ISSN 1392-1134
Žemės ūkio inžinerija, Mokslo darbai, 2013, 45(1)
Agricultural Engineering, Research Papers, 2013, Vol. 45, No 1

THE IMPACT OF BIOETHANOL FUEL ON AGRICULTURAL TRACTOR ENGINE'S EXHAUST GAS

BIOETANOLIO DEGALŲ ĮTAKA TRAKTORIAUS VARIKLIO IŠMETAMŲJŲ DUJŲ SUDĖČIAI

Risto Ilves[1], Antanas Sakalauskas[2], Jüri Olt[1]

[1]Institute of Technology, Estonian University of Life Sciences, 56 Kreutzwaldi Street, EE51014 Tartu, Estonia, E-mail: jyri.olt@emu.ee
[2]Aleksandras Stulginskis University, Faculty of Agricultural Engineering, Institute of Agricultural Engineering and Safety, Kaunas-Akademija, Studentu str. 15A, LT-53361 Kauno r., Lithuania, E-mail: antanas.sakalauskas@asu.lt

Received 2013-03-21,accepted 2013-06-12

The objective of the study was to develop an ethanol mixture with the lowest possible concentration and to use that mixture as additional fuel. The purpose was to motivate the farmers to produce local alternative fuels without using any rectification or blending processes. The study also dealt with potential methods for adjusting, at minimal cost, a common agricultural small tractor in order to use ethanol fuels. The article describes and analyzes the experimentally obtained characteristics of a diesel engine exhaust gases, when it is used simultaneously with two fuels, diesel and bioethanol from different concentrations.

The purpose of this study was to find minimum concentration of bioethanol mixture, which allows satisfactory engine operation in the overload area of test plan. Ethanol fuels EF 90; EF 80; EF 70 and EF 60 were used for performing by engine testing. The analysis of combustion process in the engine indicates that introduction of different fuels in combustion process by qualitative and quantitative method is acceptable in technical terms.

As far as the selection of ethanol fuel is concerned, 60% fuel does not cause significant deterioration of engine operation or increase the amount of other hazardous compounds in exhaust gases. It is recommended to use a 60% ethanol fuel as minimum concentration in addition to regular diesel fuel so that the ethanol fuel would comprise up to 60% of the entire fuel amount used by medium load of engine.

Fuel mixture, dual-fuel method, exhaust gas characteristics.

Intruduction

The use of biofuel as motor fuel has been studied in detail already since the 20th century. Today alternative fuel is used as motor fuel or addition to basic fuel in many countries such as USA, Brazil, Germany and Sweden [1; 2]. There are technologies developed for producing motor fuels for plain ethanol as well as its blends

with regular gasoline and diesel fuel to be used in internal combustion engines [3, 4, 5, 6]. More significant research in this field has been presented in the following patents, WO2009106647, US5628805 and DE10339355 [7, 8, 9]. Despite the research performed and existing technologies there are still several countries in the European Community, where alternative fuels are not sufficiently used in production sphere. Hence there are several other objective factors and legislative restrictions that prevent wide use of ethanol fuel in different countries and require further studies. Some of these factors are also considered in this present study.

The geographical location of the Republic of Estonia, availability of large amount of unused production land, population's high level of education and traditional connection with agricultural production create new opportunities for the development, production and use of modern liquid fuels made of local lignocellulose bio-materials. Marine climate and geographical latitude affect the specific nature of technologies for production and use of fuels in Estonia. Crucial factors include extensive fluctuations in air temperature and air humidity over the year and in different combinations. The motor fuel used in Estonia has to ensure that the engine would run at the temperature ranging from +40… -40 °C. Another geographical factor is the proximity of the Russian market. It is a well-known fact that Russia is one of the largest producers of fuel oil and motor fuels in the world. Currently Russia does not produce alternative fuels and it is not likely to be considered a priority in near future either. It is also necessary to point out the fact that the proximity of the engineering market of Russia, as Estonian neighbour state, affects the fuel market of our country. Relatively inexpensive agricultural equipment from Russia makes the Estonian farmers to favour and use the machinery manufactured in Russia. About 82% of tractors currently used in the Republic of Estonia is made in Commonwealth of Independent States (CIS). Meanwhile, the quality of these tractors is very unsteady. Considering the abovementioned facts, the test object chosen for this study is a diesel engine D-120 manufactured in Russia.

The aim of the current research is to study the impact of the 60 % bio ethanol on the exhaust fumes emissions of tractors used in agriculture. To conduct the research, the particular tractor engine is equipped with additional fuel supply system (carburetor) which has been used to dose bioethanol into the engine.

Object and methods

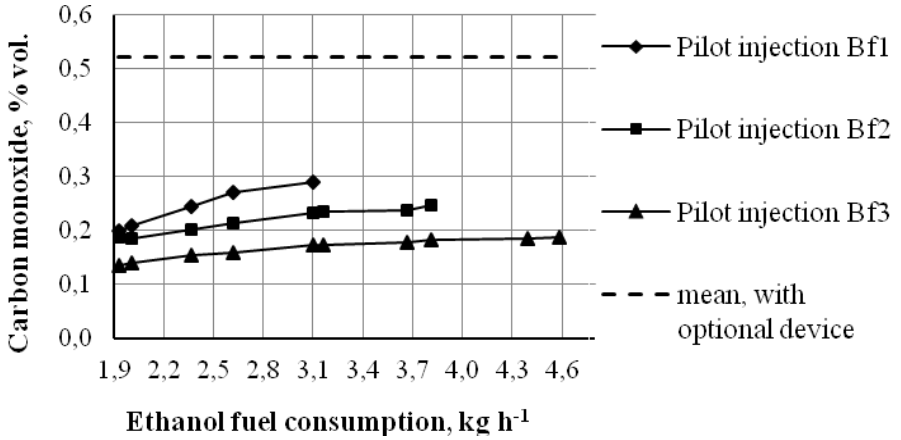
The reason behind introduction of bioethanol as additional motor fuel is the decrease in fossil fuel resources. The problem with using ethanol blended fuels consists in their lower efficiency in comparison with standard fuel. At the same time EU environmental directives provide for strict requirements on the composition of exhaust gas and emission limits thereof [10]. This is particularly relevant in case of the mechanical fuel-supply system diesel engines manufactured in CIS. The composition of exhaust gases and limits thereof in the aforesaid engines exceed the EU standards to a significant extent. One potential solution is found in improvement of the fuel-supply system of these engines by means of addition system,

which is used to introduce bioethanol in the combustion process. The composition of exhaust gases in the case of an engine operating on ethanol and diesel fuel differs significantly from the composition of exhaust gases when using standard fuel and thus this subject is open to further research in the future. This article presents the research results obtained when using ethanol made of lignocellulose biomass as additional fuel for diesel engine [11; 12]. The analysis focuses on potential uses of the fuel blend in question and the impact thereof on the combustion process in the diesel engine. Assessment of the composition of fuel mixture uses qualitative and quantitative methods of mixture formation.

Quantitative ratio of fuel components in a diesel engine is determined by controlling the adjustment characteristics of in-line high-pressure pump and load and adjustment characteristics of diesel engine [13]. Physical-chemical properties of alternative fuel are assessed by measuring the indicator parameters of engine combustion process, composition of exhaust gas and output parameters of the engine [2]. The object of the study consisted in a diesel engine D-120 equipped with two fuel-supply systems: main fuel-supply system, which ensures pilot injection of basic fuel and additional fuel-supply system, which ensures the supply of various blended ethanol fuel mixtures according to engine load mode. Such solution ensures good engine start-up and its operation within a wide range of operating modes. Additional fuel is introduced to the work process via intake collector by using relevant fitting. The loss of power resulting from the low level of basic fuel during engine operation is compensated by administering additional ethanol fuel.

Results and discussion

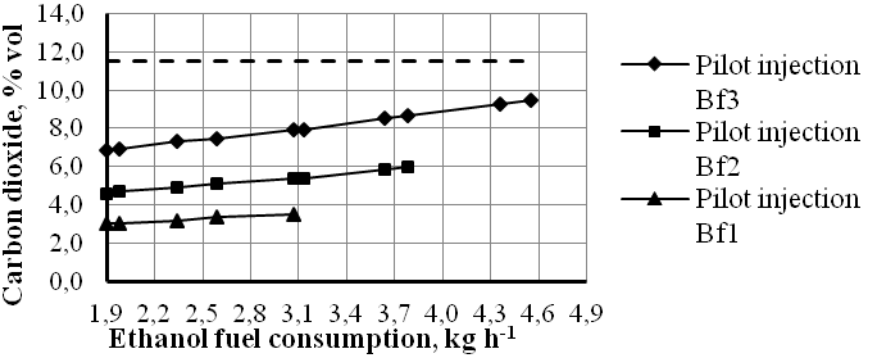
The tests were executed while the rotational speed of the engine's crankshaft was $n_e = 1300$ rpm. Ethanol was added to the air fuel mixture while the engine was still running smoothly and stable. In case of increasing pilot injection (standard diesel fuel), including at every value of the ethanol fuel consumption (Fig. 1) the amount of CO in exhaust gases decreases. Meanwhile, as the ethanol fuel consumption increases in every particular load mode, the amount of CO in exhaust gases increases monotonously. Using ethanol fuel in engine reduces the amount of CO in exhaust gases by 3…5 times, depending on the load mode of the engine.



1 pav. Etanolio degalų sunaudojimo įtaka anglies monoksido kiekiui esant skirtingam įpurškimui, kur B_{f1} = 1,35 kg/h; B_{f2} = 2,33 kg/h and B_{f3} = 3,05 kg/h

Fig. 1. Impact of the ethanol fuel consumption on the value of carbon monoxide in case of different pilot injections, where B_{f1} = 1,35 kg/h; B_{f2} = 2,33 kg/h and B_{f3} = 3.05 kg/h

Carbon dioxide (CO_2). Fig. 2 describes the change in the concentration of carbon dioxide at various engine loads and at different ethanol fuel consumption. The concentration of carbon dioxide shows linear increase upon increased delivery of ethanol fuel. The concentration of carbon dioxide also increases in case of increased pilot injection (upon increase in load mode). Test results indicate that in case of adding ethanol fuel in the amount of up to 3 kg/h the amount of carbon dioxide in exhaust gases is reduced by 2...3 times.

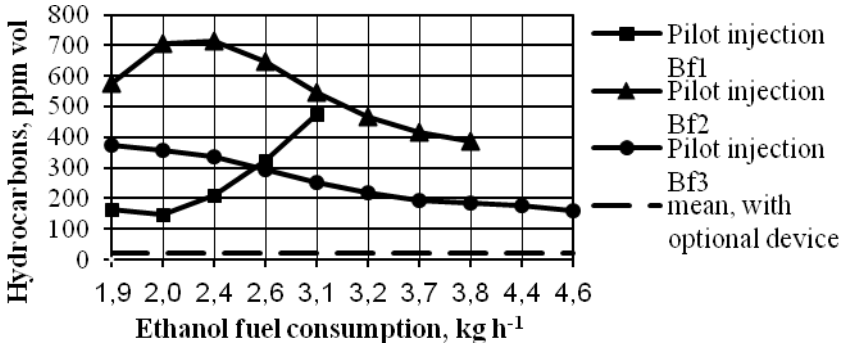


2 pav. Etanolio degalų sunaudojimo įtaka anglies diooksido kiekiui esant skirtingam įpurškimui, kur B_{f1} = 1,35 kg/h; B_{f2} = 2,33 kg/h and B_{f3} = 3,05 kg/h

Fig 2. Impact of the ethanol fuel consumption on the values of carbon dioxide in case of different pilot injections, where B_{f1} = 1.35 kg/h; B_{f2} = 2.33 kg/h and B_{f3} = 3.05 kg/h

Hydrocarbons (HC). Fig. 3 describes the change in the concentration of hydrocarbons in exhaust gases at various quantities of ethanol and diesel fuel. The

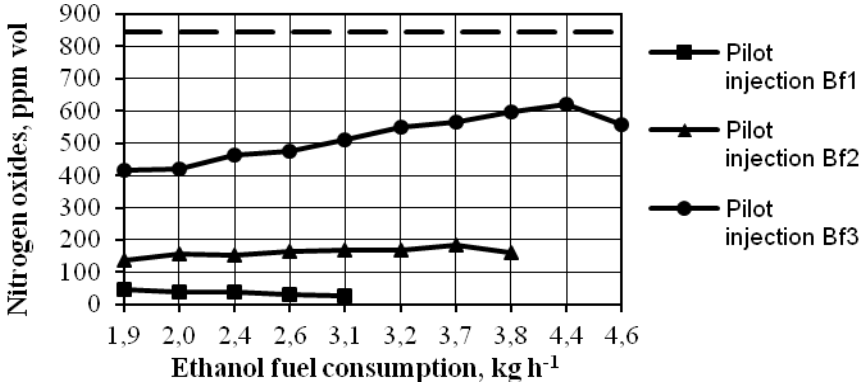
concentration of hydrocarbons in exhaust gases increases at low delivery of standard fuel, according to the increase in ethanol fuel consumption. This is caused by high proportion of ethanol fuel in the fuel mixture. The amount of diesel fuel is insufficient for full combustion of ethanol in the cylinder. In case of medium and high delivery of standard fuel the proportion of hydrocarbons begins to decrease as the ethanol amount increases. In given modes the pilot injection of diesel fuel is high enough for the ethanol to ignite and burn in the cylinder. In comparison to using plain diesel fuel the proportion of hydrocarbons in the exhaust gases increases up to 30 times when using ethanol.



3 pav. Etanolio degalų sunaudojimo įtaka angliavandenių kiekiui esant skirtingam įpurškimui, kur B_{f1} = 1,35 kg/h; B_{f2} = 2,33 kg/h and B_{f3} = 3,05 kg/h

Fig. 3. Impact of the ethanol fuel consumption on the values of hydrocarbons in case of different pilot injections, where B_{f1} = 1.35 kg/h; B_{f2} = 2.33 kg/h and B_{f3} = 3.05 kg/h

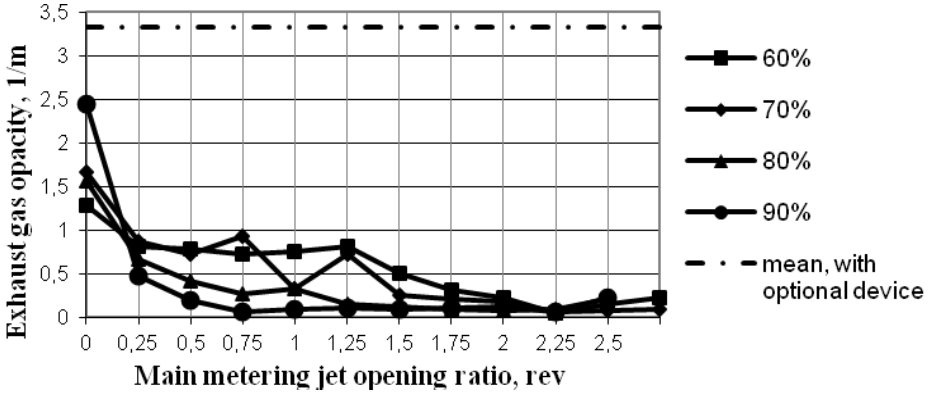
Oxides of nitrogen (NO_x). Figure 4 describes the change in nitrogen compounds in case of different quantities of ethanol and diesel fuels. In case of low pilot injection delivery the amount of nitrogen compounds decreases, because ethanol fuel cools down the combustion chamber and less nitrogen compounds are generated at lower temperatures. At average and high loads the concentration of nitrogen compounds increases as the ethanol fuel consumption increases. The proportion of nitrogen compounds in exhaust gases is reduced significantly in comparison to using diesel fuel. In case of ethanol fuel consumption up to 3 kg/h, the amount of nitrogen compounds in exhaust gases is reduced by 2…5 times. An important aspect to point out is that while using common rail fuel supply systems on high modes, the proportion of nitrogen compounds in exhaust gases increases significantly compared to using diesel fuels. [7].



4 pav. Etanolio degalų sunaudojimo įtaka azoto junginių kiekiui esant skirtingam įpurškimui, kur B_{f1} = 1,35 kg/h; B_{f2} = 2,33 kg/h and B_{f3} = 3,05 kg/h

Fig. 4. Impact of the ethanol fuel consumption on the value of nitrogen compounds in case of different pilot injections, where B_{f1} = 1.35 kg/h; B_{f2} = 2.33 kg/h and B_{f3} = 3.05 kg/h

Opacities of exhaust gases. Main pollutant in diesel engines is carbon black, which is generated during combustion of diesel fuel. Fig. 5 shows the values of opacities of exhaust gases in case of different concentrations of ethanol fuels (60…90%). The limit values indicated in the figure have been obtained with engine running with diesel fuel and in the same load modes and level of completion: operating with and without additional fuel. Crankshaft rotational speed was n_e = 1800 rpm.



5 pav. Etanolio degalų sunaudojimo įtaka išmetamųjų dujų kietųjų dalelių kiekiui

Fig. 5. Impact of the ethanol fuel consumption on the opacities of exhaust gases depending on its concentration

Based on test data the opacities of exhaust gases is significantly reduced upon using ethanol fuel with different concentration. The lower the water contents in ethanol, the lower the value of smoke in exhaust gases. When using ethanol fuels

with different concentration, the value of opacities of exhaust gases increases constantly, at even pace corresponding to the increase of the amount of water in ethanol. The higher the ethanol contents of the fuel mixture, the lower the value of opacities of exhaust gases. In case of higher fuel delivery the values of opacities of exhaust gases begin to even up and reach identical values at the delivery of 2.5 kg/h. When the fuel delivery is increased, the indicators begin to grow again.

Conclusion

Production of ethanol as local biofuel is relatively inexpensive and the technology used for production is quite simple. In technological terms, nowadays any farmer can manage producing up to 70% ethanol. Elementary carburetor is all that is necessary for adjusting the engine for ethanol fuel. Ethanol fuel consumption was changed by the extent of opening ratio of main metering jet. In the framework of follow-up research on this subject field tests shall be carried out with diesel engine D-120 in summer, in the course of which common control system for both delivery systems shall be developed. Using ethanol motor fuel enhances energy security and reduces environmental pollution.

1. As far as the selection of ethanol fuel is concerned, 60% fuel does not cause significant deterioration of engine operation or increase the amount of other hazardous compounds in exhaust gases.
2. It is recommended to use a 60% ethanol fuel as minimum concentration in addition to regular diesel fuel so that the ethanol fuel would comprise up to 60% of the entire fuel amount used by medium load of engine.
3. The concentration of exhaust gas components such as CO, CO_2, NO_X as well as the value of smoke in exhaust gas were significantly reduced when using ethanol fuel.
4. The proportion of hydrocarbons, however, was increased. This may be due to reduced efficiency of combustion process. This issue shall be subject to follow-up research.

References

1. Harndorf, H.; Schuemann, U.; Wichmann, V.; Fink, C. 2008. Motorprozessverhalten und Abgasemissionen alternativer Kraftstoffe im Vergleich mit Dieselkraftstoff, MTZ 7-8/2008, 69 Jahrgang, S. 640-646
2. Steinbach, N.; Harndorf, H.; Weberbauer, F.; Thiel, M. 2006. Motorisches Potential von synthetischen Dieselkraftstoffen, MTZ 02/2006, 67 Jahrgang, S. 96-102.
3. Bialkowski, M. T. 2009. Theoretical and Experimental Investigation of a CDI Injection System Operating on Neat Rapeseed Oil – Feasibility and Operational Studies. Submitted for the degree of philosophy on completion of research in the School of Engineering and Physical Sciences, Chemical Engineering, Heriot-Watt University. The United Kingdom. 423 pp.

4. Kim, H.; Choi, B. 2010. The effect of biodiesel and bioethanol blended diesel fuel on nanoparticles and exhaust emissions from CRDI diesel engine. Renewable Energy 35. 157–163.
5. Polak, M. 2004. Ethanol enriched biodiesel as a fuel for compression ignition engines. *RES. AGR. ENG*., *50*, 2004 (3). 107–111.
6. Kára, J. Research Biofuels with Content of Bioethanol for Diesel Engines. Czech. http://212.71.135.254/vuzt/konferen/k15.pdf (28.02.2011).
7. Courtoy, P; Smith, A; Gamble, F; Greenhalgh, D. MULTI-FUELLING AN ENGINE. Pub. No.: WO2009106647. WIPO PATENTSCOPE.
8. Lif, A; Svennberg, S. Ethanol fuel and the use of an ignition improver. Pub. No.: US5628805. Espacenet Patent search.
9. MOELLER, E. Fuel feed system for diesel engine running on biofuel derived from plants has 3/2-way valve connected to fuel tank, return line to tank and line leading to high-pressure pump. Pub. No.: DE10339355. Espacenet Patent search.
10. Robert Bosch GmbH, 2007. Bosch Automotive Handbook, 7th edition. German. 1200 pp.
11. Pulkrabek, W. W. 2009. Engineering Fundamentals of the Internal Combustion Engine. Prentice Hall. USA. 411 pp.
12. Demirbas, A. 2006. Global biofuel strategies. Energy Edu. Sci. Technol. Turkey. 336 pp.
13. Taylor C. F. 1998. The internal-combustion engine in theory and practice: V.1, Thermodynamics, fluid flow, performance. 574.pp; and V.2: Combustion, Fuels, Materials, Design 783.pp; The Massachusetts Institute of Technology. 9-th printing. England.

Risto Ilves, Antanas Sakalauskas, Jüri Olt

BIOETANOLIO DEGALŲ ĮTAKA TRAKROTIAUS VARIKLIO IŠMETAMŲJŲ DUJŲ SUDĖČIAI

Tyrimų objektas buvo sukurti mažiausios galimos koncentracijos etanolio mišinį ir panaudoti šį mišinį kaip papildomus degalus. Tikslas buvo motyvuoti ūkininkus gaminti vietinius alternatyvius degalus nenaudojant reaktifikacijos ar maišymo procesų. Tyrimais taip pat sprendžiamas minimalių kaštų potencialių reguliavimo metodų klausimas, dažniausiai eksploatuojamiems mažiems traktoriams siekiant naudoti etanolio degalus. Straipsnyje aprašomi ir analizuojami eksperimentiškai gautos dyzelinio variklio išmetamųjų dujų charakteristikos, kai tuo pat metu buvo naudojami dviejų rūšių degalai – skirtingų koncentracijų dyzelinas ir bioetanolis.

Šio tyrimo tikslas buvo surasti minimalios koncentracijos bioetanolio mišinį, kurį naudojant variklis gerai dirbtų tyrimų plane numatytų apkrovų ribose. Variklio tyrimams buvo naudojami etanolio degalai EF 90; EF 80; EF 70 ir EF 60. Degimo

proceso variklyje analizė parodė, kad įvairių degalų įvedimas į degimo procesą naudojant kiekybinius ir kokybinius metodus tenkina technines sąlygas.

Kas susiję su etanolio degalų pasirinkimu, tai 60 % degalai neblogina variklio darbo parametrų ir nedidina žalingų junginių kiekio išmetamose dujose. Rekomenduojama naudoti 60 % etanolio degalus, kaip minimalios koncentracijos priedą tradiciniuose dyzeliniuose degaluose taip, kad etanolio degalai sudarytų iki 60 % viso kuro kiekio esant vidutinei variklio apkrovai.

Kuro mišinys, dvejopo kuro metodas, išmetamųjų dujų charakteristikos.

Ристо Илвес, Антанас Сакалаускас, Юри Олт

ВЛИЯНИЕ ТОПЛИВА БИОЭТАНОЛА НА СОСТАВ ВЫХЛОПНЫХ ГАЗОВ ТРАКТОРНОГО ДВИГАТЕЛЯ

Объектом данного исследования является разработка смеси этанола с минимально возможной концентрацией и использование этой смеси в качестве дополнительного топлива. Цель состояла в том, чтобы мотивировать фермеров производить местные альтернативные виды топлива, не используя процессов реактификации или смешивания. В исследовании также рассматриваются потенциальные методы по регулировке минимальных затрат для чаще свего используемых небольших тракторов употребляя этанол как топливо. В статье описаны и проанализированы экспериментально полученные характеристики выхлопных газов дизельного двигателя, используя одновременно два вида топлива - дизельное топливо и биоэтанола в различных концентрациях. Целью этого исследования было найти минимальную концентрацию смеси биоэтанола, которая позволяет получить удовлетворительную работу двигателя в пределах перегрузок подобраных по плану тестирования. Этанольные топлива EF 90; EF 80; EF 70 и EF 60 были использованы для проведения испытаний двигателей. Анализ процесса сгорания в двигателе показал, что введение различных видов топлива в процессе горения качественными и количественными методами в техническом плане является приемлемым. Что касается выбора топливного этанола, то, 60% топлива не приводит к значительному ухудшению работы двигателя или к увеличению количества вредных соединений в выхлопных газах. Рекомендуется использовать 60% этанольного топлива в качестве добавки минимальной концентрации в обычное дизельное топливо, так что этанол составлял до 60% от всего количества топлива, используемого на средних нагрузках двигателя.

Смеси топлива, метод двух видов топлива, характеристика выхлопных газов.