Experimental studies of a wheeled tractor running on alternative fuel

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***Abstract**: The results of experimental studies of a wheeled tractor with a diesel engine converted into a spark-ignition gas engine are presented. The D-243 diesel engine was converted into a spark-ignition gas engine for operation on natural gas, and its bench tests were conducted, confirming its operational capability and demonstrating good performance indicators. It was found that the total toxicity, reduced to carbon oxide, of the gas engine is 1.9 times lower than that of the diesel engine. This is particularly important when using the vehicle for technological purposes, as it can operate indoors in this case. Using the same technology and components, the MTZ-80 tractor was also converted for operation on gas fuels. Road tests were conducted, and certain operating parameters were investigated: engine crankshaft rotation frequency, intake manifold pressure, throttle valve opening angle of the air-fuel mixer, and the rotation frequency of the vehicle's driving wheel, which can determine its speed. The obtained data were used to verify the adequacy of the mathematical model of the tractor's movement during the driving cycle.*
***Keywords:** WHEELED TRACTOR, GAS ENGINE, SPARK IGNITION, NATURAL GAS*

Problem statement

It is known that the cost of production in the agricultural sector significantly depends on the expenses for motor fuel for agricultural machinery. Diesel engines are commonly used in such machinery. However, the cost of diesel fuel is constantly increasing due to the rise in oil prices on the world market as reserves diminish. Therefore, the proposal is to transition the mobile equipment of agricultural enterprises to motor fuel with good performance and significantly cheaper than diesel fuel. Natural gas serves as such fuel. There is known experience in using gas fuel in agricultural machinery by converting diesel engines into gas-diesel engines. However, gas-diesel engines, which operate on a mixture of gas and diesel fuel, have not gained popularity as power units in vehicles used in agriculture.

Analysis of recent research and publications

Among the currently available alternative fuels, natural gas is considered one of the best substitutes for petroleum fuels because, on the one hand, it is compatible with conventional spark ignition engines or compression ignition engines, and on the other hand, it is more environmentally friendly due to lower emissions of harmful substances with exhaust gases. There are many scientific works that recognize natural gas as an environmentally friendly fuel [1-4].

As previous scientific research has shown, one of the effective ways to improve the environmental performance of diesel vehicles is to convert them to operate on natural gas, including the ability to work on biomethane, which is a product of agricultural production [5-7].

At the Lutsk National Technical University, a technology for converting automotive diesel engines into spark-ignition gas engines has been developed [8, 9]. In its development, the experience of both foreign and domestic scientific schools was taken into account. The technology allows achieving the desired engine performance with moderate conversion costs.

Purpose of the article

This publication aims to highlight the methodology and results of road tests of a wheeled tractor with a gas engine operating on natural gas.

Materials and research results

According to the developed technology in the laboratory of automobile engines at Lutsk National Technical University, the D-243 diesel engine was converted into a gas engine (fig. 1).

***Fig. 1.** Converted D-243 diesel engine into a gas engine on the test stand*

In the converted engine, spark ignition plugs are installed instead of injectors, a high-pressure fuel pump drive interrupter-distributor is installed, and contactless electronic ignition with a Hall sensor is installed in the interrupter-distributor. A custom-designed gas mixer SG-250 is installed on the intake manifold, as well as high and low-pressure gas reducers and other gas equipment. The compression ratio of the gas engine has been reduced from 16 to 12 units.

Experimental testing of the converted gas engine included engine tests on the electric brake stand KI-4893 GOSNITI. Gas analysis was performed using gas analysis equipment: carbon monoxide – 121FA01, hydrocarbons – 123FA01, nitrogen oxides – 344HL011. At the beginning of the tests, the optimal ignition advance angle was determined and set. A series of load characteristics were determined with measurements of the toxicity of exhaust gases and idle characteristics. To determine the optimal adjustment fields of the gas engine, its adjustment characteristics were recorded in terms of mixture composition and ignition advance angle using a computer with simultaneous recording of indicator diagrams by a specially developed complex of instruments based on a piezoelectric sensor installed in the combustion chamber.

The gas engine develops power approximately equal to that of the D-243 diesel. The specific effective fuel consumption is 15…20% higher than that of diesel, as the gas engine operates on richer mixtures. The level of emissions of regulated harmful substances in the gas engine is lower, and there is no soot in the exhaust gases. The total toxicity of the gas engine, reduced to carbon monoxide, is 1.9 times lower than that of diesel (fig. 2). The noise level during the operation of the gas engine is significantly lower than that of diesel.

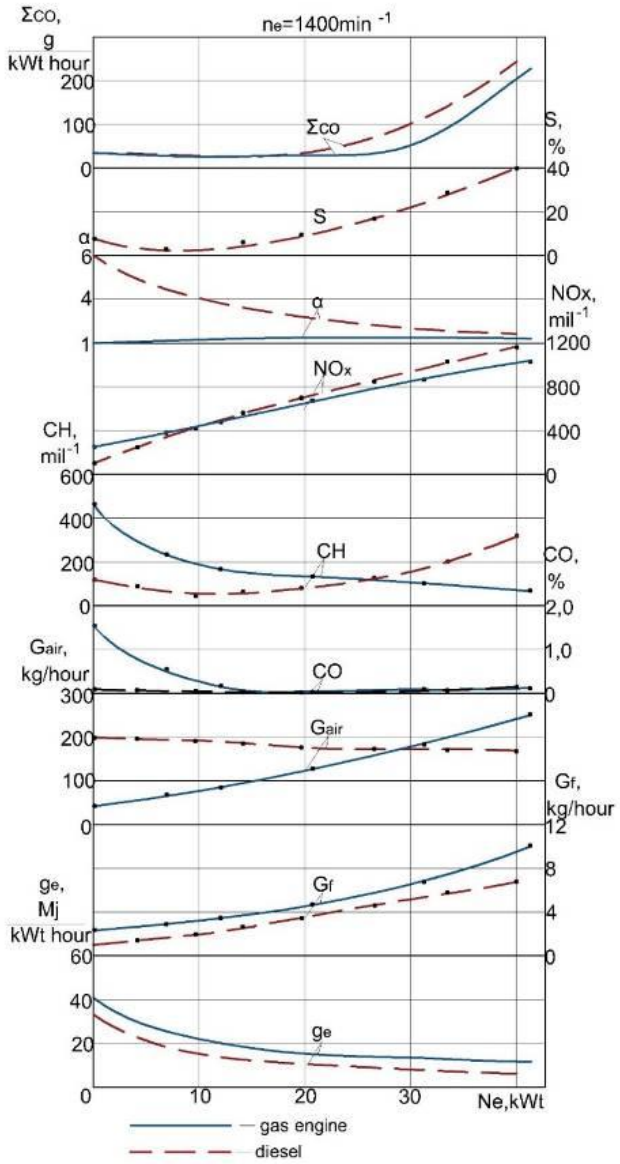


Fig. 2. *Load characteristic of gas engine*

The diesel tractor was converted into a gas engine by installing an ignition system and all elements of the fuel supply system used in the bench tests of the diesel-to-gas converted engine (fig. 3). The tractor was tested while performing transport work on both asphalt-concrete and dirt roads, with a portion of the route passing through rough terrain. The maneuverability of the tractor did not deteriorate. According to expert assessment, the power of the gas engine is no less than that of the diesel. During transportation, a normal temperature regime of the engine was ensured by the standard cooling system.

A mathematical model was used to calculate the operational indicators of the wheeled tractor with a gas engine during its movement along the driving cycle. To verify its adequacy, a special software-hardware complex was created, which allows measuring and recording the parameters of the test sample in real-time mode during movement at variable modes.

After selecting the parameters under study, corresponding sensors were chosen and installed (the installation of two of them is shown in fig. 4) to sense the values of these parameters. Serial automotive sensors were used as sensors for crankshaft rotation frequency, intake manifold pressure, and throttle position angle. A device based on a Hall sensor was fabricated to determine the wheel rotation frequency of the tractor. An analog-to-digital converter (ADC) board E14-140 from L-Card was selected to poll these sensors and transmit the obtained data to a personal computer (PC). A laptop was used as the PC.

Fig. 3. *Wheel tractor MTZ-80 with a diesel-to-gas converted engine*

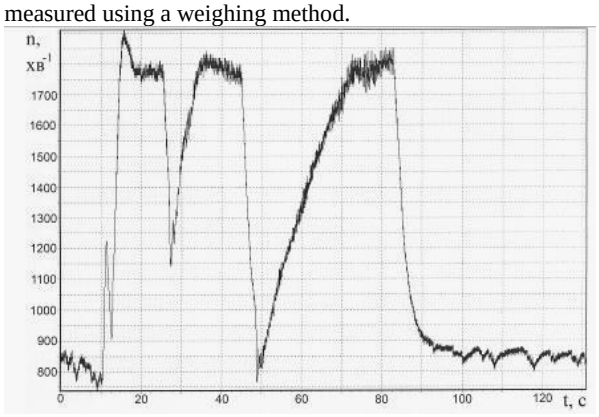
After creating the hardware part, the software component of the complex was developed for the final processing of recorded signals on a PC. The LGraph 2 program was chosen, which handles the ADC connection with the PC, allows real-time monitoring of the values of the parameters under study and their changes, and also records sensor signals with subsequent storage of these records on the hard disk. In addition to this program, a proprietary software product was developed to perform the final specific processing of the obtained data.

a

b

Fig. 4. *Installation of the throttle position sensor (a) and the wheel speed sensor (b) on the tractor.*

The developed Calc&Graph program allows loading and processing files of any size (limitations are imposed only by the hardware capabilities of the specific PC), plotting graphs of loaded signals and processed data, and saving the results of its work in a text file for further investigation and processing. While the tractor was in motion along the driving cycle with gearshifts from the 6th to the 8th and 9th, the values of four parameters (fig. 5) were continuously recorded on the laptop, and fuel consumption was measured using a weighing method.



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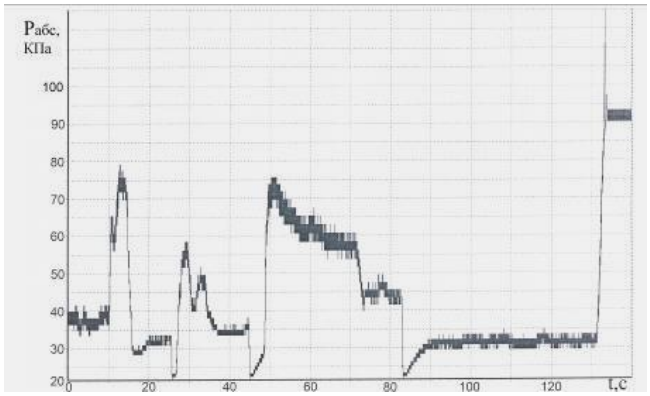

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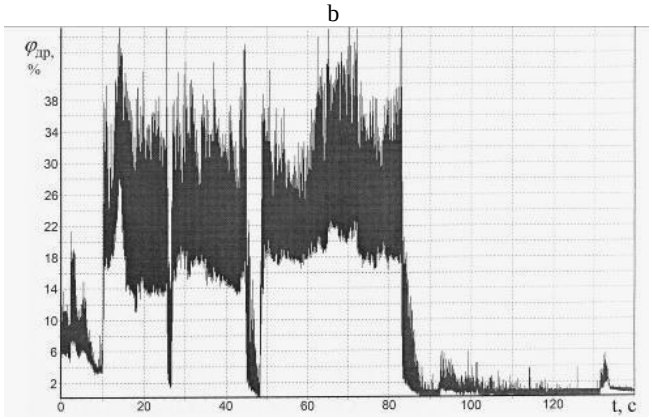

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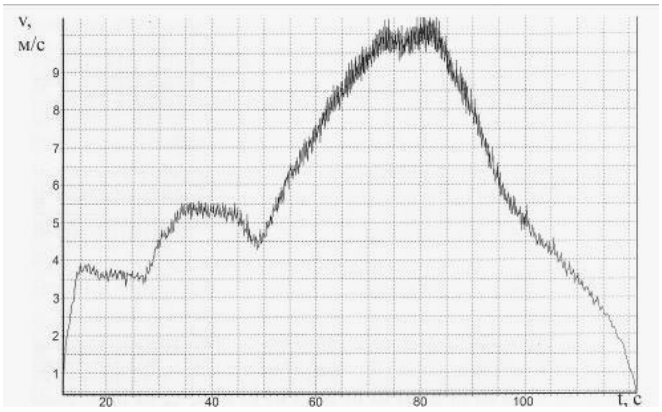

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Fig. 5. *Diagrams of the change in parameters of the MTZ-80 wheeled tractor with a gas engine during movement along the driving cycle: a) crankshaft rotation frequency; b) absolute pressure in the intake manifold; c) throttle opening angle; d) tractor speed.*

The obtained data were used to verify the adequacy of the mathematical model of the wheeled tractor's movement with the driving cycle.

The diesel conversion was carried out by installing inexpensive off-the-shelf equipment. The chosen approach allowed minimizing the costs of creating the experimental sample, reducing the number of parts and assemblies that need to be modified or manufactured. Since the conversion was done without altering the engine's design, there was no need to obtain permission from the engine manufacturer for such conversion. Such conversions can be carried out in small workshops. Converting diesel engines into gas ones is particularly justified in cases where repairs to their cylinder-piston group or fuel system are necessary. In this case, the costs of diesel conversion are partially offset by the means that would still be required for repairs.

Conclusions

Converting even a portion of agricultural machinery to gas power will yield significant economic benefits on a national scale. Additionally, there is an environmental benefit from reducing pollution of the environment by harmful emissions from engines. The total toxicity of the exhaust gases from the gas engine is 1.9 times lower compared to diesel. Therefore, such a tractor can be successfully used as a technological transport for servicing enclosed spaces with limited air exchange (greenhouses, farms).

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