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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ПОКАЗНИКІВ ДИЗЕЛЬНОГО ДВИГУНА ПРИ ЙОГО РОБОТІ НА СУМІШАХ БІОДИЗЕЛЬНОГО ПАЛИВА ОДЕРЖАНОГО З СИНЕ-ЗЕЛЕНИХ ВОДОРОСТІВ

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EXPERIMENTAL STUDIES OF DIESEL ENGINE INDICATORS WORKING ON THE MIXTURES OF BIODIESEL FUELS RECEIVED FROM BLUE-GREEN ALGAE

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ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ ПОКАЗАТЕЛЕЙ ДИЗЕЛЬНОГО ДВИГАТЕЛЯ ПРИ ЕГО РАБОТЕ НА СМЕСЯХ БИОДИЗЕЛЬНОГО ТОПЛИВА ПОЛУЧЕННОГО ИЗ СИНЕ-ЗЕЛЕНЫХ ВОДОРОСЛЕЙ

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Problem solving in general and its connection with important scientific or practical tasks

It should be noted that cheap and light oil is suitable for its exhaustion and exploration of new deposits and extraction with subsequent processing of hard-to-reach high-grade and high-viscosity grades of oil

requires large investments, the world is predicted to be unavoidably increased in prices for motor fuel. To increased requirements for environmental protection from harmful emissions from exhaust gases of internal combustion engines, there was also a serious problem with ensuring the quality of motor fuels. Process of sulphur content reducing in diesel fuels has led to a loss of a number of consumer properties. Therefore, in order to improve the lubricating properties of environmentally friendly diesel fuels, it is necessary to add anti-wearing additives in them.

Thus, today there is a multifaceted topical problem of ensuring needs of Ukrainian and European automobile transport in high-quality and environmentally friendly diesel fuel. One of the main directions for solving this problem is usage of renewable energy sources from plant biomass. At the same time, the rapid growth of production and consumption of biodiesel fuel from vegetable oils of food use in many countries of the world led to a disturbance of the balance in the structure of agro-industrial production and began to generate problems of the socio-ethical and ecological plan.

One of promising further way of biodiesel fuel developing is usage of biomass of algae, which as energy raw materials exceeds other raw bioresource by its characteristics. However, the widespread adoption of biofuel from algae as an additive to motor fuel is hampered by the insufficient study currently being undertaken on the use of biofuels in automotive engines that are made from these biomaterials. Therefore, research on the use of biofuels in automobile engines created from a large range of existing algae is opportune and relevant.

Analysis of recent research and publications

In conditions of modern production biofuels are derived from vegetable oils by the reaction of transesterification [1]. This reaction does not require complicated process equipment and high temperatures, and the resulting mixture of esters is little different from hydrocarbons of petroleum fuels with the best environmental and lubricating properties [2].

Using biodiesel from land crops a significant reduction in emissions of particulate matter (soot), carbon monoxide (II) and hydrocarbons (including carcinogens) has been found to be significant in comparison with the use of petroleum fuels [3].

The high temperature of fuel ignition (above 120 °C) makes usage, storage, and transportation of biodiesel fuel safer in comparison to diesel fuel of petroleum origin [4]. Another significant advantage of biodiesel is its ability to biodegradate unlike petroleum [5].

Biofuels from terrestrial crops (rape, sunflower, etc.) are successfully used in existing engines, extending the life of engines, and having a high cetane number [6]. Usage of biofuels as a bio additive to petroleum diesel can improve the environmental and anti-wear properties of fuels [7].

Using algae as biomaterials for the production of motor fuels, there are a number of advantages [8]: algae during the growth process absorb 80-90 % of carbon dioxide with oxygen release; for the cultivation of algae you can use waste and saline water; algae, unlike terrestrial plants, grow year-round. It has been established that bioavailability and lipid content of algae depend on the intensity of light [9]. High intensity of light leads to the accumulation of lipids in algae. Algae consume mainly light in red and blue ranges.

Low mixing of water intensifies heat and mass transfer processes in algae, promotes movement of cells into the area of illumination and increases the bioproductivity of algae [10]. It was established that the concentration of carbon dioxide [11] has a significant effect on the yield of algae. Therefore, increasing of carbon concentration of dioxide from 4 to 22 % lets to increase biomass yield of algae from four to five times.

Formation of the purposes of the article

Algae are the oldest and most persistent organisms on the Earth which arose about 350 million years ago and lives in fresh and salt water, in soil and even in snow. Among all the diversity of existing algae, the authors of the study were selected blue-green algae Cyanophyta family Chroococcfles. These algae lead to intensive «flowering» of reservoirs in Ukraine and Europe, with each year the extent of pollution of the surface of water significantly increases. The proliferation of blue-green algae leads to water rotting, the destruction of aquatic ecosystems and the destruction of rivers and lakes. The most effective way to clean the reservoirs is to use algae as fuel.

Therefore, the purposes of this article are experimental studies:

– changes in the performance characteristics of automotive diesel engines when used in these diesel fuel oil engines and their mixtures with biofuels derived from blue-green algae.

– changes in the environmental performance of automotive diesel engines with the use of petroleum diesel and their mixtures with biofuels derived from blue-green algae.

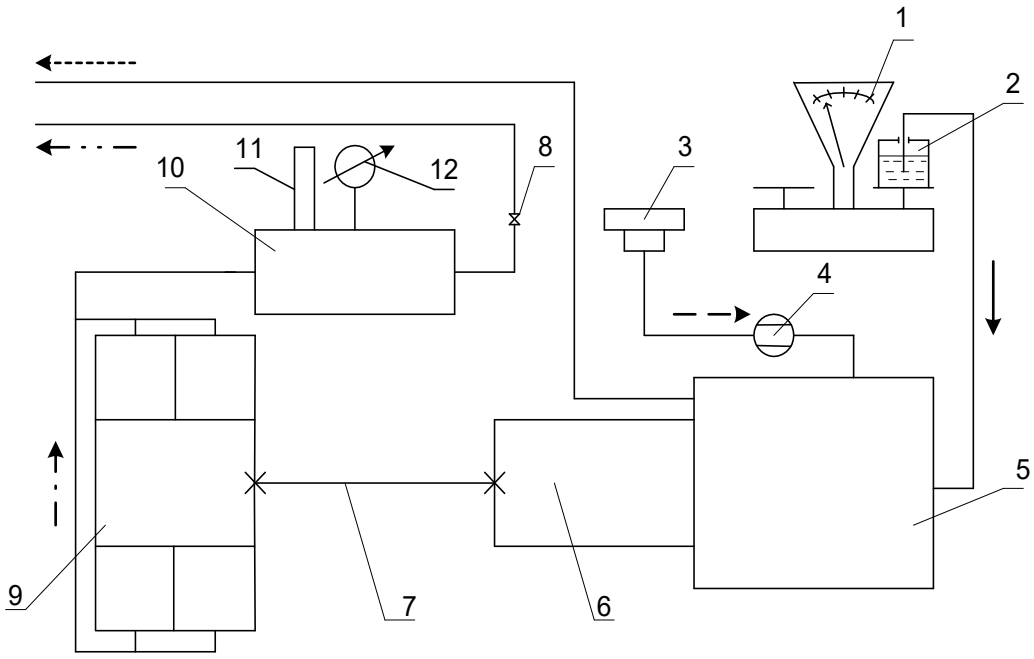
Presentation of the main research material

Stand tests were carried out on an experimental installation, which included a series diesel D21A1, a short technical characteristic of which is given in Table 1. The scheme and appearance of the diesel engine D21A1 are shown in Fig. 1. The loading for the engine D21A1 (5) is created by a four-stage four-cylinder compressor of the brand K-5M (9). The power of the K-5M compressor shaft can be adjusted in the range of one to thirty five kW which allows the diesel engine to be 100 % loaded. The torque from the D21A1 engine to the compressor is transmitted using the gearbox (5) and the gearbox (7).

Table 1 – Brief Technical Characteristics of the Experimental Diesel Engine D21A1

№ п/п	Name of engine parameters	Unit of measurement	Value
1	Type of diesel	–	Four-stroke, two-cylinder, air-cooled
2	Working volume	l	2,08
3	Method of mixing Method of mixing	–	Separate combustion chamber with direct injection of diesel fuel
4	Nominal engine power	kW (hp)	18 (25)
5	Effective specific fuel consumption	g / kWh (g / hr..h)	253 (186)
6	Frequency of the crankshaft rotation of engine at nominal power	r/m	1800
7	Frequency of the crankshaft rotation of engine at idle speeds	r/m	800
8	The mass of diesel engine	kg	280

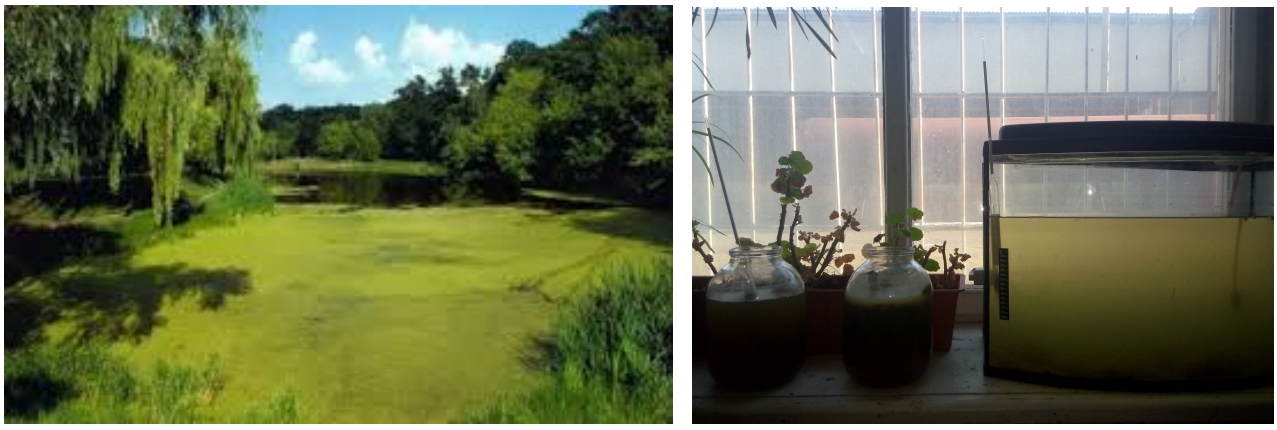
a)



b)

Figure 1 – Appearance (a) and scheme of the experimental installation on the basis of the diesel engine D21A1 (b) for studding of engine indicators on biodiesel mixtures: ⟶ – direction of fuel movement in power system of experimental installation; – – → – direction of air movement in power system of experimental installation; – · → – air flow to the receiver; ⟵ – motion of exhaust gases into environment; ← · · – – motion of air into environment; 1 – scales for measuring of fuel consumption; 2 – volume for biodiesel fuel; 3 – air filter; 4 – gasometer; 5 – experimental diesel engine; 6 – gearbox; 7 – Cardan transmission; 8 – throttle; 9 – compressor; 10 – receiver; 11 – thermometer for measuring air temperature; 12 – manometer.

Blue-green algae were collected from reservoirs around Ivano-Frankivsk region (Fig. 2a) for harvesting biofuels in the summer time, and in winter they were cultivated in phytobio-reactors (Fig. 2b).



a) b)

Figure 2 – Sources of harvesting of blue-green algae for biofuel production: natural reservoirs (a); artificial bioreactors (b)

Photobioreactor is a 60-liter transparent tank with fluorescent lamps illuminated. Algae cultivates with cycles of 14 days. Gas-air mixture inputs into this reactor using compressor and a carbonaceous cylinder on volume of 1 meter cubic in a day (carbon dioxide – 8 %). Drying of biomass was carried out in a drying cabinet to a level of humidity of 10 %.

The dietary supplement was obtained by the reaction of methanolysis of vegetable oils in the presence of a homogeneous catalyst. Pretty alcohol solution was prepared. A mixture of methyl alcohol (95,7 %) and potassium hydroxide (4,3 %) was used for its preparation. Then the prepared solution and the lipid components of the algae were fed into the apparatus, where the mixing of the reaction products and the synthesis of the dietary supplement took place. Further, the reaction mass was separated in a separator from glycerol. The resulting bioadditives were purified from impurities by an aqueous solution of orthophosphoric acid, and the residues of water evaporated. The resulting dietary supplement was mixed with petroleum diesel fuel.

Calculations have shown that combustion heat of obtained methyl esters is 35,5 MJ / kg. It should be noted that after extraction of fats dry biomass can be additionally used with combustion heat of 15,5 MJ / kg.

Thus, in experimental studies diesel fuel mixtures with derived bioactive compounds based on methyl esters of Chroococcfles, blue-green algae, in quantities of 5, 10 and 20 % and for comparison pure diesel fuel were used. In this case, the fuel tank was filled with diesel fuel of mark L of the Kremenchug oil refinery.

Volumetric particles of carbon monoxide and hydrocarbons were measured by the gas analyzer «Autotest-02.03P». The range of measurements of hydrocarbon gas analyzer is 0-2000 ppm, the absolute measurement error is 10 ppm. The range of measurement of carbon monoxide gas analyzer is 0-5 %, the absolute measurement error is 0,03%. For finding temperatures of exhaust gases thermocouples of the type «chromel-copel» and the log-meter-potentiometer UP-2M were used.

For comparative estimation of the engine indexes on diesel fuel with corresponding indicators of a diesel engine on a mixture of diesel fuel with bioactive additives on the basis of methyl esters of the lipid fraction of blue-green algae in the amount of 5, 10 and 20 % the load characteristics of the engine were removed at fixed speeds of the crankshaft. Before measuring the parameters for a stable running of the working process the engine worked at least 5 minutes in the given mode. The results of the measurements were entered in the protocol of trials with a threefold repetition at each mode of operation of the diesel engine.

As a result of performed experimental researches the dependences of the change of the effective engine power using of diesel fuel and a mixture of diesel fuel with the received bioactive supplements based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % (Fig. 3) were determined. It has been experimentally established that the effective power of an engine using a mixture of diesel fuel with the derived bioactive compounds based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % will decrease by an average of 0,9, 1,8 and 3,5 %.

As a result of the performed experimental research dependence of changes in the content of the CnHm hydrocarbons on the crankshaft speed of the engine n at the nominal loading for the various content of the dietary supplements on the basis of methyl esters of the lipophilic fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % (Fig. 4) and the dependence of the change in the content of carbon monoxide CO on the rotational speed of the crankshaft engine n at the nominal load for the various contents of bioadditives on the basis of methyl esters of the lipid fraction of blue-green algae She has Chroococcfles in the amount of 5, 10 and 20 % (Fig. 5).

It has been experimentally established that the content of CnHm hydrocarbons using of a mixture of diesel fuel with the derived dietary supplements based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % will decrease by an average of 6,2, 13,1 and 26,6 %. It has been experimentally determined that the content of carbon monoxide in the use of a mixture of diesel fuel with the derived bioactive compounds based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % will decrease by an average of 6,5, 13,9 and 28,7 %.

Conclusions and perspectives of further researches

1. Synthetic methyl ester of lipid fraction was used as an additive of 5 – 20 % to conventional diesel fuel. In the course of experimental tests it was established that on different blends of biodiesel and diesel fuels difference in power characteristics is observed in the range of 0,9-3,5 % which from the operational point of view is not a significant difference.

2. At the same time, increasing of bioadditive in biodiesel fuel environmental performance of the engines is significantly improved and content of unburnt hydrocarbons and carbon monoxides is significantly reduced. The lowest rates were recorded when using a biodiesel mixture containing 20 % of bioadditives. The content of hydrocarbons and oxides of carbon in diesel fuel with bio-additives on the basis of methyl esters of the lipid fraction of blue-green algae Chroococcfles decreased by 26,6 % and 28,7 % respectively.

The obtained results allow to optimize the choice of fuels for power systems of internal combustion engines and to reduce emissions of harmful substances in exhaust gases of automobile diesel engines. Further research will be related to the definition of fuel consumption and emissions of nitrogen oxides in exhaust gases of diesel engines converted to work on alternative fuels with bioactive additives based on methyl esters of algae.

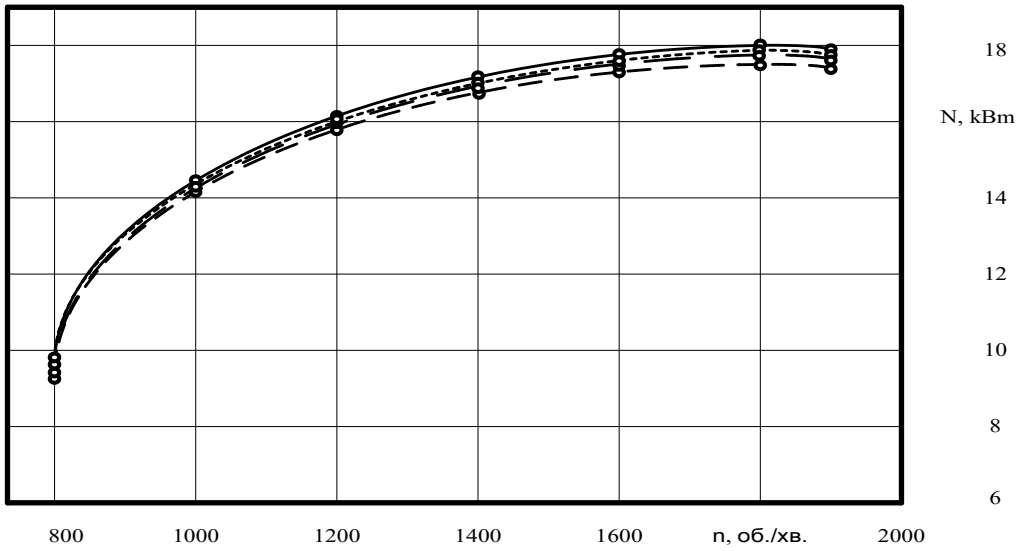


Figure 3 – Experimental dependencies of effective power N with respect to crankshaft rotational frequency n of the various contents of bioadditives: ——— engine work on 100 % petroleum diesel fuel; ····· engine work on the mixture of 95 % petroleum diesel and 5 % methyl esters; – – – – engine work on a mixture of 90 % of petroleum diesel and 10 % of methyl esters; - - - - - engine work on a mixture of 80 % of petroleum diesel and 20 % of methyl esters

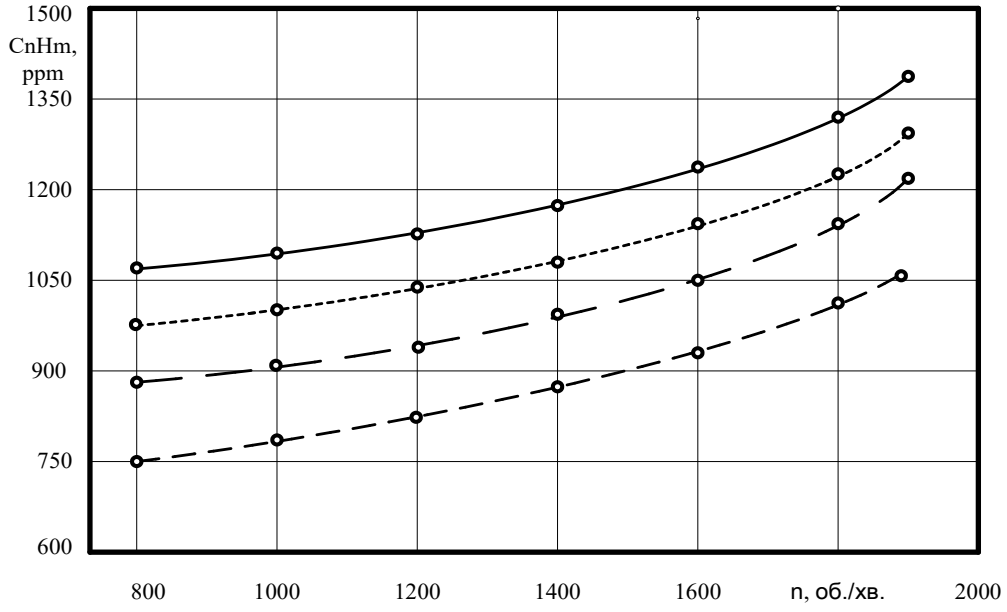


Figure 4 – Experimental dependences of the content of hydrocarbons CnHm with respect to rotational frequency of the crankshaft engine n at nominal loading for different contents of bioadditives: ——— engine work on 100% petroleum diesel fuel; ····· engine work on a mixture of 95 % petroleum diesel and 5 % methyl esters; – – – – engine work on a mixture of 90 % of petroleum diesel and 10 % of methyl esters; - - - - - engine work on a mixture of 80 % of petroleum diesel and 20 % of methyl esters

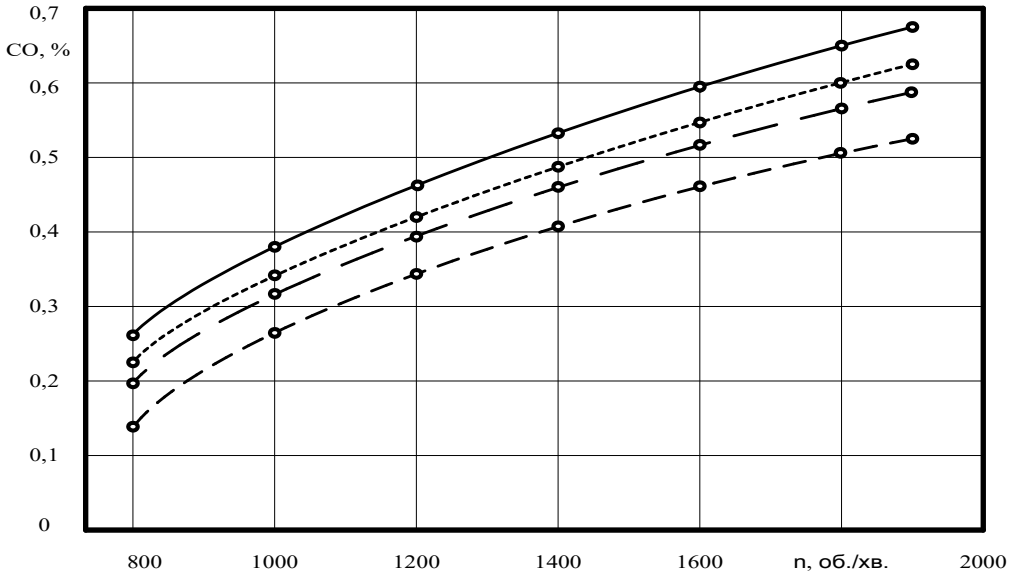


Figure 5 – Experimental dependencies of carbon monoxide CO content with respect to crankshaft rotational frequency n at nominal loads for different contents of bioadditives: ——— engine work on 100 % petroleum diesel fuel; ····· engine work on a mixture of 95% petroleum diesel and 5 % methyl esters; – – – – engine work on a mixture of 90 % of petroleum diesel and 10% of methyl esters; – - – - – engine work on a mixture of 80 % of petroleum diesel and 20 % of methyl esters

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РЕФЕРАТ

Крижанівський Є.І. Експериментальні дослідження показників дизельного двигуна при його роботі на сумішах біодизельного палива одержаного з сине-зелених водоростів / Є.І. Крижанівський, С.І. Криштопа, Л.І. Криштопа, М.М. Гнип, І.М. Микитій // Вісник Національного транспортного університету. Серія «Технічні науки». Науково-технічний збірник. – К. : НТУ, 2020. – Вип. 1 (46).

У статті розглянуто напрям використання синє-зелених водоростей в якості біоматеріалів для створення моторного біопалива.

Об’єкт дослідження – вплив сумішевих біодизельних палив з синє-зелених водоростей на екологічні та енергетичні показники дизельного двигуна.

Мета роботи – експериментальні дослідження зміни потужнісних та екологічних характеристик автомобільних дизельних двигунів при використанні нафтового дизельного палива та їхніх сумішей з біопаливами, які одержані з сине-зелених водоростей.

Методи дослідження – експериментальні, лабораторні.

В результаті виконаних експериментальних досліджень встановлені залежності зміни ефективної потужності двигуна при використанні дизельного палива і суміші дизельного палива з одержаними біодобавками на основі метилових ефірів ліпідної фракції сине-зелених водоростей Chroococcfles в кількості 5, 10 та 20 %. Експериментально встановлено, що ефективна потужність двигуна при використанні суміші дизельного палива з одержаними біодобавками на основі метилових ефірів ліпідної фракції сине-зелених водоростей Chroococcfles в кількості 5, 10 та 20 % зменшиться, в середньому, на 0,9, 1,8 та 3,5 %. Експериментально встановлено, що вміст оксиду вуглецю CO при використанні суміші дизельного палива з одержаними біодобавками на основі метилових ефірів ліпідної фракції сине-зелених водоростей Chroococcfles в кількості 5, 10 та 20 % зменшиться, в середньому, на 6,5, 13,9 та 28,7 %.

Одержані результати дозволяють оптимізувати вибір палив для систем живлення двигунів внутрішнього згорання та знизити викиди шкідливих речовин у відпрацьованих газах автомобільних дизельних двигунів.

КЛЮЧОВІ СЛОВА: БІОПАЛИВА, ДИЗЕЛЬНИЙ ДВИГУН, ВОДОРОСТІ, ПОТУЖНІСНІ ХАРАКТЕРИСТИКИ, ЕКОЛОГІЧНІ ПОКАЗНИКИ.

ABSTRACT

Kryzhanivskyi Ye.I., Kryshtopa S.I., Kryshtopa L.I., Ph.D., Hnyp M.M., Mykytii I.I. Experimental studies of diesel engine indicators working on the mixtures of biodiesel fuels received from blue-green algae. Visnyk National Transport University. Series «Technical sciences». Scientific and Technical Collection. – Kyiv: National Transport University, 2020. – Issue 1 (46).

This article considers usage of blue-green algae as biomaterials for creation of motor biofuels.

The object of the study is effect of blended biodiesel fuels from blue-green algae on the environmental and energy performances for the diesel engine.

The purpose of the work is experimental study of changes of power and ecological characteristics of automobile diesel engines using petroleum diesel and their mixtures with biofuels derived from blue-green algae.

Methods of research are experimental, laboratory ones.

As a result of performed experimental researches dependences of changing of the effective engine power on the use of diesel fuel and a mixture of diesel fuel with the received bioactive supplements based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20% were established. It has been experimentally established that the effective power of an engine using a mixture of diesel fuel with the derived bioactive compounds based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20% will decrease by an average of 0,9, 1,8 and 3,5 %. It has been experimentally determined that the content of carbon monoxide in the use of a mixture of diesel fuel with the derived bioactive compounds based on methyl esters of the lipid fraction of blue-green algae Chroococcfles in the amount of 5, 10 and 20 % will decrease by an average of 6,5, 13,9 and 28,7 %.

The obtained results allow to optimize the choice of fuels for power systems of internal combustion engines and to reduce emissions of harmful substances in exhaust gases of automobile diesel engines.

KEY WORDS: BIOFUELS, DIESEL ENGINE, ALGAE, POWERFUL CHARACTERISTICS, ENVIRONMENTAL INDICATORS.

РЕФЕРАТ

Крижановський Е.И. Экспериментальные исследования показателей дизельного двигателя при его работе на смесях биодизельного топлива полученного из сине-зеленых водорослей / Е.И. Крыжановський, С.И. Крыштопа, Л.И. Крыштопа, М.М. Гнип, И.М. Микитий // Вестник Национального транспортного университета. Серия «Технические науки». Научно-технический сборник. – К.: НТУ, 2020. – Вып. 1 (46).

В статье рассмотрено направление использования сине-зеленых водорослей в качестве биоматериалов для создания моторного биотоплива.

Объект исследования – влияние смесей биодизельных топлив с сине-зеленых водорослей на экологические и энергетические характеристики дизельного двигателя.

Цель работы – экспериментальные исследования изменения мощностных и экологических показателей автомобильных дизельных двигателей при использовании нефтяного дизельного топлива и их смесей с биотопливом, полученные с сине-зеленых водорослей.

Метод исследования – экспериментальные, лабораторные.

В результате выполненных экспериментальных исследований установлены зависимости изменения эффективной мощности двигателя при использовании дизельного топлива и смеси дизельного топлива с полученными биодобавками на основе метиловых эфиров липидной фракции сине-зеленых водорослей Chroococcfles в количестве 5, 10 и 20%. Экспериментально установлено, что эффективная мощность двигателя при использовании смеси дизельного топлива с полученными биодобавками на основе метиловых эфиров липидной фракции сине-зеленых водорослей Chroococcfles в количестве 5, 10 и 20% уменьшится в среднем на 0,9, 1,8 и 3,5 %. Экспериментально установлено, что содержание оксида углерода CO при использовании смеси дизельного топлива с полученными биодобавками на основе метиловых эфиров липидной фракции сине-зеленых водорослей Chroococcfles в количестве 5, 10 и 20 % уменьшится в среднем на 6,5, 13,9 и 28,7 %.

Полученные результаты позволяют оптимизировать выбор топлив для систем питания двигателей внутреннего сгорания и снизить выбросы вредных веществ в отработанных газах автомобильных дизельных двигателей.

КЛЮЧЕВЫЕ СЛОВА: БИОТОПЛИВА, ДИЗЕЛЬНЫЙ ДВИГАТЕЛЬ, ВОДОРОСЛИ, МОЩНОСТНЫЕ ХАРАКТЕРИСТИКИ, ЭКОЛОГИЧЕСКИЕ ПОКАЗАТЕЛИ.

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