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Increasing the efficiency of operation of agricultural machinery by improving the diesel engine power supply system

The article explores the possibilities of increasing the efficiency of automotive equipment by modernizing the diesel engine power supply system to ensure its operation according to the gas-diesel cycle. The prospects for using natural gas as an alternative component of motor fuel are considered, which allows reducing diesel fuel consumption, reducing the cost of operating vehicles and increasing their fuel efficiency. The principles of operation of diesel engines with combined fuel supply are analyzed, the design features of the standard power supply system are determined, and the advantages and possible limitations of using the gas-diesel operating mode are assessed. An analysis of modern technical solutions for the conversion of diesel engines proposed by domestic and foreign developers is performed. It is established that the implementation of a modernized power supply system will contribute to increasing the fuel efficiency of automotive equipment, reducing the negative impact on the environment by reducing harmful emissions and improving the technical and economic performance of vehicle operation, in particular in the conditions of the agro-industrial complex.
energy efficiency, agro-industrial complex, vehicles, diesel engine, power system, gas-diesel cycle, natural gas, fuel economy, modernization, operational efficiency

Problem statement. The efficiency of operation of automotive equipment used in the agro-industrial complex is largely determined by the cost of fuel and energy resources, the reliability of power units and environmental performance of vehicles. The constant increase in the cost of diesel fuel, the need to reduce the cost of transport operations and increase the energy efficiency of vehicles necessitate the search for alternative ways to organize the process of powering diesel engines [1].

One of the most promising areas is the use of a gas-diesel cycle, in which part of the diesel fuel is replaced by natural or liquefied petroleum gas, and diesel fuel performs the function of an ignition dose [2-4]. This approach allows you to reduce diesel fuel consumption, reduce operating costs and improve the environmental performance of the engine without significant intervention in its basic design.

At the same time, existing gas-diesel systems are characterized by insufficient adaptation to different engine load modes, the complexity of coordinating the supply of diesel and gas fuel, as well as the need to ensure reliability, safety and stability of the combustion process. The effectiveness of their application largely depends on the design features of the power supply system and the control algorithms for the supply of both types of fuel [5].

In this regard, an urgent scientific and practical task is to improve the power supply system of a diesel engine to operate on a gas-diesel cycle, which will ensure increased fuel efficiency and operational efficiency of vehicles of the agro-industrial complex.

Analysis of recent research and publications. The issue of increasing the energy efficiency of diesel engines through the use of alternative fuels is one of the priority areas of

modern research in the field of road transport and agricultural engineering. A significant number of scientific works are devoted to improving the power supply systems of diesel engines, studying the processes of mixture formation, ensuring stable combustion of the fuel mixture and increasing fuel efficiency by partially replacing diesel fuel with natural or liquefied petroleum gas [6-8]. In the works of Ukrainian scientists, considerable attention is paid to the development of gas-diesel power systems for diesel engines in operation. Studies show that the use of microprocessor control of gas fuel supply makes it possible to increase the fuel efficiency of the engine, reduce the toxicity of exhaust gases and expand the fuel base of vehicles without significantly changing the design of the power unit [9-11].

Analysis of modern technical solutions shows that the most widespread electronic systems are STAG Diesel, Landi Renzo Diesel Dual Fuel, Prins Dual-Fuel HD, AEB MP48 DF, Autogas Italia DDF, ELPIGAZ DEGAmix, ALEX Diesel and Blue Power Diesel, which provide partial replacement of diesel fuel with gas while maintaining the standard diesel fuel system. The main advantage of such systems is the possibility of upgrading serial diesel engines without their deep structural modification, as well as the possibility of operating the engine in both gas-diesel and traditional diesel modes.

At the same time, the analysis of literary sources shows that the efficiency of existing systems largely depends on the accuracy of gas fuel dosing, the consistency of the operation of gas and diesel subsystems, the engine load mode, the quality of the electronic control unit settings and the technical condition of the fuel equipment [12]. The greatest economic effect is achieved during engine operation at medium and high loads, while at low loads and transient modes there is a need to limit the gas supply to ensure a stable combustion process and preserve the engine resource.

Therefore, despite a significant amount of scientific research and practical developments, the issue of improving the diesel engine power supply system, which will provide the optimal ratio of diesel and gas fuel in a wide range of operating modes, remains relevant, which determines the direction of this study.

Task statement. The purpose of the study is to increase the efficiency of operation of vehicles of the agro-industrial complex by improving the diesel engine power supply system for operation on the gas-diesel cycle. Achieving the set goal involves reducing diesel fuel consumption, increasing fuel efficiency and ensuring stable engine operation when using two-component fuel.

To achieve the set goal, it is necessary to solve the following tasks:

- analyze the features of the functioning of diesel engines when operating on the gas-diesel cycle and determine the factors that affect their fuel efficiency and operational efficiency;
- investigate existing design solutions for diesel engine power supply systems for operation on a mixture of diesel and gas fuel, determine their advantages, disadvantages and possibilities of application in the conditions of the agro-industrial complex;
- substantiate the design scheme of an improved diesel engine power supply system that provides a coordinated supply of diesel and gas fuel depending on the engine operating mode;
- assess the impact of the proposed system on fuel economy, operational efficiency and the possibility of practical use of vehicles in the conditions of the agro-industrial complex.

Presentation of the main material. One of the most promising directions for increasing the efficiency of operation of vehicles of the agro-industrial complex is the use of alternative types of motor fuel without significantly changing the design of the base engine. The most appropriate solution for diesel engines is the use of a gas-diesel cycle, in which part

of the energy required for engine operation is provided by natural gas, and diesel fuel is used only as an ignition portion. This approach allows you to preserve all the advantages of a diesel engine, in particular, a high efficiency, significant torque and reliability of ignition of the fuel mixture, while simultaneously reducing the consumption of expensive diesel fuel and operating costs of the vehicle. [13,14].

The MAN TGA 33.480 truck equipped with a six-cylinder MAN D2066 diesel engine with a Common Rail injection system was taken as the basic object of the study. The choice of this particular vehicle was due to its wide use in transport provision of the agro-industrial complex, high operational loads and significant annual consumption of diesel fuel. Using such a vehicle as an object of modernization allows for the most complete assessment of the effectiveness of the gas-diesel power system.

The main purpose of the development is to create a combined power system that ensures engine operation both in normal diesel mode and in the mode of partial replacement of diesel fuel with compressed natural gas. In this case, the standard fuel equipment does not undergo structural changes, but is supplemented by a gas subsystem that provides a metered supply of natural gas depending on the engine load.

The structural diagram of the proposed system is shown in (Fig. 1). It consists of a standard Common Rail diesel system, cylinders for storing compressed natural gas, a multivalve, a refueling device, a high-pressure reducer, a gas filter, a solenoid valve, gas nozzles, pressure and temperature sensors, and an electronic control unit. The gas subsystem is integrated into the engine intake tract without changing the design of the combustion chamber.

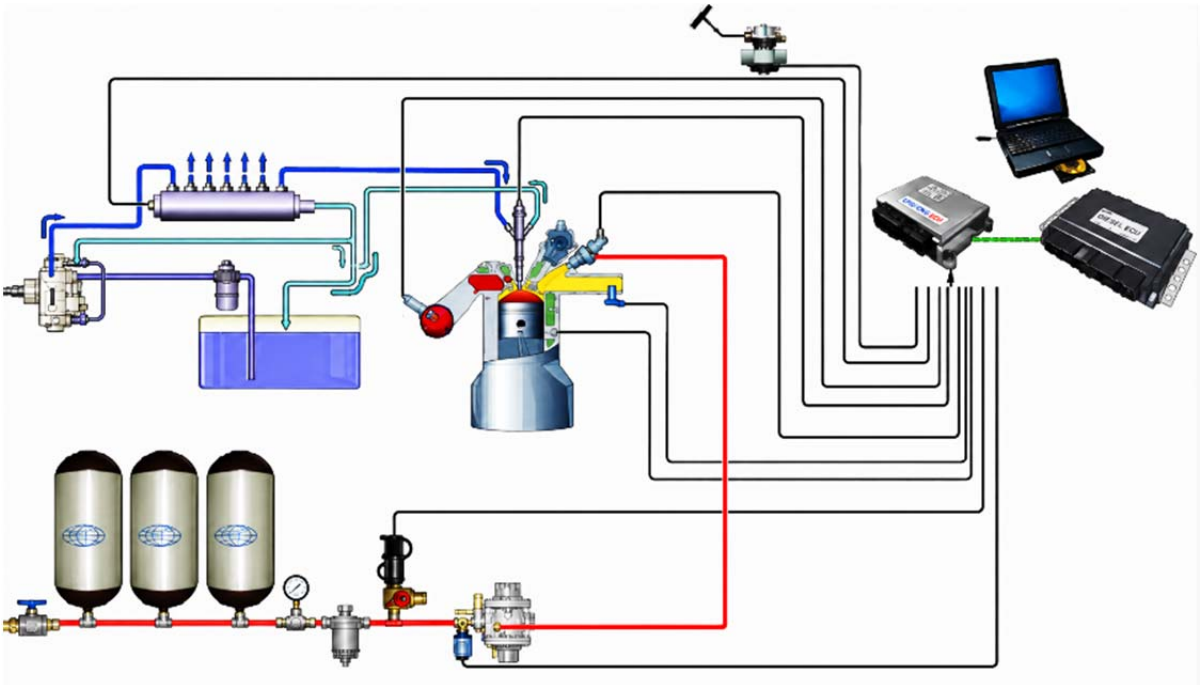

Figure 1 – Diagram of the power supply system of a MAN 2066 diesel engine adapted to operate on a gas-diesel cycle

The principle of operation of the system is that after starting the engine, its operation is carried out exclusively on diesel fuel. After reaching the required coolant temperature, the electronic control unit switches the engine to gas-diesel mode. Gas from the cylinders enters through a reducer, in which the pressure is reduced to the operating value, after which it is fed into the intake manifold through gas nozzles. Diesel fuel, as before, is injected directly into the cylinder by standard nozzles in an amount sufficient for self-ignition. After the ignition of

the diesel ignition portion, the combustion of the previously prepared gas-air mixture occurs. The electronic control unit constantly monitors the crankshaft rotation speed, engine load, temperature, gas pressure and other parameters, ensuring the optimal ratio between diesel and gas fuel. Unlike the complete conversion of a diesel engine into a gas engine, the proposed system does not require changing the compression ratio, the design of the piston group or the installation of a forced ignition system. This significantly simplifies the modernization of the car, reduces its cost and provides the possibility of a quick return to the traditional diesel mode of operation.

To assess the effectiveness of the proposed design, design and technological calculations were performed. The main indicator is the coefficient of substitution of diesel fuel with natural gas:

$$K_z = \frac{Q_g}{Q_d},$$

where K_z – diesel fuel substitution coefficient; Q_g – amount of energy coming from natural gas, *MJ*; Q_d – the amount of energy coming from diesel fuel, *MJ*.

In the calculations carried out, it was assumed:

$K_z = 0{,}30,$

i.e. 30% of the energy is provided by natural gas and 70% by diesel fuel. This ratio is optimal in terms of ensuring stable ignition of the mixture and preventing detonation processes.

The annual consumption of diesel fuel after conversion is determined by the formula

$$Q_{dg} = Q_d * (1 - Kz),$$

where Q_{dg} – diesel fuel consumption after conversion, *L*; Q_d – diesel fuel consumption before conversion, *L*.

Provided that

$Q_d = 24108$ *L*,

we will get

$Q_{dg} = 24108 \cdot (1 - 0{,}30) = 16876$ *L*.

The annual diesel fuel savings are determined by the expression

$$Q_{dg} = Q_d * (1 - Kz)$$

After substituting the numerical values, we have

$\Delta Q = 24108 - 16876 = 7232$ *L*.

Therefore, the use of a gas-diesel system ensures a reduction in diesel fuel consumption by 7232 liters per year.

To assess fuel efficiency, the residual diesel fuel consumption coefficient was determined:

$$K_{ek} = \frac{Q_{dg}}{Q_d}.$$

After substitution we get

$K_{ek} = 16876 / 24108 = 0{,}70.$

The diesel fuel economy coefficient is determined by the dependence

$$K_{ed} = 1\text{-}K_{ek}$$

From here

$K_{ed} = 1 - 0{,}70 = 0{,}30$.

Thus, the modernization of the power supply system allows you to reduce diesel fuel consumption by approximately 30%.

The economic effect of using a gas-diesel system is determined by the formula

$$E = B_1 - B_2,$$

where B_1 –annual fuel costs before modernization, *a.u.*; B_2 –annual costs after modernization, *a.u.*

According to the results of the calculations

$B_1 = 1325940$ *a.u.*;

$B_2 = 1205876$ *a.u.*

Then

$E = 1325940 - 1205876 = 120064$ *a.u.*

The relative reduction in fuel costs is determined by the formula

$$\eta = \left(\frac{E}{B_1} \right) * 100\% .$$

After substituting the values, we get

$\eta = (120064 / 1325940) \cdot 100 = 9{,}1$ %.

The results obtained show that even with partial replacement of diesel fuel with natural gas, a noticeable economic effect is provided, especially for vehicles with high annual mileage.

An additional advantage of the proposed system is the improvement of environmental performance. Natural gas is characterized by a higher hydrogen content and a lower amount of heavy hydrocarbons compared to diesel fuel, which ensures more complete combustion of the fuel-air mixture. As a result, the smoke of exhaust gases, the concentration of particulate matter and other products of incomplete combustion are reduced.

The efficiency of the gas-diesel system largely depends on the engine load mode. The best results are achieved at medium and high loads, when favorable conditions for complete combustion of the gas-air mixture are provided. At low loads and idle, the proportion of gas fuel should be limited, which prevents unstable combustion and ensures reliable engine operation. That is why the electronic control unit continuously adjusts the gas supply in accordance with the current engine operating mode.

Thus, the performed design and theoretical calculations confirm that the proposed diesel engine power supply system for operation on the gas-diesel cycle is technically feasible and economically feasible. The use of a combined system, the design of which is shown in (Fig. 1), allows, without changing the basic engine design, to provide partial replacement of diesel fuel with natural gas, reduce its annual consumption by 7232 *L*, reduce fuel consumption by approximately 9.1%, and also improve the environmental performance of vehicles. This confirms the prospects of using the proposed system on trucks of the agro-industrial complex.

Conclusions. As a result of the research, it was established that the use of the gas-diesel cycle is one of the most effective ways to increase the energy efficiency of vehicles in the agro-industrial complex. An analysis of the features of the operation of diesel engines showed that partial replacement of diesel fuel with natural gas allows for a stable work process without making significant structural changes to the base engine.

The analysis of modern domestic and foreign gas-diesel power systems confirmed that the most promising are electronically controlled gas fuel dosing systems that provide automatic

regulation of its supply depending on the engine operating mode. At the same time, it was established that existing systems need to be improved to ensure the accuracy of gas dosing and optimize the joint operation of the gas and diesel subsystems.

The design scheme of an improved diesel engine power system is substantiated, which involves the integration of the gas subsystem with the standard Common Rail system without changing the engine design. The proposed technical solution provides automated natural gas supply in accordance with the engine load and the implementation of the gas-diesel cycle while maintaining the possibility of operating the vehicle in traditional diesel mode.

The theoretical calculations performed confirmed the effectiveness of the proposed system. It was established that with a diesel fuel substitution coefficient of 30%, the annual diesel fuel savings are 7232 liters, and fuel costs are reduced by approximately 9.1%, which provides an annual economic effect of 120064 *a.u*. The results obtained confirm the technical feasibility and economic efficiency of using the proposed power system on vehicles of the agro-industrial complex.

References

1. Zhang, X., Gao, J., Fan, D., Yang, Q., Han, F., & Yu, H. (2024). Impact of pilot diesel injection timing on performance and emission characteristics of marine natural gas/diesel dual-fuel engine. *Scientific Reports, 14*, Article 10713. https://doi.org/10.1038/s41598-024-61672-5
2. Liu, J., Zhao, W., Zhang, X., Ji, Q., Ma, H., Sun, P., & Wang, P. (2024). Optimizing combustion and emissions in natural gas/diesel dual-fuel engine with pilot injection strategy. *Thermal Science and Engineering Progress, 48*, Article 102418. https://doi.org/10.1016/j.tsep.2024.102418
3. Sehili, Y., Tarabet, L., Cerdoun, M., Loubar, K., & Lacroix, C. (2024). Toward improving efficiency and mitigating emissions in a natural gas/diesel direct injection dual fuel engine using EGR. *International Journal of Engine Research, 25*(11). https://doi.org/10.1177/14680874241261003
4. Muhssen, H. S., Zöldy, M., & Bereczky, Á. (2024). A comprehensive review on the hydrogen–natural gas–diesel tri-fuel engine exhaust emissions. *Energies, 17*(15), 3862. https://doi.org/10.3390/en17153862
5. Pribadi, E. C. W., Semin, Santoso, A., Cahyono, B., Iswantoro, A., Prasutiyon, H., & Felayati, F. M. (2024). Lateral swirl combustion system development of dual fuel diesel engine piston to improve efficiency and reduce NOx emission: A brief review. *International Journal on Engineering Applications, 12*(4), 218–225. https://doi.org/10.15866/irea.v12i4.23008
6. Channapattana, S. V., Ramesh, K., & Kumar, G. N. (2024). Performance and emission characteristics of diesel engines running on gaseous fuels in dual-fuel mode. *International Journal of Hydrogen Energy, 49*(Part B), 868–909. https://doi.org/10.1016/j.ijhydene.2023.09.130
7. Lievtierov, A. M., & Avramenko, A. M. (2024). Vybir parametriv hazovoho zmishuvacha dlia konversii dyzelnoho motor-heneratora u hazodyzelnyi [Selection of gas mixer parameters for conversion of a diesel generator engine to dual-fuel operation]. *Dvyhuny vnutrishnoho zghoriannia [Internal Combustion Engines], 2*, 16–24. https://doi.org/10.20998/0419-8719.2024.2.02
8. Marchenko, D., Dykha, A., Aulin, V., Matvyeyeva, K., Tishechkina, K., & Kurepin, V. (2020). Development of technology and research of method of electric hydropulse hardening of machine parts. In *Proceedings of the 25th IEEE International Conference on Problems of Automated Electric Drive. Theory and Practice (PAEP 2020)*. IEEE. https://doi.org/10.1109/PAEP49887.2020.9240796
9. Kryshtopa, S. I., Kryshtopa, L. I., Kozak, F. V., Demianchuk, Ya. M., Trukhanivskyi, A. M., & Hrishtor, T. T. (2024). Analiz enerhoefektyvnosti dyzelnykh dvyhuniv naftohazovoho tekhnolohichnoho transportu, konvertovanykh na alternatyvni vydy palyva [Analysis of the energy efficiency of diesel engines of oil and gas technological transport converted to alternative fuels]. *Matematychne modeliuvannia [Mathematical Modeling], 1*(50), 53–61. https://doi.org/10.31319/2519-8106.1(50)2024.305598
10. Zubiekhina-Khaiiat, O., Hruban, V., Lymar, O., & Marchenko, D. (2026). Designing technologies for strengthening tractor and self-propelled machine parts in agricultural conditions. *Ukrainian Black Sea Region Agrarian Science, 30*(1), 44–61. https://doi.org/10.56407/bs.agrarian/1.2026.44
11. Marchenko, D., Matvyeyeva, K., Lymar, O., & Kurepin, V. (2025). Enhancing the reliability and wear resistance of high-speed cutting tools through the use of ionized air-oil lubrication media in machine part restoration. *Problems of Tribology, 30*(4/118), 72–78. https://doi.org/10.31891/2079-1372-2025-118-4-72-78

12. Marchenko, D., & Matvyeyeva, K. (2023). Development and research of an automatic system for regulating the frequency of rotation of a diesel engine crankshaft. In *2023 IEEE 5th International Conference on Modern Electrical and Energy System (MEES)*. IEEE. https://doi.org/10.1109/MEES61502.2023.10402401
13. Rizopoulos, N., & Papagiannakis, R. (2025). Comparative evaluation of the effect of exhaust gas recirculation usage on the performance characteristics and emissions of a natural gas/diesel compression-ignition engine operating at part-load conditions. *Energies, 18*(3), 710. https://doi.org/10.3390/en18030710
14. Ariani, B., Felayati, F. M., & Batutah, M. A. (2024). Experimental investigation of oxy-hydrogen injection in natural gas/diesel dual-fuel engine: Performance and emission analysis under low load operation. *Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan, 21*(1), 10–16. https://doi.org/10.14710/kapal.v21i1.61692

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Підвищення ефективності експлуатації автомобільної техніки АПК шляхом удосконалення системи живлення дизельного двигуна

У статті розглянуто питання підвищення ефективності експлуатації автомобільної техніки агропромислового комплексу шляхом удосконалення системи живлення дизельного двигуна для роботи за газодизельним циклом. Обґрунтовано доцільність використання природного газу як додаткового моторного палива для зменшення споживання дизельного палива, підвищення паливної економічності, скорочення експлуатаційних витрат і покращення екологічних показників транспортних засобів.

Проведено аналіз сучасних підходів до переобладнання дизельних двигунів для роботи за газодизельним циклом та досліджено конструктивні особливості штатної системи живлення і наявних технічних рішень щодо подачі природного газу. Запропоновано удосконалену систему живлення дизельного двигуна MAN D2066 із системою впорскування Common Rail, яка забезпечує автоматизовану подачу природного газу відповідно до режимів роботи двигуна без суттєвого втручання в його конструкцію. Виконано теоретичне обґрунтування параметрів модернізованої системи, визначено коефіцієнт заміщення дизельного палива природним газом, розраховано річну економію палива та економічний ефект від упровадження запропонованого технічного рішення. Оцінено вплив модернізованої системи живлення на паливну економічність, експлуатаційні характеристики та екологічні показники автомобільної техніки агропромислового комплексу.

Встановлено, що використання удосконаленої системи живлення забезпечує заміщення до 30 % дизельного палива природним газом, сприяє зниженню експлуатаційних витрат приблизно на 9,1 %, підвищує паливну економічність і зменшує негативний вплив транспортних засобів на навколишнє середовище. Запропоноване технічне рішення не потребує суттєвого переобладнання базового двигуна та може бути впроваджене на автомобільній техніці агропромислового комплексу. Отримані результати підтверджують перспективність застосування газодизельних технологій для модернізації дизельних двигунів і створюють практичне підґрунтя для подальшого підвищення ефективності експлуатації транспортних засобів.

енергоефективність, агропромисловий комплекс, транспортні засоби, дизельний двигун, система живлення, газодизельний цикл, природний газ, паливна економічність, модернізація, експлуатаційна ефективність

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