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EXHAUST EMISSIONS OF DUAL FUEL SPARK IGNITION ENGINE FUELLED GASOLINE AND METHANOL

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Abstract

Today, more and more attention is paid to search for alternative fuels, which would be not only environmentally friendly, but also cost-competitive to petroleum fuels. In the recent years much attention is paid to investigations at adaptation of combustion engine to run on bio-fuels. Results of the investigations show, that methyl and ethyl alcohols could belong to one from the most promising and future bio-fuels, being a serious alternative to petroleum fuels. Interest in these fuels comprises such areas as exploration of raw materials to production of the alcohols, development of technology of their production, especially 2nd generation of ethyl alcohol, special fuelling and control systems, design changes of the engines fuelled with alcohols. In the present paper are shown test results of Fiat 1.3 Multipoint engine fuelled in dual fuel system with methanol and gasoline. In this engine one assembled prototype fuel supply system with duplex injectors on each cylinder, to injection of methanol and gasoline. Implemented system enables fuelling with gasoline only, with methanol only, or simultaneously with gasoline and methanol with any fraction of the methanol. Change of fuelling system and change of methanol fraction can be accomplished in course of engine operation. Performed investigations showed advantageous effect of the methanol on toxicity of exhaust gases. One confirmed reduction of emissions of hydrocarbons, nitrogen oxide and carbon dioxide. The biggest changes in the concentration occurred in case of fuelling with the methanol only, and amounted to: 2-3 times reduction of the THC, reduction of NO_x with 40-60%. Differences in concentration of NO_x increased together with growth of engine load, and hence, they concern such areas of engine operation, where the biggest quantities of the NO_x are emitted. In case of dual fuel feeding, effect of reduction of concentration of the components discussed here decreases according to reduced fraction of the methanol. Changes in the emissions discussed here are obtained with maintained engine performance and growth of overall efficiency of the engine. Implemented system eliminates problems of stratification of methanol-gasoline mixture in low temperatures and in presence of water. The system can be adapted to any liquid fuels.

***Keywords**: methanol, gasoline, spark ignition engine, dual fuel, exhaust emissions*

1. Introduction

Nowadays, more and more attention is paid to search for alternative fuels, which would be not only environmentally friendly, but also cost-competitive to petroleum fuels. Due to it, in the recent years much attention is paid to investigations at combustion engine to feeding with bio-fuels. The studies published in the recent period of time show that methyl and ethyl alcohols could belong to one from the most promising and future bio-fuels, being a serious alternative to petroleum fuels. Interest in such fuels comprises such areas as search for raw materials to production of the alcohols, development of technology of their production, especially 2nd generation of ethyl alcohol, special fuel supply and control systems, design changes of the engines fuelled with alcohols.

Usage of alcohol fuels doesn't belong to new issues, because the alcohols have been used for decades [1, 3, 5, 6, 9, 10]. Special intensification of such trends occurred during the 1st and the 2nd Word War, what was connected with shortage of petroleum fuels, and during seventies of the previous century, what was caused by serious fuel crisis and rapid growth of crude oil price. However, alcohol fuels have never been adopted in a widespread use, and as early as worldwide situation underwent normalization, one always returned to petroleum fuels. Probably, it resulted from disadvantages of the alcohols and from design, fuel supply and control of the engines, which were optimized to petroleum fuels mainly. Since phenomenon of stratification of gasoline-alcohol mixtures belongs the main problems of the alcohols, especially in low temperatures and in presence of water, concentration of the alcohol was limited to a few percent. The concentration was increased with use of stabilizers, like ethers, but concentration of the alcohol in the mixtures never exceeded over a dozen volumetric percent.

From application to the engines point of view, more advantageous is usage of the alcohols as a pure fuel, because it allows taking full advantage of high knocking resistance of the alcohol, allowing increase of compression ratio, growth of overall efficiency and unit horsepower of the engine [1, 10, 11, 13]. Such direction is developed in Brazil, USA, New Zeeland and Sweden [3, 7, 14, 17, 18].

Except stratification of the alcohol-gasoline mixture, low volatility of the vapours is the second drawback of the alcohols, what at negative ambient temperatures can lead to start-up difficulties [1, 2, 4, 8, 10, 12, 21].

The drawbacks discussed above do not have any significant importance in prototype fuelling system developed within framework of the present study [11, 12, 16, 17]. The system is based on the Dual Fuel system– feeding system of the engine system two fuels. The system consists in injection of the fuels in area of the inlet valve with use of two injectors controlled electronically. Mixing of the both fuels occurs in the cylinder directly before combustion. Proposed system enables supply of the engine with alcohol only, or gasoline only, or with gasoline-alcohol mixture with any fraction of the alcohol. Among the obvious advantages of this system, one should specify maintained start-up properties (engine start-up with gasoline only), engine operation at minimal loads with gasoline, and engine operation in dual fuel system at any fraction of the both fuels, depending on operational speed and load of the engine.

2. The engine and the test stand

The tests were performed on four cylinders, spark ignition engine with multipoint injection of the Fiat 1100 MPI type. Technical data of the engine are listed in the Tab. 1.

Tab. 1. Technical data of engine Fiat 1100 MPI

,	Fiat 1100 MPI
Bore x Stroke	70 x 72 mm
Displacement	1108 cm^3
Compression ratio	9.6
Maximal power/engine revolution	40 kW/5000 rpm
Maximal torque/ engine revolution	88 Nm/3000 rpm

Additional injectors were installed in the suction manifold. Factory assembled injectors (located in area near the inlet valve) served to injection of the methanol, while additional ones served to injection of the gasoline. Scheme of prototype suction manifold is presented in the Fig. 1.

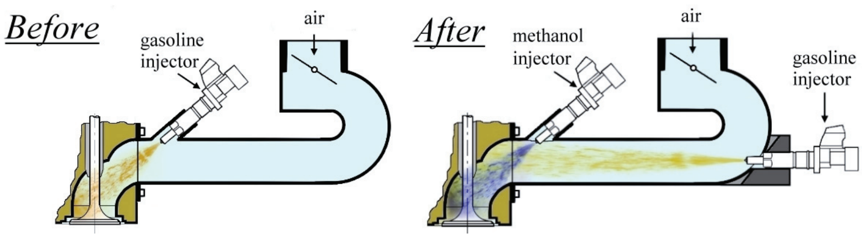

Fig. 1. Schema of the prototype inlet manifold of engine Fiat 1100 MPI

Prototype suction manifold with the injectors after rework and adaptation to the Fiat 1100 MPI engine is presented in the Fig. 2.

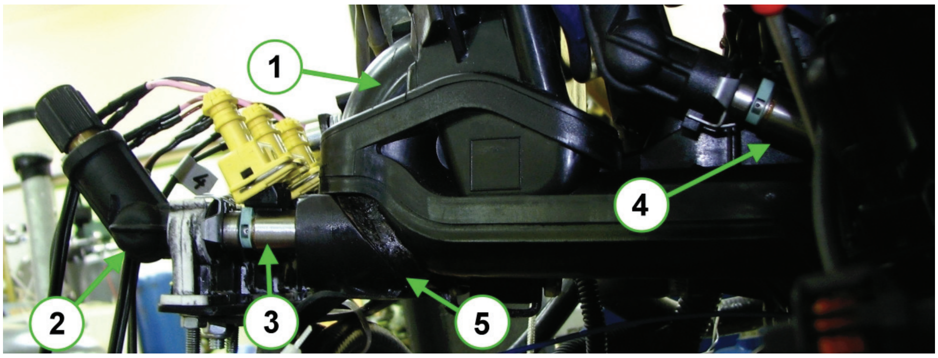

Fig. 2. Prototype inlet manifold of dual fuel engine Fiat 1100 MPI: 1 – manifold, 2 – common rail, 3 – gasoline injector, 4 – methanol injector, 5 – position where sleeve of the injector is glued

For the purpose of engine indication, in cylinder head of the second cylinder one drilled a hole for adapter of not-cooled sensor made by the AVL. To recording of quick-changing pressures in the combustion chamber one make use of the INDIMETER 619 system made by the AVL.

In the test stand one installed a system to automatic acquisition of measurement data to the Excel calculation sheet. To needs of the testing, in the test stand one installed a dual system of fuelling for the alcohol and for the gasoline. Each from the systems was equipped with individual fuel pump and pressure stabilization system, and system to measurement of fuel consumption. Fuelling system enabled control of instantaneous consumption of the fuels, what considerably facilitated selection of engine adjustment and recording of time of consumption of a determined dose of the fuel. Selection of dose size was dependent on fraction of the fuels, engine load and rotational speed. View of the test stand is presented in the Fig. 3.

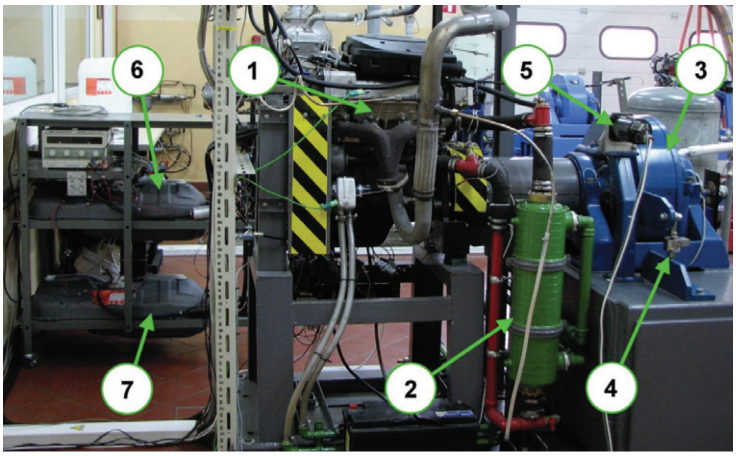

Fig. 3. Test stand – general view: 1 – research engine of Fiat 1100 MPI type, 2 - radiator, 3 – eddy-current engine brake made by Schenck,4 – transducer of engine load, 5 – engine speed sensor, 6 – alcohol tank, 7 – gasoline tank

3. Analysis of test results of the engine run in dual fuel system

Comparison of CO concentrations in exhaust gases measured downstream the exhaust valve (in front of the catalyst) is presented in the Fig. 4 and 5. The comparison shows, that at low engine loads and small fractions of the methanol, concentrations of the CO in case of dual fuel supply exceed concentrations recorded in case of fuelling with the gasoline only. It could result from worsening of quality of adjustment of stoichiometric composition of combustible mixture by lambda sensor, what is connected with use of the methanol and reduced temperature of exhaust gases. The second from significant reasons can be connected with distance of gasoline injector from the inlet valve, what can lead to sedimentation of the gasoline on the walls, generation of fuel film with changing dynamic parameters, and in consequence to worsening of uniformity of fuelling from one cycle to another.

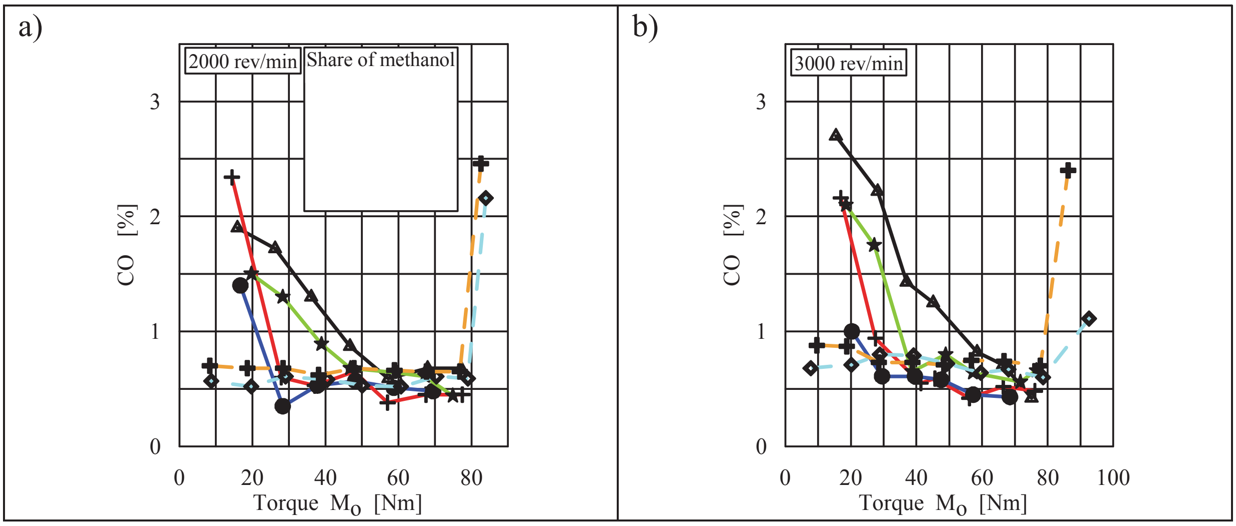

Fig. 4. Comparison of CO concentrations in exhaust gases of the engine fuelled with gasoline and run in dual fuel system at various shares of the methanol

In range of medium and maximal engine loads, concentrations of the CO are comparable or lower than the concentrations when fuelling with gasoline. In case of dual fuel feeding is seen a clear tendency to reduction of CO concentrations as the engine load increases in complete range of rotational speed. Improvement of quality of adjustment of combustible mixture composition at a higher loads, or increase of average temperatures of the charge in initial phases of the combustion can have impact on such tendency.

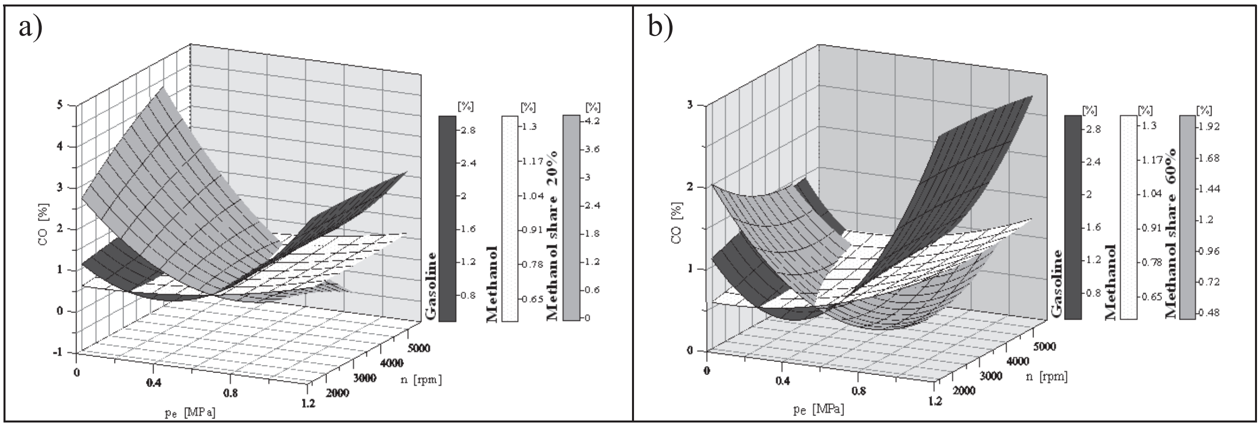

Fig. 5. Comparison of the CO concentrations for the engine run in dual fuel system – grey colour, gasoline fuelling – dark grey colour, and run on methyl alcohol only – white colour

Comparison of summary concentrations of the THC presented in the Fig. 6 and 7 shows, that in case of dual fuel supply is present a clear tendency to reduction of hydrocarbons emission, irrespective of alcohol fraction in the combustible mixture. An exception is only operation at low engine loads, where in case of small fraction of the alcohol can occur increase of the THC emissions, comparing to gasoline fuelling. Probably, it is connected with worsening of conditions of gasoline-air mixture formation, related to distance between the injector and the inlet valve. Reduction of THC concentration in exhaust gases depends on size of methanol additive in the mixture and grows together with growth of methanol fraction in the mixture. The biggest reduction is present in case of methanol fuelling only. Observed concentrations of the THC were about 2-2.5 times lower, comparing to gasoline fuelling.

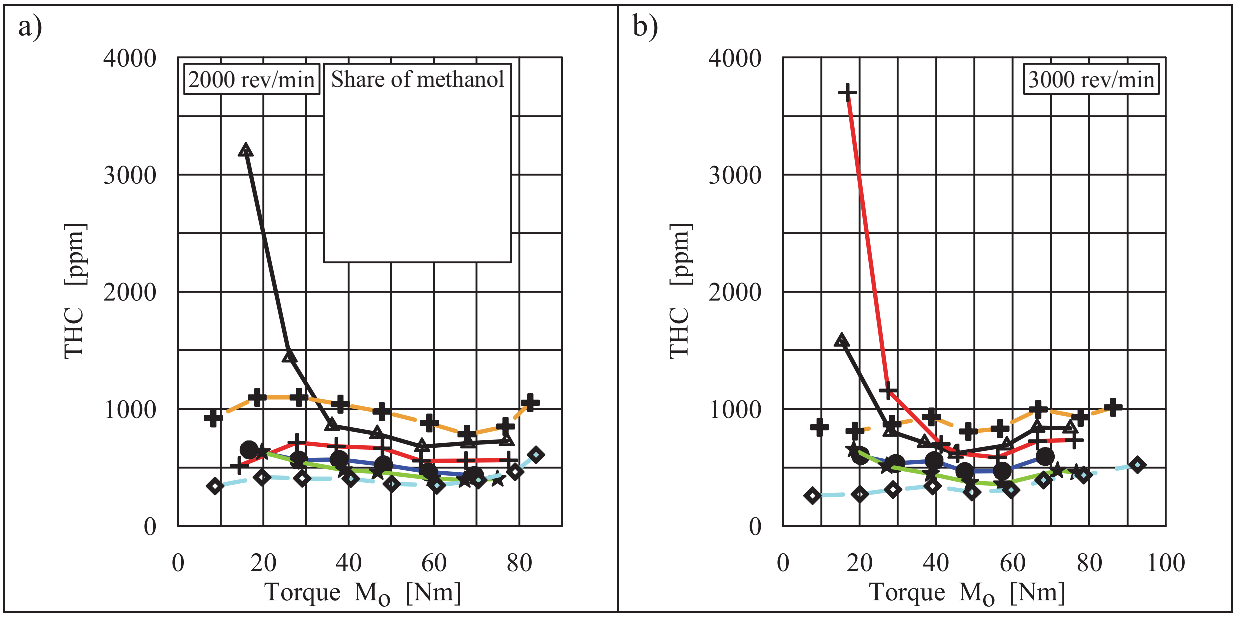

Fig. 6. Comparison of summary concentrations of the THC in exhaust gases of the engine run on gasoline and the engine run in dual fuel system at various fractions of methanol

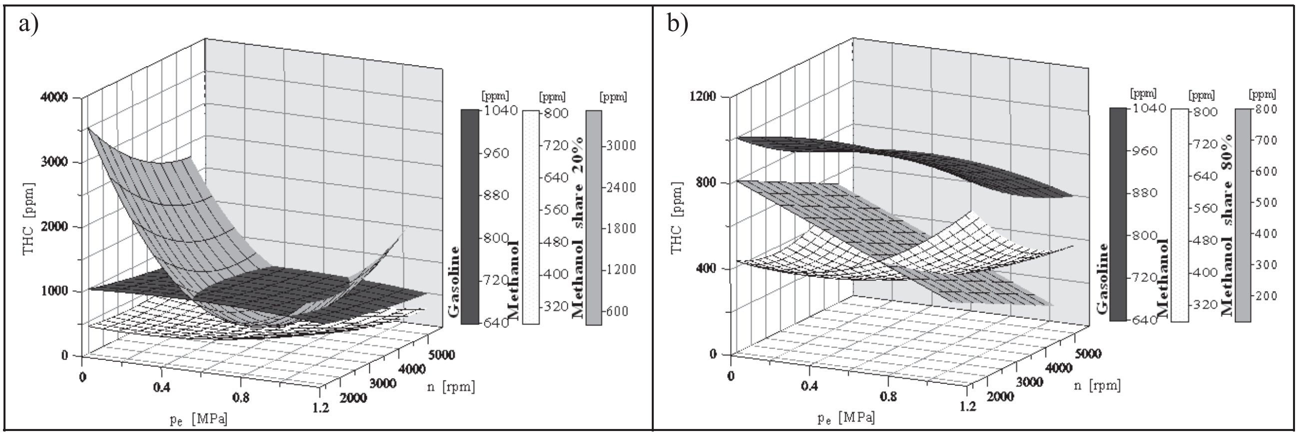

Fig. 7. Comparison of the THC concentrations of the engine run in dual fuel system – grey colour, gasoline fuelling – dark grey colour, and run on methyl alcohol only – white colour

Effect of methanol addition in the charge on change of the NO_x concentration, shown in the Fig. 8 and 9, is dependent on fraction of the methanol and engine load. For low engine loads, regardless of the fraction of methanol, one observed reduction of the NO_x concentration, comparing to gasoline fuelling. However, at a higher engine loads was seen a slight growth of the concentration in range of 10-15%. The probable reason for growth of the NO_x concentration can be fact, that in course of the testing, the engine run in dual fuel system was fed with slightly leaner mixture, comparing to run on gasoline only, and run on methanol only. In majority of measuring points, in case of dual fuel operation, the engine was fuelled with the mixture having average composition $\lambda = 1.02\text{-}1.08$, and hence more lean than stoichiometric composition. Excess of oxygen during combustion, according to Zeldowicz theory, results in excessive emission of the NO_x. Since composition of the mixture was maintained by original lambda sensor, it can be concluded that presence of the methanol in the charge may have effect on accuracy of adjustment of the composition. If this assumption is confirmed in further studies, a special sensors or correction of engine control unit should be performed. In range of low engine loads, where reduction of NO_x was observed, changes in course of methanol combustion or reduction of combustion rate, connected with worsening of conditions of formation of homogenous gasoline-air mixture, can play an important role.

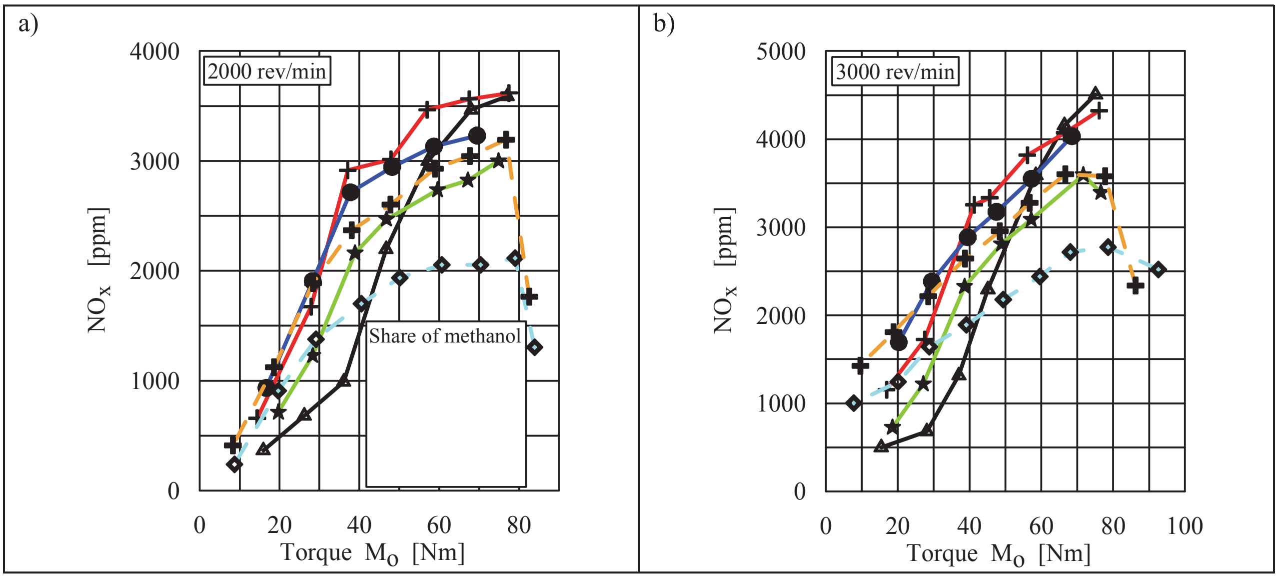

Fig. 8. Comparison of the NOx concentration in exhaust gases of the engine run on gasoline and operated in dual fuel system with various fractions of the methanol

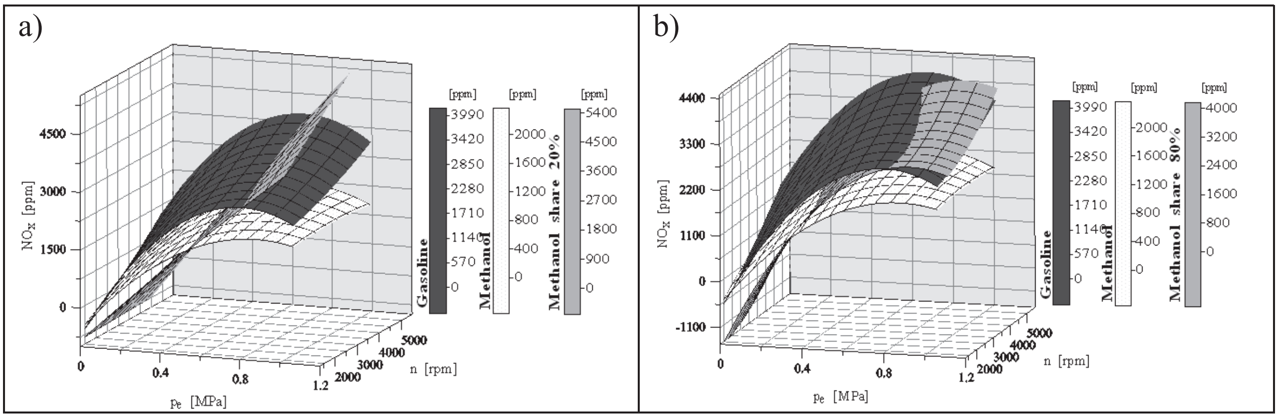

Fig. 9. Comparison of the NOx concentrations for the engine operated in dual fuel system – gray colour, gasoline fuelled – dark gray colour, and run on methyl alcohol only – white colour

Clear reduction of the concentration occurs only when the engine is running on the methanol only, what is seen in the Fig. 8 and 9. Explanation of the NO_x concentration described here in case of dual fuel supply is not easy in situation, where composition of gaseous mixture is dynamically changed by the lambda sensor. It requires additional studies to identify a reasons of discussed changes. The studies shall be continued in the Department of Combustion Engines and Vehicles.

4. Conclusions

On the base of performed investigations it is possible to draw conclusions of a general nature.

1. Combustion of alcohol fuel leads to reduction of emissions of toxic components of exhaust gases, especially: summary hydrocarbons THC, nitrogen oxides NO_x, and carbon dioxide CO_2.
2. The highest reduction of the THC emission is present in case of run on the methanol only, and is nearly 2-3 times lower. In case of dual fuel supply, reduction of the THC emission depends on fraction of the alcohol in total dose of the fuel. Reduction of the THC emission is connected with different chemical structure of the alcohol and higher rate of its oxidation.
3. The highest reduction of the NO_x concentration was present in case of run on pure methanol and amounted to 40-60%, depending on engine load and rotational speed. Differences in concentrations of the NO_x are growing together with growth of engine load, and hence, they concern such areas of engine operation, in which the biggest quantities of the NO_x are emitted. The main reasons of the NO_x emission in exhaust gases are:

- lower temperature of the flame of steichiometric methanol-air mixture,
- higher combustion rate and shorter time of complete combustion of the charge,
- high oxygen contents in particle of the methanol, CH_3OH, which when released during combustion, enters directly into oxidation reactions of carbon and hydrogen atoms.

4. Reduction of emission of greenhouse gas, CO2, is connected with lower fraction of carbon atoms in particle of methanol, comparing to the gasoline, and with growth of engine efficiency operated in dual fuel system. Reduction of the CO2 emission is proportional to fraction of the methanol in total dose of energy supplied to the engine, and proportional to increase of its overall efficiency. If the methanol is produced from the biomass, emission of the CO2 can be considered as „zero", because all quantity of the CO2 from combustion of the methanol is absorbed in process of photosynthesis to formation of the biomass.
5. Changes in the emissions discussed here are obtained with maintained performance of the engine, and growth of overall efficiency of the engine.
6. Implemented system eliminates problems of stratification of the methanol-gasoline mixture in low temperatures and in presence of water. The system can be used with any liquid fuels.

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