VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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IMPROVEMENT OF DIESEL ENGINE ECOLOGICAL PARAMETERS BY USING BIOBUTANOL AND BIODIESEL MIXTURES

SUMMARY OF DOCTORAL DISSERTATION

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Jonas MATIJOŠIUS

DYZELINIO VARIKLIO EKOLOGINIŲ RODIKLIŲ GERINIMAS NAUDOJANT BIOBUTANOLIO IR BIODYZELINO MIŠINIUS

DAKTARO DISERTACIJOS SANTRAUKA

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Introduction

Topicality of the problem. Internal combustion engines, especially diesel engines, are one of the major sources of environment contamination. When burning petroleum fuels a large amount of harmful substances is released into the air. One of the ways to avoid harmful environmental impact of exhaust gases and to overcome energy dependence on more and more expensive oil-origin fuel is using biobutanol and biodiesel (RME) mixtures.

A new biofuel mixture composed of biobutanol and biodiesel is being used and tested. Scientific literature sources lack data on engine performance and exhaust emission parameters measured when using these mixtures.

Particular matter from internal combustion engines, which consists of carbon, is usually covered with machine oil, fuel residues, sulphates, water, polar organic and non-organic materials, metals, etc.; carbonate aerosol is described in literature sources. Its particles are actively studies in order to determine their effect on climate change and human health. Stable isotope mass spectrometry has been applied for study of aerosol particles since 1981, for the purpose of establishing the origin of aerosol particles found in the atmosphere. Due to kinetic isotopic effect the ratio of $^{13}C/^{12}C$ carbon changes during transition from one environment to another (e.g. it differs in atmospheric air, trees, soil). Therefore, the ratio of stable carbon isotopes $^{13}C/^{12}C$ is one of the major methods of establishing the origin of aerosol particles.

Object of the research. The object of research there are ecological parameters of a diesel engine, which are running on biobuthanol and biodiesel mixtures.

Aim and tasks of the work. Aim of the work – the primary purpose of the research is to conduct theoretical and experimental studies and to substantiate the possibilities of using biofuel mixtures, composed of biobutanol and biodiesel, in a diesel engine, evaluating the engine performance efficiency, economic efficiency and ecological indicators.

In order to achieve the purpose of the research the following objectives need to be accomplished:

1. To examine physical and chemical characteristics of biodiesel and biobutanol mixtures.
2. To conduct an experimental study of ecological, power, fuel-efficiency parameters of a diesel engine using biobutanol and biodiesel mixtures lieu mineral diesel fuel.

3. To explore the properties of carbonate aerosols (PM), produced by burning of biobutanol and biodiesel mixtures, by applying stable isotope mass spectrometry and aerosol condensation methods.
4. To evaluate the possibility of adapting methods, approved by other authors, ecological and thermodynamical parameters of the mathematical model of a diesel engine.

Methodology of research. Theoretical and experimental research methods were applied in the thesis. The theoretical analysis performed is based on hydrodynamics, theoretical mechanics and the theory of combustion process dynamics, with application of analytical and digital research methods.

Scientific novelty. The following new results in transport engineering science were obtained when preparing the doctoral thesis:

1. The percentage amount of biobutanol in biobutanol and biodiesel mixtures which ensured physical and chemical properties of biofuel meeting the standard requirements and improved performance efficiency and ecological parameters of a diesel engine was established.
2. It was established that in the case of using biobutanol and biodiesel mixtures the known methods of calculation of kinematic viscosity are not absolutely precise.
3. A mathematical model of using biobutanol and biodiesel mixtures, evaluating the performance efficiency and ecological parameters of a diesel engine running on these mixtures, was created.
4. The carbon aerosol dispersity distribution and the total aerosol particle emissions from diesel engine using by Biobutanol and biodiesel blends was sattled by particle stable mass spectrometry and aerosol concentration methods. It is very important in determining engine exhaust effects and degree of hazard to human health.

Practical value

1. Performing test appointed that the maximum possible to 20 percentage amount of biobutanol in biobutanol and biodiesel mixtures which ensures meeting the fuel quality requirements and improves performance efficiency and ecological parameters of a diesel engine was established.
2. There was proved that only biological-origin mixture was used and its application in a diesel engine was substantiated – this allows to completely abandon mineral-origin fuel.

3. It was noted during the process of calculation of kinematic viscosity that all the known methods of calculation of kinematic viscosity was not absolutely precise for calculation of biofuel kinematic viscosity, which was due to low accuracy of calculations as compared with experiment results.
4. It was established that the dispersability properties of carbonate aerosols (PM) and aerosol particles total emission by applying stable isotope mass spectrometry and aerosol condensation methods.

Defended propositions

1. Performing test appointed that the maximum possible to 20 percentage amount of biobutanol in biobutanol and biodiesel mixtures which ensures meeting the fuel quality requirements and improves performance efficiency and ecological parameters of a diesel engine.
2. Using biobutanol and biodiesel fuel mixtures can completely replace the mineral-origin diesel fuel.
3. The dispersability properties of carbonate aerosols (PM) and aerosol particles total emission could be definite by applying stable isotope mass spectrometry and aerosol condensation methods.

The scope of the scientific work. The thesis is presented in the Lithuanian language. It consists of introduction, three chapters and the list of 150 references. The thesis comprises 109 pages without the annexes, 9 tables, including 40 ilustrations.

1. Analysis of Biofuel Production and Use

The following issues are analyzed in this section: substantiation of feasibility of using biofuel, based on scientific and legislative sources, the biofuel resources available in the European Union and in Lithuania, application of butanol and biodiesel and their mixtures with mineral fuels in engines, particulate matter exhausted by a diesel engine and the methods of its analysis, application of isotope mass spectrometry and other methods for analysis of internal combustion engine exhaust gases.

2. Methodology of Biobutanol and Biodiesel Mixtures Analysis

The analysis of physical and chemical properties of biobutanol and biodiesel mixtures was performed in the accredited Biocomponents Research Laboratory of Institute for Fuels and Renewable Energy (IPIEO).

These were tested for biofuels and their mixtures:

- ✓ Biodiesel – rapeseed oil fatty acid methyl ester (RME), derived from refined canola oil double its absolute methanol transesterification using an alkaline catalyst (KOH) method. Product line with the European standard EN 14214:2001 requirements.
- ✓ Biobutanol – anhydrous n-butanol obtained in 96 % neutral butanol by distillation twice, plus 10 % $CaCl_2$.

There were evaluated for quality indicators in the studies:

- ✓ Density by EN ISO 12185.
- ✓ Viscosity by EN ISO 3104.
- ✓ Flash point by EN ISO 3679.
- ✓ Cetane number by EN ISO 5165.
- ✓ The amount of water by EN ISO 12937.
- ✓ Corrosion on copper plate by EN ISO 2106.
- ✓ Acidity by EN ISO 14104.
- ✓ Iodine number by EN ISO 14111.
- ✓ The cold filter plugging point, and calorific value by EN 116.
- ✓ Sulfur by EN ISO 20846.
- ✓ Monoaciloglycerol, diaciloglycerol, triaciloglycerol, free glycerol and total glycerol content in accordance by EN ISO 14105.

For the purposes of theoretical studies of biobutanol and biodiesel mixtures, i.e. for modelling engine operation processes and emission of particulate matter and nitrogen oxides, an original mathematical model was created in the “Fortran 11” computer software environment. Moreover, modelling computer software “Diesel-RK 4.1.3.171” for simulating diesel engine operation processes, which was designed by the scientists of Moscow State Techical University named after N. E. Bauman, was used for the abovementioned processes.

Experimental tests of biobutanol and biodiesel engines were conducted at Internal Combustion Engine Test Laboratory, located in Transport Vehicle Institute (IP) of Automobile and Machinery Faculty (SIMR) of Warsaw University of Technology. Experimental tests were performed on the basis of the international technical standard ICS 43.060 (Automobile engines. Methods of bench tests). The following parameters were measured during the tests: torque Ms, pre-set fuel amount consumption time t, rated pressure p, excess-air coefficient α, exhaust: CO, CO_2, O_2, CH, NO_x, PM.

For conducting experimental tests a laboratory test stand was created, which consists of: turbulent currents engine dynamometer, mounted together with a diesel internal combustion engine, as well as exhaust and fuel consumption measuring equipment. The scheme of the test stand is presented in Fig. 1.

The analysis of exhaust gases of a diesel engine running on biobutanol and biodiesel fuel mixtures, employing the methods of stable isotope mass spectrometry and aerosol condensation, was performed on 15–21 December 2010 at Internal Combustion Engines Laboratory of the Department of Automobile Transport, which belongs to the Faculty of Transport Engineering Vilnius Gediminas of Technical University, in collaboration with the Nuclear and Radioactive Research Laboratory and Environmental Physics and Chemistry Laboratory of the Physics Institute of the Centre for Physico-technological Science of the State Scientific Research Institute.

The following equipment was used for the purposes of stable isotope mass spectrometry and aerosol condensation tests: "Audi-80" 1Z type diesel internal combustion engine, electric engine test stand КИ-5543 with a weight dynamometer, a stable isotope mass spectrometer "ThermoFinnigan Delta Plus Advantage" with a connected burner "FlashEA 1112" and a condensation aerosol particle meter UF-02.

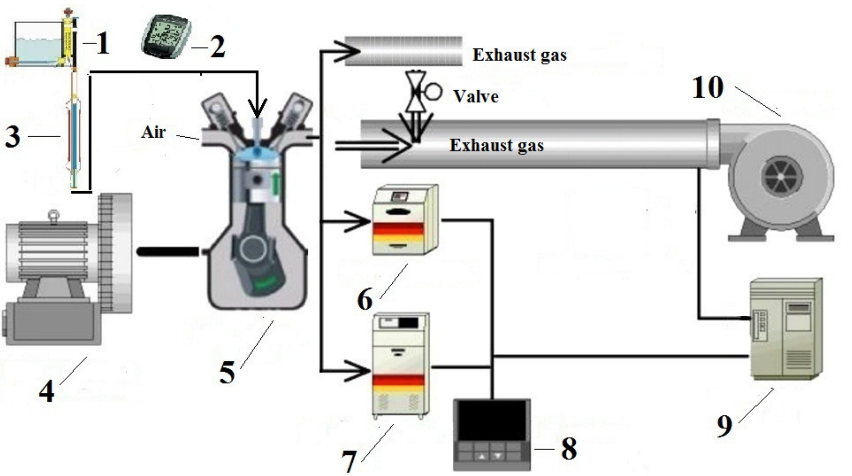


Fig. 1. Laboratory test stand: 1 – fuel tank with the fuel used for tests, complete with thermometer; 2 – electronic chronometer "Sigma BC 400"; 3 – calibrated glass for measuring the volume of the fuel consumed; 4 – turbulent currents engine dynamometer "SCHENCK WT190"; 5 – diesel internal combustion engine "Perkins 1104c-44"; 6 – engine exhaust gases' smokiness measuring device AVL 415S; 7 – oxide analyser "Horiba 7170DEGR"; 8 – data registration device – portable computer "LENOVO T410"; 9 – power supply equipment; 10 – drawing ventilation

3. Studies on Biobutanol and Biodiesel Mixtures

It has been established during the tests that the following biobutanol and biodiesel mixtures complied with the quality requirements set out in regulatory acts: with 10 % concentration of biobutanol (sample B) and with 20 % concentration of biobutanol (sample C). Pure biodiesel fuel (sample A) failed to comply with only one parameter.

Upon sample C reaching the threshold quantity of water (biobutanol is prone to absorbing water and increase of its concentration in a mixture results in an increase of the amount of water absorbed) and kinematic viscosity (biobutanol is more volatile than biodiesel and increase of its concentration results in decrease of density, as well as viscosity of the mixture), flash temperature and cetane number (the increase of biobutanol concentration in a mixture causes decrease of the mixture's calorific capacity, it becomes more volatile and thus evaporates and ignites more easily), acidity (potassium chloride which is contained in biobutanol is prone to acidify the mixture and this is increasingly more noticeable after increasing biobutanol concentration in the mixture) reaching the threshold values no further tests based on physical and chemical methodological guidelines for biobutanol and biodiesel mixtures were conducted. Other physical and chemical parameters complied with the requirements set out in regulatory documents.

It is feasible to continue further research tests with mixtures characterized by 10 % and 20 % biobutanol concentration in biodiesel.

Kinematic viscosity determines not only fuel supply capacity, but also operation of fuel equipment and fuel spraying in the combustion chamber – the course of the whole operation process. Even though kinematic viscosity of biobutanol and biodiesel mixtures depends on kinematic viscosity of the initial substances, its calculation according to the additivity principle shall be inadequate.

The most appropriate dependency (Fig. 2), meeting the experiment requirements, was established.

The most acceptable results are ensured by the dependancy proposed by Zdanovsky. The maximum inaccuracy of this dependency, when comparing the calculation data with the experimental data, constitutes 17 percent, which is absolutely unacceptable and the higher the concentration of biobutanol in the mixture, the greater is this difference. For conducting further calculations cetane number of the mixtures was established according to the approximation dependency, which describes the experimental data.

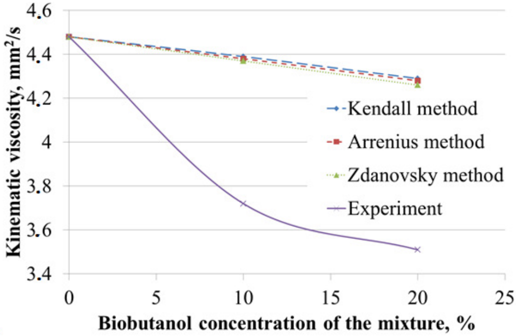


Fig. 2. Changes of biobutanol and biodiesel mixtures' kinematic viscosity

As compared to the oil-origin fuel biodiesel is characterized by the following ignition and combustion properties within an engine cylinder. Due to a higher cetane number (51 versus 40 of diesel fuel) the ignition delay period of biodiesel is shorter as compared to mineral diesel fuel. The evaporation temperature (315 °C versus 250 °C of diesel fuel) determines the smaller amount of fuel prepared for combustion in a diesel engine cylinder during the ignition delay period. As a result, there is a decrease of the heat amount released during the first kinetic phase of fuel combustion. On the other hand, the fuel combustion during the second combustion phase is becoming more intense, which improves the energy parameters, primarily the rated efficiency coefficient of the cycle, and decreases the concentration of incomplete combustion products (CO and PM) in exhaust gases. Up to the moment of achieving the maximum pressure of a cycle (p_{max}) the amount of the heat released is increasing as compared to the diesel fuel. As it is commonly known, the major part of NO_x in a cylinder is formed before reaching p_{max}, thus the emission of NO_x when using biodiesel is increasing as compared to the cases of using mineral diesel fuel. Alcohol (in our case biobutanol) additives to biodiesel, due to their lower cetane number and lower evaporation temperature (118 °C of biobutanol versus 315 °C of biodiesel) in general influence the shift of the combustion process to the exhaust stroke. Without essential change of the typical phases of the combustion process a high cycle efficiency coefficient is retained, in the meantime PM concentration decreases several times due to a higher amount of oxygen in the elemental composition of alcohol (11.5 % of biodiesel versus 21.6 % of biobutanol). In case of a prolonged ignition delay period the use of alcohol can cause deviation of the work process parameters from the optimal condition. This may cause deterioration of the efficiency coefficient and increase the emission of incomplete combustion products, mainly CO, in exhaust gases. In such case an optimization of the diesel engine adjustment parameters is required.

These peculiarities related to the use of biobutanol and biodiesel mixtures in a diesel engine have to be considered during the analysis of experiment results and conducting mathematical modelling research.

Increase of biobutanol percentage in a mixture at an average engine rpm speed (1400 min^{-1}) extends the ignition delay period (Fig. 3), which increases the pressure increment rate during the second combustion phase and the engine is producing more noise. The maximum combustion pressure is achieved at an optimum moment (12–13 ° after top dead centre, TDC) and little differs from the maximum combustion pressure developed by biodiesel.

Increasing the engine rpm speed to 2200 min^{-1} (Fig. 3) and raising concentration of biobutanol in biodiesel results in a significant extension of the ignition delay period in relation to the shaft rotation angle. The increment of the second combustion phase is also increasing, however the maximum combustion pressure is lower than that of biodiesel and the net efficiency coefficient is decreasing.

Upon comparison of the rated pressure (Fig. 3), measured during the use of biobutanol and biodiesel mixtures, a tendency of its reduction with the increase of biobutanol concentration is observed. This fact can be explained in terms of decreasing lower calorific capacity of the mixtures with the increase of biobutanol concentration.

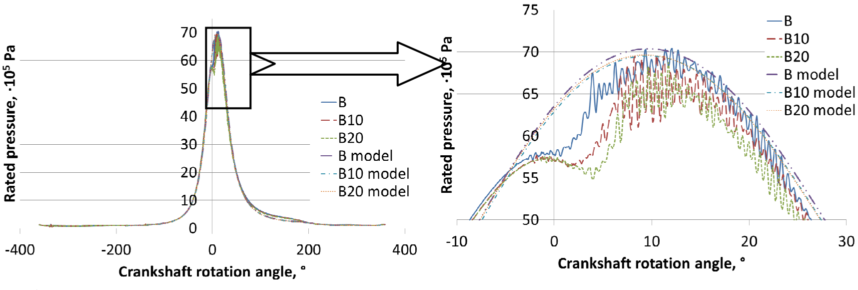
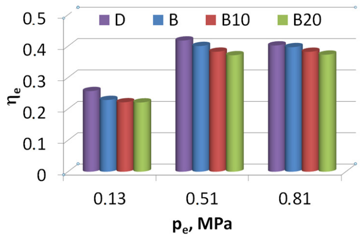


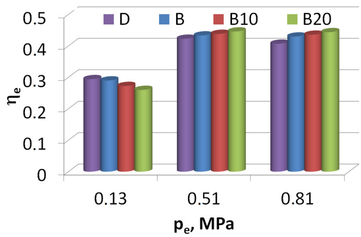
Fig. 3. Rated pressure is modeled for an engine running on biobutanol and biodiesel mixtures

In order to use biobutanol and biodiesel mixtures efficiently, the fuel supply advance angle needs to be optimized, which would allow to shorten the ignition delay period, to reduce the noise produced by the engine and would allow to achieve the maximum pressure in a cylinder at the right moment. This would increase the mean effective pressure of an engine.

Net efficiency coefficient is presented in Figure 4 a and b. It should be noted that it is the opposite of comparative fuel consumption and small lower calorific capacity of the fuel. Taking this into account could explain the obtained values of the net efficiency coefficient. It was observed that the increase of the amount of biobutanol in mixtures results in the increase of net efficiency coefficient, which is caused by physical and chemical properties of the fuel and the spraying quality at 1400 min^{-1} engine rpm speed. Whereas increase of the engine rpm speed to 2200 min^{-1} causes decrease of net efficiency coefficient, which can be explained by the decreasing lower calorific capacity. This corresponds to the statement of Rokopoulos, which claims that the bigger is the percentage of biobutanol additive in the mixtures, the leaner they get and the greater is the temperature decrease in the cylinder.



a)

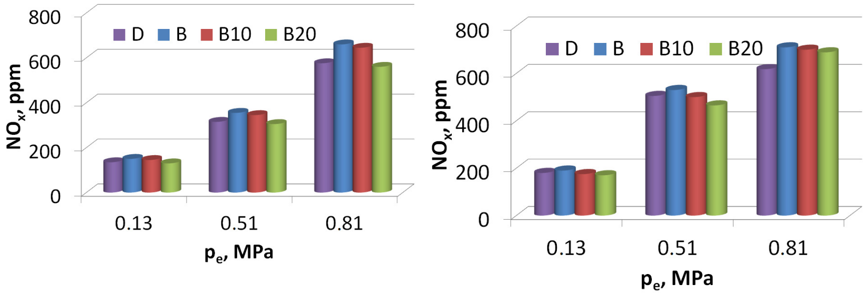


b)

Fig. 4. Net efficiency coefficient: a) at constant engine rpm speed 1400 min^{-1}; b) at constant engine rpm speed 2200 min^{-1}

An 11–22 % decrease of NO_x concentration (Fig. 5) has been observed when using biodiesel and biobutanol mixtures in a diesel engine at 2200 min^{-1} and 1400 min^{-1} rpm speed. Smaller NO_x emissions of the engines running on biobutanol and biodiesel mixtures were observed and the emissions decrease proportionally with the increase of biobutanol concentration in the mixtures. This is explained by the fact that the increasing biobutanol concentration progressively leans the mixture and decreases the temperature in the cylinder (due to decreased lower calorific capacity and higher vaporization heat of biobutanol). According to Corkwell, another significant factor is the lower cetane number (and this is the means of extending the ignition delay period).

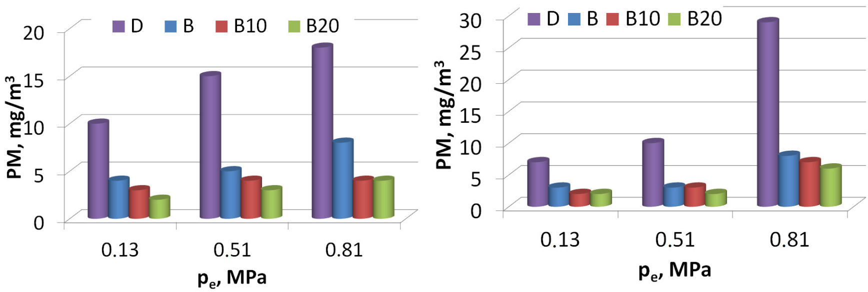
PM emission is presented in Figure 6. It should be highlighted that comparing with the starting point, the mineral diesel fuel, the amount of PM decreased dramatically as opposed to both pure biodiesel fuel (by 53–73 %) and to biobutanol and biodiesel mixtures (by 71–76 % as compared to B20).



a) b)

Fig. 5. NO_x gas emission: a) at constant engine rpm speed 1400 min^{-1}; b) at constant engine rpm speed 2200 min^{-1}

This is attributed to the additional amount of oxygen in the mixtures. Increasing biobutanol concentration in biodiesel also results in decrease of PM emission, which could be explained by the fact that the shorter is the hydrocarbon molecule the better is its combustion and the lower C/H chemical elemental ratio.



a) b)

Fig. 6. PM amount: a) at constant engine rpm speed 1400 min^{-1}; b) at constant engine rpm speed 2200 min^{-1}

Aerosol particles, emitted in internal combustion engine, were investigated by isotope ratio mass spectroscopy methods. Biodiesel and biodiesel with a butanol were used as a fuel. The purpose of these additional data was to evaluate experimentall, which fuel mixture types and at which vehicle settings emit aerosol particles to the environment and at which extent.

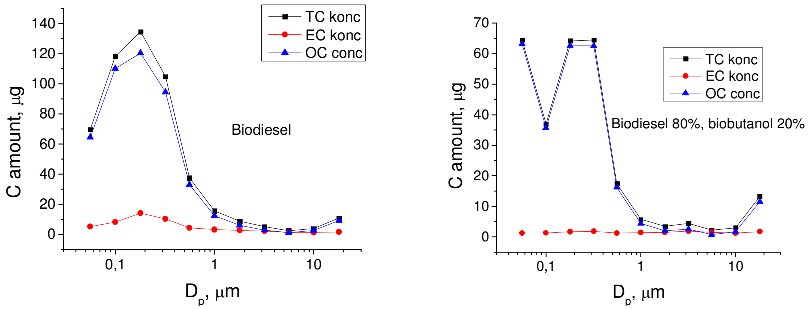
In addition to the total particle mass, aerosol mass in size segregated aerosol particles (PM) were also measured.

Highest aerosol particle mass concentration was measured in size range from 0.18 to 0.32 μm, when B mixture was used. In the case with B20 mixture, highest aerosol particle concentration was in the size range from 0.056 to 0.1 μm and from 0.18 to 0.56 μm (Fig. 7).

Comparing amount of the emissions, bigger aerosol particle mass was emitted using B fuel mixture (biodiesel). The amount of smallest aerosol particles, which can easily penetrate to the human lungs, was comparable when using B or B20 mixture.

Higher aerosol particle concentrations were measured in all particle sizes using B mixture. This shows that B20 mixture emit carbonaceous aerosol particles at lower extent.

In the aerosol particles size range from 0.056 to 1 μm organic carbon was dominating, when used B and B20 mixtures. The amount of the elemental carbon was 10 times smaller, comparing with the organic carbon in both cases (Fig. 7).



a) b)

Fig. 7. Dependence of C amount on dispersive capacity of particles: a) using biodiesel, b) using B20 fuel mixture

The carbon isotopic ratio of the biodiesel, used in the experiment, was $\delta^{13}C=-30.54\pm0.44$ ‰, for the biobutanol $\delta^{13}C=-31.28\pm0.45$ ‰. Fuel mixture B20, composed of 80 % of biodiesel and 20 % of the biobutanol $\delta^{13}C=-30.69$ (Fig. 8).

Carbon isotopic ratio in the different size aerosol particles was ranging from –36 to –26 ‰. Isotopic pattern for the elemental carbon is different from the organic carbon. $\delta^{13}C$ values for elemental carbon were about $\delta^{13}C=-28$ ‰, and was no difference between B and B20 fuel mixtures. Organic carbon isotopic values were changing depending on the aerosol size.

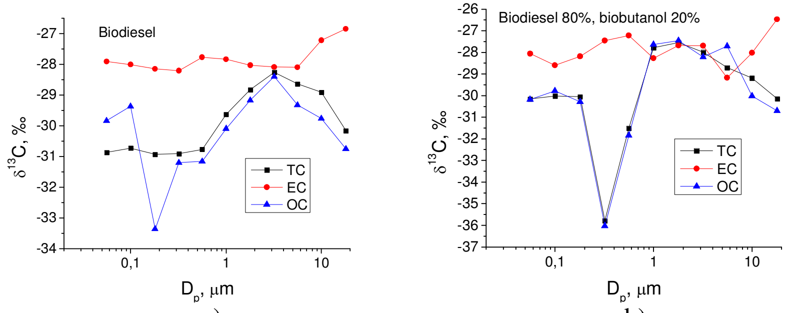


Fig. 8. Dependence of δ^{13}C on dispersive capacity of particles: a) using biodiesel, b) using B20 fuel mixture

This can be related with the processes, involving particle grown during coagulation. For the estimation of the biobutanol influence to the new particle formation, biobutanol with different carbon isotopic ratio is needed. From the difference of δ^{13}C between initial fuel and exhaust particles is possible to determine the effectiveness of the burning efficiency, because at bigger isotopic difference indicate higher burning efficiency.

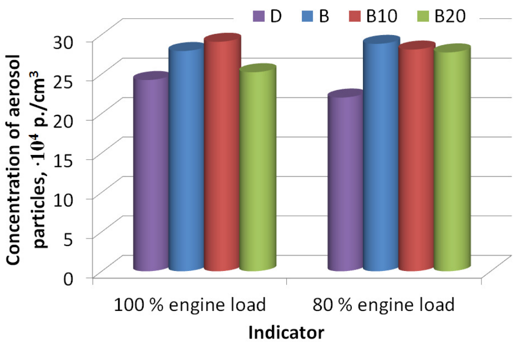


Fig. 9. Dependence of aerosol particles concentration on the fuel type and engine load

Considering the total concentration of the aerosol particles released (Fig. 9) it is apparent that the concentration of aerosol particles released by an engine running on mineral diesel fuel at 80 % of maximum engine load and of engine running on B and B10 fuel at maximum engine load was similar, however using B20 fuel caused a quite significant decrease (17 %) of aerosol particles concentration. When the engine was running at 80 % of its maximum load the amount of aerosol particles remained unchanged regardless of the fuel used: B, B10 or B20.

General Conclusions

1. Performing physical and chemical tests appointed that the maximum possible to 20 percentage amount of biobutanol in biobutanol and biodiesel mixtures which ensures meeting the fuel quality requirements and improves performance efficiency and ecological parameters of a diesel engine was established.
2. The analysis of kinematic viscosity methods revealed that neither of them can be applied for the purposes of the research of biobutanol and biodiesel mixtures.
3. The experimental research of a diesel engine supplied with biobutanol and biodiesel mixtures have been obtained:

a) reduction of particle matter amount, carbon dioxide and nitric oxide appreciable emissions have been decreased in engine exhaust compared with the engine operating in a pure mineral diesel. But carbon monoxide and unburned hydro carbonates have been increased;

b) the appointed carbon particle size application of stable isotope mass spectrometry and aerosol concentration methods has revealed a diesel engine using pure diesel, B, B20 fuels. The kind of prevalence carbon has been appointed too;

c) depending on the concentration of biobutanol in biodiesel the net efficiency coefficient has been increased, but increasing of engine rpm speeds the effective efficiency coefficient has been decreased;

4. Practical application of the mathematical model of a diesel engine to the tests performed has established the following that without comprehensive information on the initial characteristics of a diesel engine the modelling results obtained were inconsistent with the rated pressure and some of exhaust emissions experimental results.
5. Further correction and modification of the model shall be mainly related to the law of heat emission and calculation of energy parameters of biofuel.

List of Published Works on the Topic of the Dissertation
Article in a scientific journals

Matijošius, J., Sokolovskij, E. 2009. Research into the quality of fuels and their biocomponents, *Transport*. Vol. 24, No. 3. p. 212–217 ISSN 1648-4142 (Thomson ISI Web of Science)

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DYZELINIO VARIKLIO EKOLOGINIŲ RODIKLIŲ GERINIMAS NAUDOJANT BIOBUTANOLIO IR BIODYZELINO MIŠINIUS

Mokslo problemos aktualumas. Vidaus degimo varikliai, ypač dyzeliniai, yra vienas pagrindinių aplinkos taršos šaltinių. Deginant naftinius degalus į atmosferą išmetamas didelis kiekis žalingų medžiagų. Vienas iš būdų, padedančių išvengti žalingo naudotų dujų poveikio aplinkai ir atsisakyti energetinės priklausomybės nuo vis brangstančių naftinės kilmės degalų, yra biobutanolio ir biodyzelino (RME) mišinių kaip degalų naudojimas.

Disertacijoje tiriamas biodegalų mišinys, susidedantis iš biobutanolio ir biodyzelino. Duomenų apie deginių emisijos ir variklio darbo rodiklius, naudojant būtent minėtus mišinius, literatūros moksliniuose šaltiniuose nepakankama.

Vidaus degimo variklių kietosios dalelės, kurias sudaro anglis, dažniausiai būna „aplipusios" tepalų, degalų likučiais, sulfatais, vandeniu, poliarinėmis organinėmis ir neorganinėmis medžiagomis, metalais ir t. t., literatūroje aprašomas karbonatinis aerozolis. Jo dalelės aktyviai tyrinėjamos dėl jų poveikio klimato kaitai ir žmogaus sveikatai. Todėl stabiliųjų anglies izotopų santykis $^{13}C/^{12}C$ yra vienas pagrindinių metodų aerozolio dalelių kilmei nustatyti.

Tyrimų objektas. Darbo tyrimų objektas – biobutanolio ir biodyzelino mišiniais veikiančio dyzelinio variklio ekologiniai rodikliai.

Darbo tikslas ir uždaviniai. Darbo tikslas – teoriškai ir eksperimentiškai ištirti bei pagrįsti biodegalų mišinių, susidedančių iš biobutanolio ir biodyzelino, dyzeliniame variklyje naudojimo galimybes, įvertinant variklio darbo ekologinius, ekonominius ir efektyvumo rodiklius.

Darbo tikslui pasiekti darbe reikia spręsti šiuos uždavinius:

1. Ištirti biodyzelino ir biobutanolio mišinių fizinius ir cheminius rodiklius, siekiant užtikrinti kokybės standartų reikalavimus, taikomus degalams ir biodegalams.
2. Eksperimentiškai ištirti dyzelinio variklio ekologinius, darbo efektyvumo ir energinius rodiklius, kai vietoje mineralinio dyzelino varikliui tiekiant biodegalų mišinius.
3. Išmatuoti anglingo aerozolio (PM) dalelių koncentraciją skirtinguose dydžių intervaluose bei nustatyti bendrą išsiskiriančių aerozolių dalelių koncentraciją dyzeliniame variklyje deginant biobutanolio ir biodyzelino mišinius.
4. Įvertinti galimybę pritaikyti pagal kitų autorių aprobuotas metodikas sudarytą matematinį modelį dyzelinio variklio ekologiniams ir termodinaminiems procesams nustatyti.

Tyrimų metodika. Darbe taikyti teoriniai ir eksperimentiniai tyrimo metodai. Atlikti teoriniai tyrimai yra pagrįsti hidrodinamikos, teorinės mechanikos ir degimo proceso dinamikos teorija, pritaikius analitinius ir skaitinius tyrimo metodus.

Mokslinis naujumas

1. Fiziniais, cheminiais ir analitiniais metodais nustatytas biobutanolio procentinis kiekis biobutanolio ir biodyzelino mišiniuose, kuriam esant fizinės ir cheminės biodegalų savybės atitiko standartų reikalavimus ir pagerino dyzelinio variklio ekologinius parametrus.
2. Anglingojo aerozolio dispersiškumo pasiskirstymui bei bendrai aerozolio dalelių emisijai nustatyti buvo panaudoti stabilių masių spektrometrijos ir aerozolių koncentracijos metodai. Tai yra labai svarbu nustatant variklio išmetamųjų dujų pavojingumo laipsnį bei poveikį žmonių sveikatai.

3. Atliktas dyzelinių variklių dvizonio matematinio modelio ekologinių rodiklių pritaikymas ir aprobavimas biobutanolio ir biodyzelino mišiniams.
4. Nustatyta, kad dėl santykinai aukštos šaltojo filtro užsikimšimo temperatūros biobutanolio ir biodyzelino mišinius galima naudoti šiltuoju ir pereinamuoju metų laikais.
5. Nustatyta, kad naudojant biobutanolio ir biodyzelino mišinius žinomos kinematinės klampos apskaičiavimo metodikos nėra visiškai tikslios.

Praktinė vertė

1. Nustatyta, kad maksimali biobutanolio koncentracija biobutanolio ir biodyzelino mišiniuose – 20 %, kuri atitinka degalų kokybei keliamus reikalavimus ir pagerina dyzelinio variklio ekologines charakteristikas.
2. Įrodyta, kad dyzeliniame variklyje pritaikytas tik biologinės kilmės degalų mišinys ir tai leidžia visiškai atsisakyti mineralinės kilmės degalų.
3. Skaičiuojant kinematinę klampą pastebėta, kad visos žinomos kinematinės klampos apskaičiavimo metodikos nėra visiškai tikslios biodegalų kinematinei klampai apskaičiuoti dėl didelės paklaidos tarp skaičiavimų ir eksperimentų rezultatų.
4. Nustatyta, kad stabiliųjų izotopų masės spektrometrijos ir aerozolių koncentracijos metodais galima nusakyti anglingų aerozolių pasiskirstymą pagal dispersiškumą, kas yra labai svarbu nusakant ypač mažų dalelių poveikį žmonių sveikatai, ir bendrą išsiskiriančių aerozolio dalelių emisiją.

Ginamieji teiginiai

1. Atlikus fizinius ir cheminius tyrimus nustatyta, kad maksimali biobutanolio koncentracija biobutanolio ir biodyzelino mišiniuose – 20 % atitinka degalų kokybei keliamus reikalavimus ir pagerina dyzelinio variklio ekologines charakteristikas.
2. Naudojant biobutanolio ir biodyzelino mišinius ir optimizuojant degalų įpurškimo parametrus galima visiškai pakeisti mineralinės kilmės dyzeliną.
3. Anglingojo aerozolio (PM) dispersiškumo pasiskirstymas bei bendroji aerozolio dalelių emisija gali būti nustatoma taikant stabilių masių izotopų ir aerozolių dalelių koncentracijos tyrimo metodus.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, trys skyriai, išvados, literatūros sąrašas, publikacijų sąrašas ir priedai. Bendra disertacijos apimtis – 109 puslapiai be priedų, 40 iliustracijos, 9 lentelių ir 5 priedai.

Pirmasis skyrius skirtas literatūros analizei, jame apžvelgti biodegalų vartojimą skatinantys veiksniai, butanolio ir biodyzelino naudojimo vidaus degimo varikliuose tyrimų rezultatai, dyzelinio variklio kietųjų dalelių poveikis aplinkai ir žmonių sveikatai, izotopų masės spektrometrijos ir kitų metodų taikymas variklio išmetamosioms dujoms tirti. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai.

Antrajame skyriuje pateikiama biodyzelino ir biobutanolio mišinių tyrimo metodika.

Trečiajame skyriuje nustatoma biobutanolio ir biodyzelino mišinių sudėtis, atitinkanti degalams keliamus reikalavimams, nagrinėjami teoriniai biobutanolio ir biodyzelino mišinių naudojimo dyzeliniuose varikliuose aspektai, aprašomi biobutanolio ir biodyzelino mišinių eksperimentiniai tyrimų rezultatai.

Bendrosios išvados

1. Atlikus fizinius ir cheminius tyrimus nustatyta, kad maksimali biobutanolio koncentracija biobutanolio ir biodyzelino mišiniuose – 20 %. Tokio mišinio kokybės rodikliai atitiko dyzelino ir biodyzelino apibrėžtus norminių aktų reikalavimus.
2. Kinematinės klampos metodikų analizė parodė, kad dėl per didelių paklaidų, lyginant su eksperimento rezultatais, nė vienos iš jų nerekomenduojama taikyti biobutanolio ir biodyzelino mišinių klampai nustatyti.
3. Atlikus eksperimentinius dyzelinio variklio, veikiančio biobutanolio ir biodyzelino mišiniais palyginamuosius tyrimus, nustatyta:
   a) kietųjų dalelių iki 82 %, anglies dvideginio iki 23 % ir azoto oksidų iki 22 % kiekiai išmetamosiose variklio dujose apčiuopamai mažėjo, lyginant su varikliu, veikiančiu grynu mineraliniu dyzelinu, tačiau anglies viendeginio iki 30 % ir angliavandenilių kiekiai iki 61 % – didėjo;
   b) pritaikius stabiliųjų izotopų masės spektrometrijos ir aerozolio koncentracijos metodus nustatytas išmetamų anglies dalelių dydis, varikliui veikiant dyzelinu, B ir B20 degalais. Taip pat nustatytas vyraujančios anglies pobūdis, naudojant skirtingus degalų mišinius;
   c) efektinis naudingojo veikimo koeficientas gerėjo iki 4 % didinant biobutanolio kiekį biodyzeline, tačiau didinant variklio sūkius iki 2200 min^{-1} efektinis naudingojo veikimo koeficientas

mažėjo iki 13 %.

4. Skaičiuojamieji matematinio modeliavimo rezultatai parodė, kad trūkstant išsamios informacijos apie dyzelinio variklio pradinius duomenis gauti indikatorinio slėgio bei kai kurių teršalų emisijų modeliavimo rezultatai neatitiko gautų eksperimento rezultatų.
5. Ateityje planuojama įvertinti šilumos išsiskyrimo priklausomybių ir biodegalų energetinių parametrų įtaką skaičiuojamojo modelio tikslumui.

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IMPROVEMENT OF DIESEL ENGINE ECOLOGICAL PARAMETERS BY USING BIOBUTANOL AND BIODIESEL MIXTURES

Summary of Doctoral Dissertation
Technological Sciences, Transport Engineering (03T)

Jonas MATIJOŠIUS

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