

[12] Chłopek Z., Bardziński W., Jarczewski M., Sar H.: *Pollutants emission from the engine powered by fuel with the vegetable oil methyl ester, in the dynamic tests*. Journal of KONES 2005.

[13] Cole R.L., Poola R.B., Sekar R., Schaus J.E., McPartlin P.: *Effects of Ethanol Additives on Diesel Particulate and NOx Emissions*. SAE 2001–01–1937.

[14] Guerrieri D.A., Caffrey P. J., Rao V.: *Investigation into the Vehicle Exhaust Emissions of High Percentage Ethanol Blends*. SAE 950777.

[15] Hygrell L.: *BioEthanol…The Saab Way*. Bioethanol and the road to sustainable transport. Imperial College. London March 22, 2006. BAFF – BioAlcohol Fuel Foundation. http://www.baff.info/Filer/BioEthanolLondon/.

[16] Johansson U.: *Ethanol Buses – experiences and prospects for sustainable urban transport*. Bioethanol and the road to sustainable transport. Imperial College. London March 22, 2006. BAFF – BioAlcohol Fuel Foundation. http://www.baff.info/Filer/BioEthanolLondon/.

[17] Kelly K.J., Beiley B.K., Coburn T.C., Clark W., Lissiuk P.: *Federal Test Procedure Emissions Test Results from Ethanol Variable–Fuel Vehicle Chevrolet Luminas*. SAE 961092.

[18] Scania AB – internal materials not published.

[19] SEBAB AB – internal materials not published.

[20] Strömberg J.: *Towards Sustainable Travel in Stockholm's Public Transport*. Bioethanol and the road to sustainable transport. Imperial College. London March 22, 2006. BAFF – BioAlcohol Fuel Foundation. http://www.baff.info/Filer/BioEthanolLondon/.

[21] Taylor A.: *Bio–ethanol: an Environmental Opportunity for UK?!* Bioethanol and the road to sustainable transport. Imperial College. London March 22, 2006. BAFF – BioAlcohol Fuel Foundation. http://www.baff.info/Filer/BioEthanolLondon/.

Prof. Ph. D. Eng. Zdzisław Chłopek
Warsaw University of Technology
02–524 Warsaw, 84 Narbutta Str., Poland
E–mail: zchlopek@simr.pw.edu.pl