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DESIGN IMPROVEMENT OF DIESEL ENGINES TAKING INTO ACCOUNT MODERN ENVIRONMENTAL REQUIREMENTS

Statement of the problem in a general form. Modernization of medium- and high-speed diesel engines at the current stage is reduced to increasing their energy efficiency with simultaneous strengthening of environmental requirements to combat global warming. This process involves not only a change in the structure and technical characteristics of vehicles, but also a transition to the use of alternative types of fuel. In our paper, we explore the key technical aspects of this transition, including fuel systems and their adaptation to the new requirements of today's medium- and high-speed diesel engines. The results of our research will reveal important information about the improvement of diesel fuel systems, contributing to the improvement of their operational efficiency and compliance with the new standards.

The transition to new environmental standards is becoming especially relevant in the current conditions of geopolitical challenges. This process involves not only adaptation to equipment standards, but also transition to the use of new types of fuel and improvement of their supply systems.

An important aspect of our research is the analysis and assessment of advantages and disadvantages associated with the use of alternative fuels and modification of fuel systems. Our findings will make it possible to develop optimal solutions for increasing the productivity of trucks, reducing the negative impact on the environment, and increasing the overall reliability and efficiency of military vehicles.

Analysis of recent research publications.

Considering the possibilities of using alternative types of fuel and modifying the fuel systems of medium and high-speed diesel engines, several basic lines can be identified that contribute to improving the performance of diesel engines, reducing the negative impact on the environment, and increasing the overall reliability and efficiency of military vehicles:

– replacing traditional petroleum fuels with biofuels (for example, biodiesel or bioethanol) can help reduce CO_2 emissions and other pollutants (the use of biofuels can be particularly useful in areas where there is access to renewable sources of raw materials such as vegetable oil or biomass) [1];

- the introduction of hybrid systems that combine two or more energy sources, such as electricity and diesel fuel, can reduce fuel consumption and improve the performance of trucks (electrification can also provide the ability to use vehicles in "silent mode", which is important in military operations) [2];

– modification of the fuel system for more effective recirculation of exhaust gases back to the engine can lower the combustion temperature and reduce emissions of nitrogen oxides (NOx), which is an important argument for compliance with environmental regulations [3];

– the use of compressed natural or liquefied natural gas can be effective, since gas is a less polluting fuel compared to traditional types of fuel [4];

– the use of modern electronic engine management systems to optimize engine parameters and control the fuel system can increase productivity and reduce fuel consumption [5];

– the use of new materials in the construction of diesel engines can lead to a decrease in fuel consumption [6].

It is important to note that the successful modernization of the fuel system to use alternative fuels requires thorough research and testing to ensure safety, reliability and compliance with environmental standards. It may also require the development of new components and technologies to ensure efficient operation with different types of fuel [7].

Application of the above-mentioned methods can help solve the problems associated with increasing the efficiency of diesel engines and improving their environmental performance, but they require large and expensive costs for development and improvement.

Setting objectives. We offer a solution to these problems by using a cheap additional power system in the form of a vortex mixer-evaporator [8]. The vortex mixer-evaporator works on the energy of waste gases and allows the use of cheap, compared to the standard ones, low-cetane fuels, for example, stable gas condensate without processing.

But the use of high-viscosity fuels in engines is complicated by the fact that their thermophysical parameters differ from traditional fuels, which require a careful approach when evaluating the formation of a fuel mixture - atomization, evaporation and mixing with an oxidizer. In addition, the high sulfur content poses additional challenges, especially regarding the environmental cleanliness of exhaust gases [9].

Presentation of the main research material.

Improvements in fuel delivery and hybrid fuel systems are important areas of research that can contribute to more efficient use of resources, reduction of harmful emissions, and increased flexibility in the use of fuels for motor vehicles and the armed forces. The use of advanced fuel delivery systems such as the Rank tube can be an effective way to improve the efficiency and environmental safety of modern military vehicles.

A Rank tube is a device designed to prepare fuel for combustion by vaporizing it, mixing it with exhaust gases, and recirculating it back into the engine. This facilitates more complete use of fuel, reducing emissions of harmful substances and increasing engine efficiency.

The use of a Rank tube in the fuel supply system can lead to the following advantages:

– evaporation of fuel and its mixing with exhaust gases contributes to better combustion, which leads to a decrease in emissions of harmful substances into the atmosphere;

– more efficient burning of fuel reduces emissions of harmful substances, which is an important aspect for compliance with environmental standards;

– increased efficiency and more efficient use of fuel can increase the range of vehicles.

However, the implementation of such systems requires a thorough engineering approach, testing and adaptation to the specific conditions and requirements of military automotive equipment. In addition, it should be taken into account that any changes in the fuel supply system must ensure the reliability and safety of operation of automotive equipment in conditions of combat or intensive operation.

Using the thermal energy of exhaust gases with an additional power supply system (a part of the thermal energy is used when the ambient temperature drops significantly) for heating fuel flow, and by using the kinetic energy of the exhaust gases to atomize the heated fuel, the above requirements of the diesel engine are met. The ratio of recirculated exhaust gases to fresh air is chosen so that the combustion of low-cetane fuels is detonation-free at all speed and load modes of operation. The additional power supply system is a direct-flow Ranka tube with a forced vortex flow in the nozzle inlet, which houses a fuel atomizer (Fig. 1).

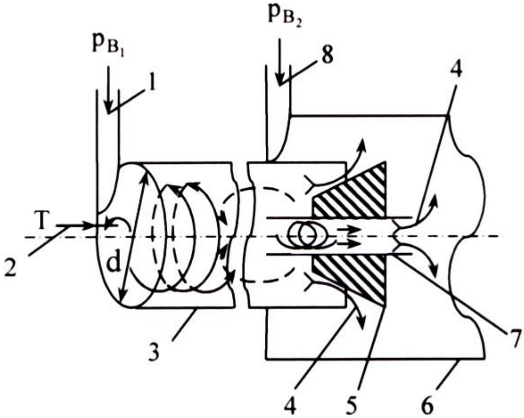

Fig. 1. Scheme of the vortex additional diesel power supply system:
1 – tangential supply of air from the HTN compressor (p_{B_1}); 2 – fuel supply from the priming pump (T); 3 – cylindrical part of the vortex tube; 4 – flows aerosol prepared part of the working mixture; 5 – regulator consumption of the mixture and frequency of rotation of the vortex flow; 6 – diesel intake manifold; 7 – diaphragm of the vortex system feeding; 8 – tangential air supply (secondary vortex air flow from HTN (p_{B_2}))

This design of this device allows you to use an aerodynamic spraying method with the formation of fuel droplets with a diameter of 0.1–40 microns, which satisfies the combustion regime in terms of burnout speed and completeness at any engine speed.

To prove the plausibility of the stated arguments, we will present the analysis of experimental data of motorless tests on the quality of spraying and evaporation in the vortex system (Fig. 2).

Taking into account the fact that the fuel consumption through the evaporator-mixer does not exceed 50% of the hourly maximum fuel consumption by the engine, we conducted tests on three loaded modes of engine operation with changes in fuel consumption up to 7.7 kg/h (Fig. 3).

The analysis of the results shows that with increasing fuel consumption, the quality of sawing deteriorates, while a sharp "jump" in the deterioration of sawing occurs at the maximum torque Me_{max}, when the fuel consumption G_T = 2 kg/h, at the maximum power Ne_{max}, G_T = 2.9 kg/h and the maximum rotation frequency $n_{max\ x/x}$, G_T = 6.5 kg/h.

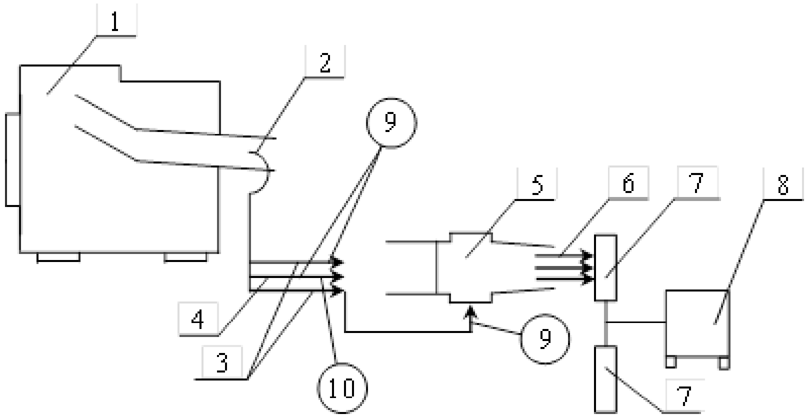

Fig. 2. The general scheme for determining the quality of fuel atomization in the vaporizer-mixer:
1 – internal combustion engine; 2 – gas reservoir; 3 - gas pipelines in sprayer and in volute; 4 – fuel line; 5 – evaporator-mixer; 6 – a mixture of fuel and exhaust gases; 7 - plate (smoked ash, covered with a film of magnesium oxide); 8 – electric motor; 9 – temperature and pressure sensors; 10 – fuel flow meter

Such a jump from an aerosol state to a torch (by a torch we mean a state when the average volume diameter of a droplet is higher than 5-8 microns) can be explained by the fact of the lack of pressure and temperature of the exhaust gases.

It should be noted that with a fuel consumption of up to 3 kg/h, the mixture meets the requirements of aerosol mixing and evaporation, that is, at $D_{30} < 1$ μm, which significantly exceeds the quality of fuel preparation. The appearance of large drops with a diameter of more than 40 μm is determined as a mismatch of the geometric dimensions of the tube and atomizer to the parameters of the gases, and it can also occur due to the greater heat of vaporization of the fuel compared to the heat contributed by the exhaust gases.

The geometric dimensions of the tube, atomizer, gas-subducting channels with the gas collector determine the frequency of rotation of the vortex and the fuel ejection flow through the nozzle of the tube, i.e., directly affect the quality of the mixture.

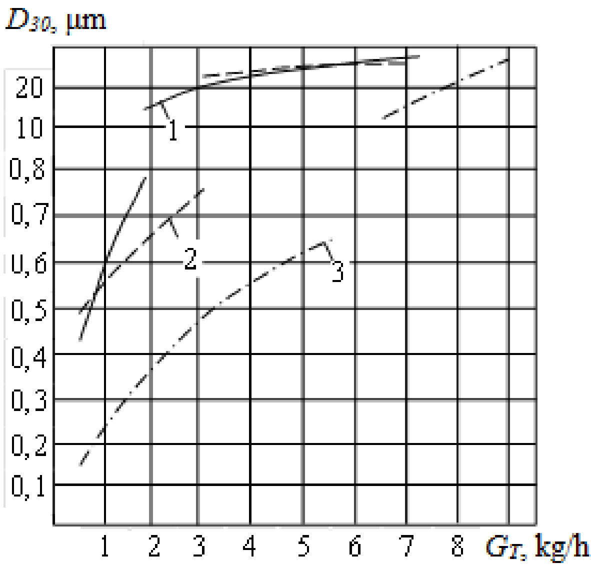

Fig. 3. Dependence of fuel atomization quality on engine operation modes and hourly fuel consumption:
1 – maximum torque; 2 is the maximum power; 3 – maximum rotation frequency

An increase in the pressure of exhaust gases at the nozzle inlet leads to a decrease in the concentration of oxygen in the total charge, which contradicts the idea of improving the ratio of fuel consumption and oxygen in the total volume of the charge.

Taking into account this fact, we will consider the influence of exhaust gas pressure on the quality of spraying, i.e., we will find the marginal minimum pressure necessary to obtain an aerosol state at a constant hourly consumption of fuel G_T = 2.0; 2.9; 6.5 kg/h.

Below are the research results for the maximum power mode Ne_{max} = 77.3 kW (Fig. 4).

As expected, with increasing pressure, the quality of spraying improves, and with increasing fuel consumption, it significantly deteriorates. Despite the fact that the aerosol state is achieved for all modes of fuel consumption at a pressure value of less than 0.1 MPa, it is necessary to limit the minimum pressure that satisfies aerosol formation. Namely, for D_{30} < 1 µm at consumption G_T = 2 kg/h – point A at P_1 = 0.015 MPa; for G_T = 2.9 kg/h – point B at P_1 = 0.02 MPa; for G_T = 6.5 kg/h – point C at P_1 = 0.055 MPa.

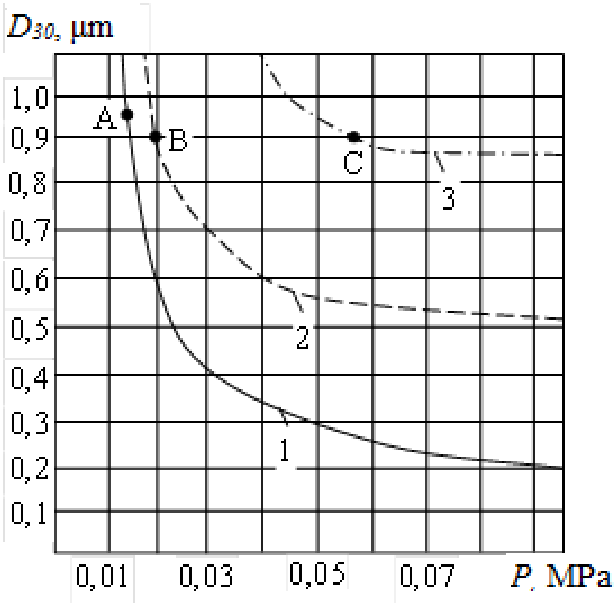

Fig. 4. Dependence of fuel atomization quality on gas pressure at the entrance to the tangential entrance and vortex sprayer tubes:
1 – fuel consumption *Gp* = 2 kg/h; 2 – fuel consumption *Gp* = 2.9 kg/h;
3 – fuel consumption *Gp* = 6.5 kg/h

These findings are of particular value when designing an evaporator-mixer for diesel engines with large hourly fuel consumption.

Conclusions and prospects for further research. The use of a Rank tube in the fuel supply system can contribute to an increase in engine efficiency for several reasons:

1. The Rank tube provides more effective preparation of fuel before it is fed to the engine cylinders. This involves vaporizing the fuel and mixing it with the exhaust gases, which helps to mix the fuel-air mixture better. When the fuel is evenly distributed in the air, more complete and uniform combustion occurs, which increases the efficiency of the engine.

2. The Rank tube allows more efficient use of fuel, preventing its leaks and losses in the form of unused fuel. This is especially important in combat operations or long maneuvers where fuel efficiency is critical.

3. The use of the Ranka tube also allows the exhaust gases to be recirculated back into the combustion system. This contributes to lowering the combustion temperature, reducing the formation of harmful substances and improving the combustion efficiency. Due to more efficient fuel com-

bustion, less harmful emissions such as nitrogen oxides (NO_x), hydrocarbons (HC) and carbon monoxide (CO) are produced. Reducing their formation helps reduce the harmful effects of motor vehicles on the environment.

4. Reducing emissions of harmful substances allows transport equipment to comply with environmental norms and standards established by governments and international organizations. Military vehicles, like civilian vehicles, are subject to strict requirements to reduce environmental impact, and the use of a Rank tube can help in this direction.

As a result of the use of the Rank tube and the effective preparation of fuel before combustion, the efficiency of the engine increases, which leads to more efficient use of fuel energy and an increase in the overall performance of vehicles. This is especially important for military vehicles, where the efficiency and reliability of engines are critical to a variety of tasks.

The given results give us grounds for conducting further theoretical and experimental studies for gas turbine installations. This is a separate direction of advanced researches.

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