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Research on the Impact of Supplying the Air-Cooled D21A1 Engine with RME B100 Biodiesel on Its Operating Parameters

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Abstract: It is known that the use of alternative fuels leads to changes in the operating parameters of internal combustion engines, and the nature of the changes in most cases is not known. Therefore, the question of researching the main operating indicators of the internal combustion engine supplied with RME B100 biodiesel fuel is important, and the results will help to eliminate or reduce negative factors that can lead to the deterioration of the operational and technical indicators of the internal combustion engine. The purpose of the research was to develop an experimental research facility using appropriate equipment and to study the main operational and technical parameters of the air-cooled D21A1 diesel engine on RME B100 biodiesel fuel. To reach the goal, the following tasks were formulated: the development of a test facility and research on the main technical and operational performance indicators of the D21A1 diesel engine on RME B100 biodiesel fuel. The authors' previous research results were applied in the setting of the D21A1 test engine in the process of RME B100 biodiesel research; namely, to achieve maximum fuel combustion efficiency, the injection moment was increased by 6°. The results ensured the maximum efficiency of using RME B100 biodiesel in engines without making changes to the design of the latter. System analysis and the comparison method were used during the research. In the process of using RME B100 biodiesel fuel on the air-cooled D21A1 engine, we found a decrease in engine torque of 6.5%; a decrease in effective power of 6.7%; a growth in specific effective fuel consumption of up to 22.3%; and an increase in hourly fuel consumption of 14.1%. This is because the use of RME B100 fuel requires changes in the engine design that improve the mixture formation process.

Keywords: engine; alternative fuels; biodiesel; rapeseed oil; cost; economy; power; torque; improvement; environmental friendliness

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1. Introduction

Nowadays, in connection with the growing requirements for the quality and environmental friendliness of fuel for engines and the decreasing number of available fossil energy carriers, the question of their replacement with alternative, renewable energy sources is widely raised [1]. In the process of using alternative fuel on internal combustion engines (ICEs), several difficulties arise; these are related to the engine and its system's adaptation to the combustion conditions [2]. Nevertheless, using alternative fuels has essential economic and environmental implications and is thus extremely important [2]. The use of alternative fuels leads to a change in the technical parameters of the internal combustion engine, and the direction of the changes is not known in most cases [3]. Therefore, the question of researching the key performance indicators of the internal combustion engine while using RME B100 biodiesel fuel is relevant, as it has economic and environmental importance, and the research results will help to eliminate or reduce negative factors that can lead to the deterioration of the technical parameters and the operational behavior of the internal combustion engine [3,4].

The use of alternative fuels reduces the need for petroleum products and improves the environmental characteristics of diesel engines. Numerous publications have indicated that with a certain decrease in power and economic performance of the diesel engine, the use of fuel mixtures containing vegetable oil esters significantly reduces the toxicity of engine exhaust gases [1–3].

In [5–7], scientists studied the combined effect of the biodiesel mixture from B5 to B70 (from 5 to 70% biodiesel addition in mixtures), the engine rotation velocity, and the load on the parameters of diesel engines. The results showed that changes in the proportion of the fuel mixture led to an increase in emissions of nitrogen oxides (NO_x) and a decrease in specific fuel consumption and carbon oxide (CO). This study indicates the main ways to improve engine performance and reduce toxic emissions into the environment.

In works [8,9], the issue of physicochemical properties of biodiesel fuels was investigated; according to the results of these studies, it was established that the quality indicators of biodiesel fuel containing ethyl esters of rapeseed and rye oil meet the requirements for the quality of biodiesel fuel and petroleum diesel fuel. However, scientists have not investigated the impact of biodiesel fuel based on rapeseed oil B100 on the technical, operational, and environmental performance of the engine.

Palm oil biofuel has increasingly been proposed for use, but its density and kinematic viscosity are higher than those of diesel fuel, which might influence the atomization characteristics [10–12].

The emission characteristics of biodiesel produced from the microalgae Dunaliella tertiolecta are also being investigated for the first time. The results obtained in [13] showed the significant ability of microalgae Dunaliella tertiolecta to be a source of clean fuel; however, the technology to produce such fuel is expensive. An important issue in biofuel research is the impact of biodiesel fuel of different origins on emissions and technical and operational performance indicators of internal combustion engines in comparison with that of commercial diesel fuel. In particular, in [14–16], it was established that biodiesel combustion improved and soot, CO, and CH emissions were reduced when the additive was added to mixtures of diesel fuel, biodiesel, and ethanol, and engine torque and power increased. It was also established in [17,18] that a relationship exists between the proportion of a mixture containing biodiesel, the injection moment, and the engine parameters. In particular, with an increase in the content of biodiesel in a mixture, the injection moment approaches the top dead center, which leads to a decrease in engine power, an increase in fuel consumption and NO_x discharge, and a decrease in CO and soot emissions.

The possibility of using safflower oil, soybean oil, non-edible oil, and used motor oil as additives to diesel fuel has been considered [19,20]. According to the research results, compared with diesel fuel without additives, the torque and power decrease and the specific fuel consumption increases. In addition, CO and CH emissions decreased and NOx emissions increased. The results of the above studies demonstrate that this type of fuel is not suitable for use without admixtures.

The research in [21–23] outlines the possibility of using biodiesel obtained from non-edible oil [21]; used motor oil [22]; and biofuel obtained from hazelnut oil (HOB), waste fish oil (FOB), rapeseed oil (ROB), and waste cooking oil (WCOB) by the method of esterification [23]. In [24], the authors tested corn oil–diesel (C30), hazelnut oil–diesel (H30), soybean oil–diesel (S30), sunflower oil–diesel (Su30), rapeseed oil–diesel (Ca30), and Crambe abyssinica oil–diesel (Cr30) mixed with regular diesel fuel. The results proved that the emissions of CH, CO, and soot decreased with biodiesel blends compared with regular diesel for all engine loads, while the emissions of NO_x increased. The influence of these fuels in their pure form on the performance of internal combustion engines is unknown.

The effect of fuel based on rapeseed and soybean oil on the quality of mixture formation and heat release in the internal combustion engine cylinder has also been studied [25–27]. These studies have shown that the aforementioned biofuels have better viscosity–temperature ratios and anti-friction properties, but the influence of the use of these fuels on technical and operational indicators of engines has not been investigated.

In studies [28–30], methanol, ethanol, and kerosene were added to diesel fuel by fumigation and mixing. Such mixtures provide a reduction in peak pressure in the cylinder, NO_x, and soot, but this negatively affects thermal efficiency and emissions of hydrocarbons and carbon monoxide. The use of such fuel mixtures leads to a deterioration of the quality of ignition due to a decrease in the cetane number of the mixture. Scientists [31–33] have concluded that among the various mixtures, the mixture containing 10% methanol (DM10) is the most suitable for compression ignition engines in terms of engine performance. Performance improvements of up to 7% with this mixture without any changes to engine and fuel system design are very promising but understudied.

It has been proposed to use mixtures of diesel fuel with kerosene [34] and used cooking oil [35–37]. B20–B80 biodiesel blends showed lower emissions of the exhaust gas (except for the NO_x level), while the hybrid fuel was characterized by a significant reduction in NO_x level and comparable emissions of other exhaust gas (except unburned hydrocarbons) due to lower thermal efficiency compared with petrodiesel. Research results [38–40] have confirmed the feasibility of using mixtures of pongamia oil (MEOP), a 20% mixture of methyl ether of mahua oil (MEOM), and a 20% mixture of methyl ether of hybrid vegetable oil (MEHVO) with 80% pure diesel. However, a study of the influence of this fuel on technical and operational indicators has not been conducted.

Therefore, based on the results of the review of literary sources, we found that the main technical and operational indicators of the internal combustion engine in the process of using biodiesel fuel are influenced by factors such as the type of biofuel, its share in fuel mixtures, and the content of hydrogen and oxygen in it. In further research, we will use biodiesel fuel based on rapeseed oil, as its production is cheap and the cultivation of rapeseed is profitable, and the D21A1 diesel engine, as it is economical, has a simple design, and is not demanding in terms of fuel. The novelty of the research is the use of the D21A1 test engine with an air-cooled system instead of a liquid one, which helps reduce the weight of the engine and ensures ease of maintenance and its environmental friendliness since no toxic antifreeze is used for cooling. This will provide an opportunity to investigate the influence of RME-based biodiesel fuel in its pure form on the technical and operational indicators of the selected internal combustion engine.

In this study, an experimental installation based on the diesel air-cooled D21A1 testing engine was developed, with a K-5M compressor used as a load consumption unit. Commercial diesel fuel and RME B100 biodiesel fuel in different load ranges were investigated. The authors' previous research results [1] were applied in the setting of the D21A1 test engine in the process of RME B100 biodiesel research to achieve maximum combustion efficiency.

2. Materials and Methods

To improve the environmental and operational properties of the commercial fuels and the large-scale production of alternative mixed bio-diesel fuels with RME, it is required to develop an experimental research facility using specific equipment and to investigate the main technical parameters and operational behavior of the D21A1 diesel engine (Kharkiv Tractor Plant, Kharkiv, Ukraine) on RME B100 biodiesel fuel.

The following tasks were formulated:

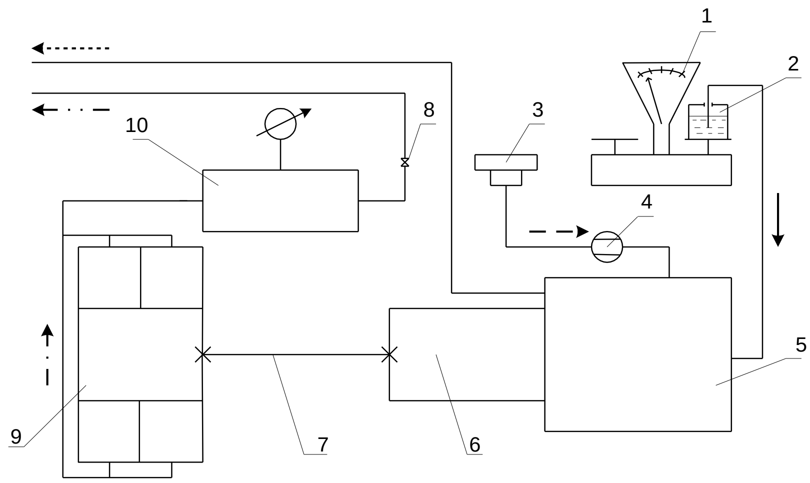
- The development of an installation for researching the main technical and operational performance indicators of the D21A1 diesel engine on RME B100 biodiesel fuel;
- A study on the technical and operational parameters of the D21A1 diesel engine on RME B100 biodiesel fuel.

To carry out studies on the work process in the engine when using biodiesel fuel, there is a need to check the validity of the assumptions put forward, which can be carried out by several methods. Among these methods, the most effective are system analysis and the comparison method. They make it possible to analyze, using objective criteria of comparative efficiency, the influence of conditions in the engine's working volume on the engine performance.

The comparison method allows:

- The analysis of the influence of factors related to the use of alternative fuels on the nature of work processes in the internal combustion engine;
- The systematization and analysis of the proposed ways of organizing the working process and the determination of the most suitable parameters of the combustion chamber for improved mixture formation in internal combustion engines.

The developed experimental installation included a D21A1 diesel engine with a device exerting a variable load on it. This was a diesel four-stroke two-cylinder D21A1 engine with a nominal power of 21 kW with a system controlling its operating modes. The engine crankshaft rotation speed varied between 600 and 1800 rpm. To ensure the variability of engine operation modes, the experimental installation was equipped with an auxiliary loading device—a K-5M compressor (JSC "Poltava Turbomechanic Plant", Poltava, Ukraine). The installation was also equipped with auxiliary devices (starting system, clutch, and gearbox) and a set of recording and measuring devices (manometers, thermometers, frequency meter, gas meter, and fuel flow meter). The scheme of the developed installation is shown in Figure 1. Fuel enters the engine (5) through the pipeline from the fuel tank (2), which is located on the fuel mass flow meter (1). Air enters the engine through the air filter (3) and the gas meter (4) (PJSC "Yampil Instrumentation Plant", Yampil, Ukraine). The engine starting system included an electric starter. The rotation frequency of the engine crankshaft was measured by a mechanical portable tachometer TCH10-P (PP "Kip-Electro", Kyiv, Ukraine). The torque from the crankshaft of the diesel engine (5) through the clutch, four-speed gearbox (6), and cardan shaft (7) is transmitted to the compressor (9). The air compressed by the compressor (9) in the pipeline is stabilized in the airflow regulator (10), in which the pressure is measured by a manometer. The pressure is regulated using the valve (8). The ambient temperature was measured with a mercury thermometer with an error of ±0.5 °C.



—direction of movement of fuel in the system;
—the direction of air movement in the system;
—air movement to the regulator;
—movement of air into the environment;
—movement of waste gases into the environment;

Figure 1. The scheme of the experimental installation for testing the technical and operational performance indicators of the D21A1 diesel engine on RME B100 fuel: 1—analytical weight; 2—fuel tank; 3—air filter; 4—gas meter; 5—diesel engine; 6—gearbox; 7—cardan shaft; 8—valve; 9—compressor; 10—airflow regulator.

Before studying the load characteristics of the D21A1 diesel engine (PJSC «Kharkiv Tractor Plant», Kharkiv, Ukraine), it was necessary to set the gear shift lever to direct transmission. Diesel engine testing was carried out according to the load characteristic when the engine speed changed from 800 to 2000 rpm. The diesel engine was warmed up before starting the tests until the oil temperature reached at least 40 °C.

The following indicators were recorded during each study:

- Weight readings of the fuel tank to determine the mass consumption of fuel mixtures during the experiment;
- Readings of the excess pressure manometer in the airflow regulator;
- The air temperature at the compressor outlet, the air temperature at the intercooler between the compressor stages, as well as the ambient temperature using a mercury thermometer;
- The engine crankshaft rotation frequency using the TCP10-P tachometer.

The engine power has been determined by the work L done by the compressor to create the absolute pressure p_2:

$$L = \frac{L_T}{\eta_c} = \frac{n}{(n-1)\cdot\eta_c}\cdot p_1 V_1\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right],\ \mathrm{J/h} \tag{1}$$

where:

η_c—compressor efficiency;

n—index of polytropic compression;

V_1—compressor supply according to parameters T_1, p_1, and m^3/h;

p_1—absolute air pressure at the compressor inlet, MPa;

p_2—absolute air pressure at the compressor outlet, MPa.

The ratio p_1/p_2 denotes λ, which is a measure of the pressure increase between compressor stages.

The index of compression polytropy in the compressor n was determined from the ratio:

$$\frac{T_1}{T_2} = \left(\frac{p_1}{p_2}\right)^{\frac{n}{n-1}}. \tag{2}$$

where:

T_1 and T_2—absolute air temperature at the inlet and outlet of the compressor, K.

The compressor drive power N_{DR} was found using the equation:

$$N_{DR} = \frac{L_1}{3600\cdot 1000\cdot\eta_1\cdot\eta_2\cdot\eta_3},\ \mathrm{kWh} \tag{3}$$

where:

η_1 = 0.98; η_2 = 0.99; η_3 = 0.71—efficiency of the gearbox, cardan transmission, and reciprocating two-stage compressor, respectively.

A brief description of the D21A1 testing engine is given in Table 1, and the main operating modes of the engine are given in Table 2. The layout of the injector nozzle sprayers is shown in Figure 2.

Table 1. Brief technical characteristics of the D21A1 engine.

Parameter Name	Unit of Measurement	Parameter Value
Cylinder diameter	mm	105
Piston stroke	mm	120
Degree of compression	-	16.5
Minimum rot. speed	rpm	800
Nominal rot. speed	rpm	1800
Nozzle	-	closed type with a multi-jet sprayer, pinless

Table 1. *Cont.*

Parameter Name	Unit of Measurement	Parameter Value
The number and diameter of the nozzle holes	mm	3 × 0.3
Engine displacement volume	cm^3	2000
Engine power	kW	21
Torque	Nm	103
Specific effective fuel consumption	g/(kWh)	241
Engine mass	kg	295

Table 2. Modes of operation of the experimental D21A1 engine installation.

Rotation Speed, rpm	λ_D	λ_{RME}	T_1, K	T_2, K	N_{KD}, kW	N_{KRME}, kW
800	2.50	2.35	295	338	11.2	10.1
1000	2.80	2.72	295	339	13.4	12.8
1200	3.20	3.04	296	341	16.2	15.1
1400	3.47	3.26	296	345	18.2	16.7
1600	3.64	3.46	297	347	19.4	18.1
1800	3.70	3.50	296	348	19.9	18.5
2000	3.63	3.47	296	348	19.4	18.1

λ_D, λ_{RME}—measure of pressure increase between compressor stages during the use of diesel fuel and RME B100; N_{KD}, N_{KRME}—power developed by the compressor in the process of using diesel fuel and RME B100.

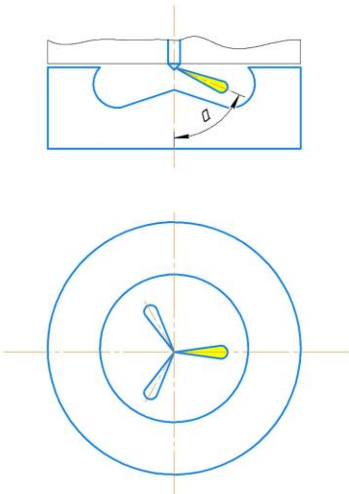


Figure 2. Scheme of fuel atomization in the D21A1 engine: α—spray angle; the yellow color indicates the nozzle that coincides with the cross-sectional plane of the combustion chamber.

Table 3 shows the main physicochemical parameters of RME B100 biodiesel fuel. The chemical composition of the fuel, heat of combustion, sulfur content, and molecular weight were determined by the chromatography method followed by the analysis of the mass of certain molecules by the mass spectrometry method. The cetane number of the diesel fuel and the RME B100 biodiesel fuel was determined by the express method using the SHATOX SX-150 (LLC Ukrpribor, Kyiv, Ukraine) device with a cetane number measurement range of 20–100 units. Fuel density was determined using a laboratory hydrometer 85N-62 (LLC Petroline, Kyiv, Ukraine) with a scale range of 0.8–0.85 kg/m^3 and an 86N-62 (LLC Petroline, Kyiv, Ukraine) with a range of 0.85–0.9 kg/m^3.

Table 3. The main physical and chemical parameters of diesel fuel according to DSTU 7688:2015 [41] and RME B100 biodiesel fuel.

Indicator Name	Unit of Measurement	Value for Diesel Fuel	Value for RME B100
Chemical composition: C H O	%	87 12.6 0.4	77 12.1 10.9
Sulfur content	%	0.0010	0.0015
Lower heat of combustion	MJ/kg	42.50	39.45
Cetane number	-	51.0	54.4
Density at temperature 323 K	kg/m^3	820–845	874
Saturated vapor pressure at temperature 481 K	bar	-	0.001
Molecular weight	kg/kmol	180–200	296

The reference indicators for comparison were the parameters obtained for the selected D21A1 engine in the process of using commercial diesel fuel at full loads.

The factory setting for the fuel spray angle α is 70°.

3. Results and Discussion

The main engine parameters affecting its dynamics and fuel consumption are:

- Torque;
- Effective power;
- Specific effective fuel consumption;
- Effective pressure.

Figure 3 graphically represents the change in the effective power of the D21A1 engine during the use of RME B100 biodiesel.

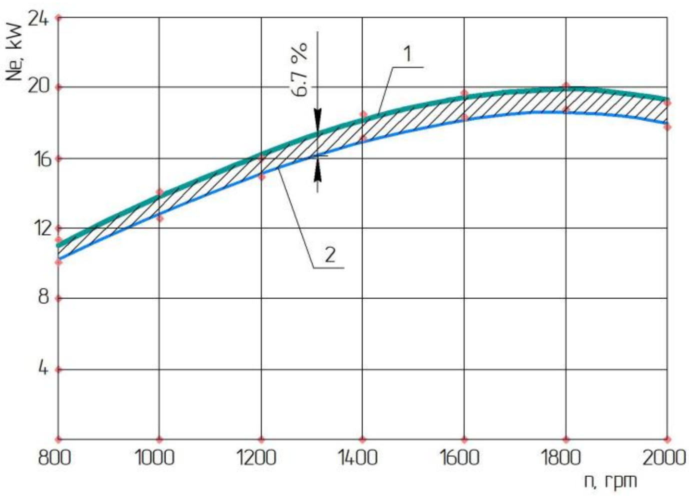


Figure 3. Change in the effective power of the D21A1 engine: 1—diesel fuel; 2—RME B100 fuel, correlation coefficients: $R_1^2 = 0.98$ and $R_2^2 = 0.99$.

The experimental data (Figure 3) were approximated by the following equations:

$$Ne_1 = -7.7786 + 0.0308 \times n - 9{\cdot}10^{-6} \times n^2, \quad (4)$$

$$Ne_2 = -9.4429 + 0.0304 \times n - 8{\cdot}10^{-6} \times n^2, \quad (5)$$

where:

Ne_1—engine power during operation on diesel fuel, kW;

Ne_2—engine power during operation on RME B100, kW;

n—crankshaft rotational speed, rpm.

According to the results of the study, when using B100 fuel, we found a decrease in the effective power of 6.7%.

The effect of RME B100 biodiesel fuel on the measured torque of the D21A1 engine is shown in Figure 4.

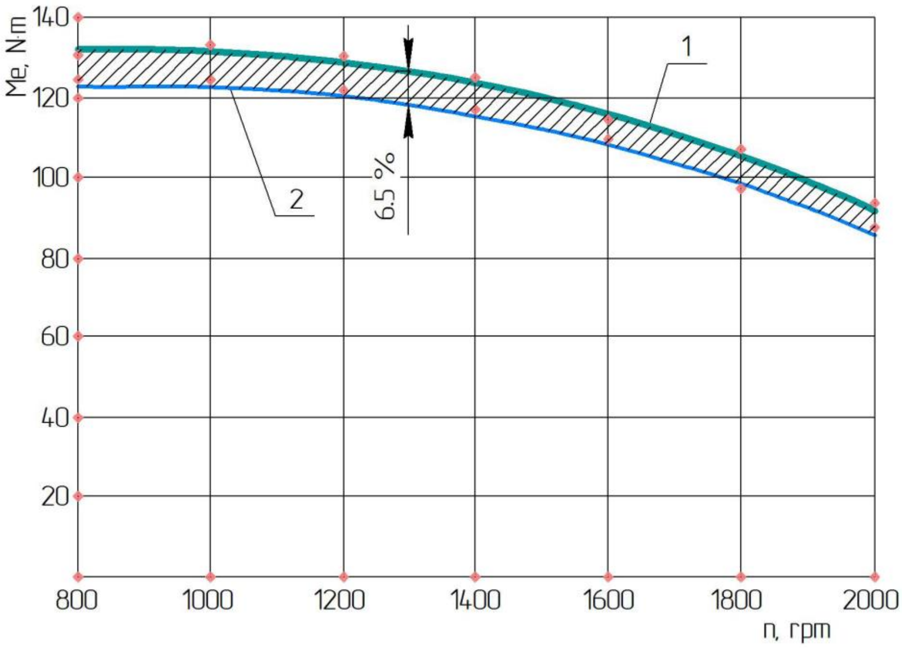


Figure 4. Torque of the D21A1 engine: 1—diesel fuel; 2—RME B100 fuel; correlation coefficients: $R_1^2 = 0.99$ and $R_2^2 = 0.99$.

The experimental data (Figure 4) were approximated by the following equations:

$$Me_1 = 108.89 + 0.0531 \times n - 3 \cdot 10^{-5} \times n^2 \quad (6)$$

$$Me_2 = 94.043 + 0.062 \times n - 3 \cdot 10^{-5} \times n^2 \quad (7)$$

where:

Me_1—the torque of the engine during operation on diesel fuel, Nm;

Me_2—the torque of the engine during operation on the RME B100, Nm.

As a result of the study of the influence of biodiesel fuel on the change in engine torque, Figure 4 reveals that when using B100 fuel, a maximum decrease in engine torque of up to 6.5% was observed.

Therefore, according to the indicators of effective engine power and torque, the use of RME B100 biodiesel fuel does not have a significant effect on the motor's performance, and therefore, it can be used with high efficiency in diesel internal combustion engines.

Figure 5 shows the specific effective fuel consumption of the D21A1 engine using diesel fuel and RME B100.

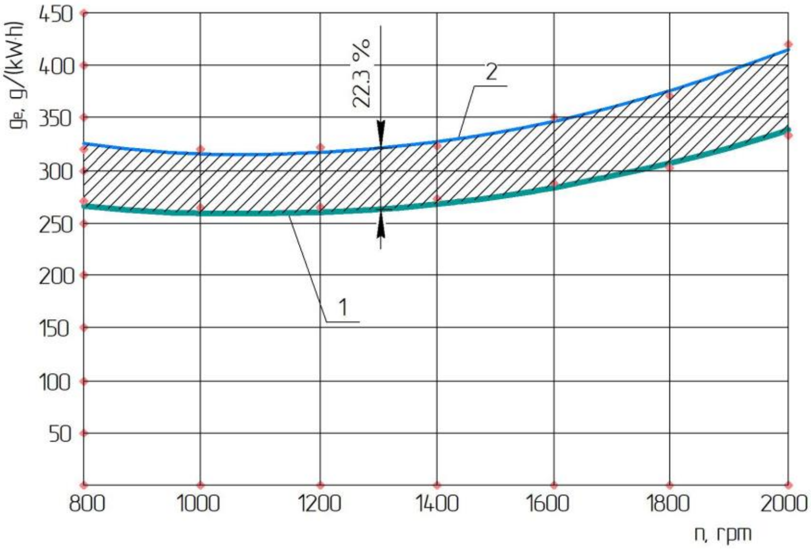


Figure 5. Specific effective power of the D21A1 engine: 1—diesel fuel; 2—RME B100 fuel; correlation coefficients: $R_1^2 = 0.99$ and $R_2^2 = 0.99$.

The measurements (Figure 5) were approximated by the following equations:

$$ge_1 = 357.79 - 0.1869 \times n - 9{\cdot}10^{-5} \times n^2 \tag{8}$$

$$ge_2 = 426.64 - 0.2064 \times n + 1{\cdot}10^{-4} \times n^2 \tag{9}$$

where:

ge_1—specific effective fuel consumption of the engine during operation on diesel fuel, g/(kWh);

ge_2—specific effective fuel consumption of the engine during operation on RME B100, g/(kWh).

Figure 6 shows the hourly fuel consumption of the D21A1 engine when using diesel fuel and RME B100.

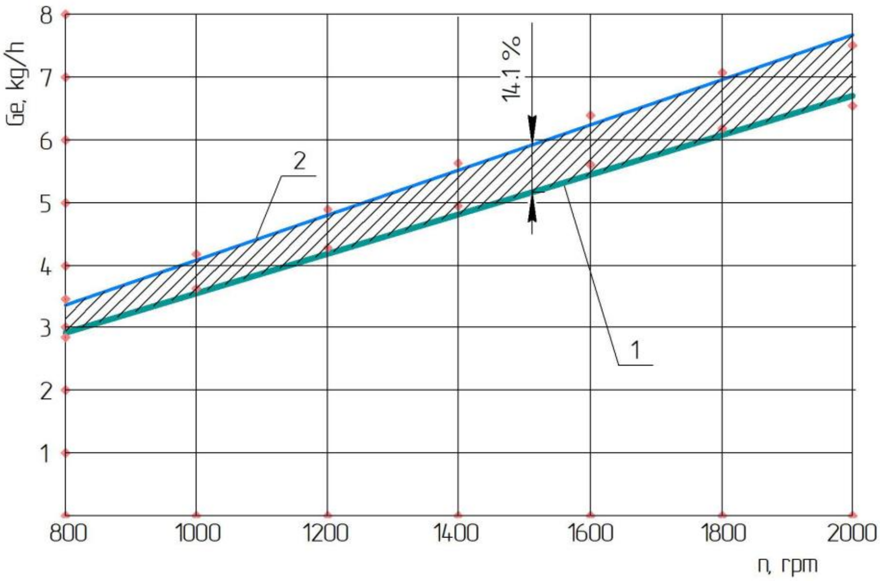


Figure 6. Hourly fuel consumption of the D21A1 engine: 1—diesel fuel; 2—RME B100 fuel; correlation coefficients: $R_1^2 = 0.99$ and $R_2^2 = 0.99$.

The experimental dependencies (Figure 6) were approximated by the following equations:

$$Ge_1 = 0.375 + 0.0032 \times n, \quad (10)$$

$$Ge_2 = 0.7182 + 0.0035 \times n, \quad (11)$$

where:

Ge_1—hourly engine fuel consumption during operation with diesel fuel, kg/h;

Ge_2—hourly engine fuel consumption during operation with RME B100, kg/h.

The error of determination of Ne, Me, ge, and Ge (Figures 3–6), depending on the magnitude of the measured values, varied from 5.5 to 9.6%.

According to the research results (Figure 5), an increase in specific effective fuel consumption of 22.3% and an increase in hourly fuel consumption of 14.1% (Figure 6) were observed, which was a consequence of a drop in engine power and a decrease in the lower calorific value of the fuel based on RME, as well as the deterioration of the mixture formation, due to which the amount of the heat released decreased and, as a result, fuel consumption increased.

In the process of using RME B100 biodiesel fuel on the D21A1 engine, we found that there was an increase in specific effective fuel consumption of up to 22.3% (Figure 5), in contrast to the studies carried out in works [5–7], in which fuels from B5 to B70 were used, and an increase in the proportion of the mixture in the fuel led to a decrease in the specific fuel consumption. This can be explained by the fact that the use of RME B100 fuel, in contrast to fuels [5–7] B5–B70, requires changes to the engine design to improve the mixture formation process, and therefore, further research can be directed at increasing heat generation due to complete fuel combustion, thereby increasing power and torque and reducing fuel consumption.

In the publications [42,43], it was established that the operation of a diesel engine on biodiesel, including B100 biodiesel, does not require additional regulation of the fuel supply system—neither the maximum cycle frequency nor the static phase of fuel injection. The operation of the diesel engine with biodiesel B100 does not increase the thermal and mechanical load on the parts of the cylinder sleeve group and does not deteriorate the reliability indicators. However, according to the results of this study (Figures 3 and 4), in the crankshaft rotation frequency range of 800–2000 rpm on RME B100 fuel, a decrease in engine torque of 6.5% and a drop in effective power to 6.7% were observed. This is influenced by the difference in the physicochemical parameters of B100 biodiesel and commercial diesel fuel, as well as its lower calorific value.

In work [44], the effect of B100 biodiesel fuel on engine oil was investigated, and it was concluded that the usage of B100 impacts motor oil viscosity—pure biodiesel fuel reduced the service life of engine oil from 20,000 to 13,000 and from 15,000 to 10,000 km, respectively. This direction of research is quite important and can be continued in our further work because, in addition to the effect of RME B100 fuel on oil viscosity, the effect on density, flash point, and corrosive properties were not investigated.

Important results were obtained in works [45–47], in which it was proposed to use 20% pine oil with diesel fuel and a dioxane additive [45,46] and low-viscosity bio-oil with an ignition booster (di-tert-butyl peroxide) and a non-metallic nano-additive as fuel (rice husk) [47]. Although this negatively affected engine performance, it significantly reduced CO, CH, NOx, and smoke emissions. A decrease in the performance of the D21A1 engine was also established in our research, which confirms the adequacy of the obtained results, and the effect of dioxane additives on the environmental parameters of the engine can be investigated in our further work.

Also, further research should be performed on an internal combustion engine with a turbocharger system and pre-chamber ignition, which should ensure good mixture formation and the ignition of the fuel-air mixture.

Also, further research should be aimed at identifying the impact of RME B100 biodiesel on the environmental impact of diesel engine operation.

4. Conclusions

It is known that the use of RME biodiesel leads to a change in the operating parameters of the internal combustion engine, and the nature of the changes when using B100 fuel has not been investigated before. Therefore, researching the main performance indicators of the internal combustion engine using RME B100 biodiesel fuel is relevant. In order to fulfill the research objectives, we developed an experimental setup in which the results of the authors' research were used and the process of the influence of the use of RME B100 biodiesel fuel on the technical and operational parameters of the air-cooled D21A1 engine was investigated. According to the research results, when using RME B100, the power drop in relation to petrodiesel was up to 6.7%, the maximum power value was reached at n = 1800 rpm, and the minimum power was reached at n = 800 rpm.

The torque of the D21A1 engine decreased by 6.5%, the maximum torque value was reached at n = 1000 rpm, and the minimum torque was reached at n = 2000 rpm.

The difference in the change in torque and power percentages is explained by the fluctuation of the measurement error and the nature of the curves on the graphs, namely the max and min values at different crankshaft speeds.

The specific effective fuel consumption increased by 22.3%, its maximum value was recorded at n = 2000 rpm, and its minimum value was recorded at n = 1200 rpm.

The increase in hourly fuel consumption increased by 14.1%, with the consumption growing proportionally to rotational speed.

Such a change in the specific effective and hourly fuel consumption is explained by the fact that the specific effective fuel consumption is influenced by a number of physical and chemical properties of the fuel, namely: density, kinematic viscosity, cetane number, and the mixture formation process. Therefore, as we see from the research, the lower heat of the combustion of fuel is not directly proportional to fuel consumption.

According to the results of studies on the operation of the D21A1 engine on commercial and RME B100 biodiesel fuel, it was established that the use of biodiesel fuel leads to a deterioration of its technical and operational performance. This is explained by the fact that the use of RME B100 fuel requires changes to the engine design to improve the mixture formation process since the physical and chemical properties of diesel fuel and RME B100 fuel, namely the density, kinematic viscosity, and cetane number, differ from each other (Table 3).

Density and kinematic viscosity significantly affect the pumping of fuel through the engine power system and the quality of the atomization and mixing process, and therefore, the fuel supply and atomization system need to be adjusted.

The cetane number affects the auto-ignition delay period of the fuel; the higher it is, the longer this period is. Therefore, according to our research results obtained in [1], the fuel injection moment must be increased by 6°.

However, the torque and power did not change significantly, and therefore, the use of RME B100 biodiesel in diesel engines, even without making changes to their design, will not have significant negative consequences.

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