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Method of Cleaning the Piston-Cylinder Engine Part of the Internal Combustion Engines of Agricultural Equipment

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Abstract:
The article describes a method and device for non-elective cleaning of carbon deposits of parts of the cylinder-piston group of internal combustion engines of agricultural machinery, which is installed directly on the vehicle. The developed method consists in the fact that there is a restoration of the main characteristics of the engine by cleaning the parts of the cylinder-piston group and the timing mechanisms, by supplying a mixture of fuel and water of high dispersion, in which the droplet sizes are 3...5 microns. In the combustion chamber, water droplets at high temperature boil and randomly moving, hit the carbon, gradually destroy it. The size of the chipped particles of soot are so small that they are easily removed from the combustion chamber through the exhaust without affecting engine parts. The developed samples of devices are mounted in any free place of the engine compartment of automotive equipment and are connected with each other by flexible rubber fuel lines. Standard tanks can be used as water tanks. The use of the developed devices for non-disassembly cleaning of parts of the cylinder-piston group of the engine from carbon deposits during the operation of the automotive equipment will increase the life of the engine and fuel equipment by reducing the formation of solid particles (carbon) and lacquer films on the parts in the combustion chamber and the high-pressure fuel pump.

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I. INTRODUCTION

Tilling is one of the main processes that take place on the soil to break the surface layer and create suitable conditions that allow water and air to penetrate (14). Diesel engines are one of the primary sources of energy for mobile vehicles and can also be used as stationary or mobile power sources (1).

The continuous growth of the energy capacity of agriculture is based on the introduction of new high-performance and reliable equipment. One of the main tasks of tractor and agricultural engineering enterprises in the coming years is to significantly increase the unit power of engines of energy-saturated agricultural machines.the tillage is the largest consumable energy of the tractor (2),

A promising direction in improving the operational characteristics of automotive engines is the use of emulsion fuels with different levels of water concentration, as well as various methods of direct injection of water into internal combustion engines (16). The use of aqueous emulsions in internal combustion engines can reduce detonation, improve fuel combustion characteristics, increase fuel economy, and reduce emissions of pollutants (10,12,7,3,11).

Other modern trends in the design of internal combustion engines (ICE) of agricultural machinery are determined by the desire for forcing by increasing the average effective pressure. As a result of forcing tractor engines, there is a significant increase in temperature and load conditions of their parts. High-temperature engine operation is most dangerous from the point of view of deposits and varnishes on the details of the cylinder-piston group (CPG) and coking of the piston rings.

Currently, due to the acceleration of internal combustion engines and the implementation of multi-fuel, researchers are actively engaged in the problem of carbon deposits, which has become a serious obstacle to the further development of engines of agricultural machines (5).

It should also be noted that at the moment, an urgent issue for agricultural machinery (ST) is the extension of the internal combustion engine's life to overhaul, because due to the low quality of spare parts and motor fuel, this figure is sharply reduced today. An analysis of the processes occurring in the ICE cylinders shows that heavy hydrocarbon fractions in hydrocarbon fuel do not completely burn out during the combustion cycle, as a result of which carbon deposits (piston bottom, seats and valve plates) form in the form of tar deposits, which eventually grow in the form of a solid layer (13).

Therefore, the main cause of increased wear of ICE parts is carbon deposits formed on parts of the cylinder-piston group due to incomplete combustion of the combustible mixture. The formation of carbon deposits is also promoted by the low quality of motor fuels containing a large number of carbon-forming additives. Deposition of soot on the ICE parts leads to a deterioration in their heat transfer, which leads to an increase in their size and, as a consequence, increased wear and a reduced service life.

As can be seen from Figure 1, which shows the appearance of the piston, which has a lot of solid deposits in the form of soot on the piston head 1, between the first 2 and second 4 compression rings, as well as on the oil scraper ring 5, which negatively affects the operation of the internal combustion engine. When the piston moves, these deposits will scratch the mirror surface of the ICE cylinder.

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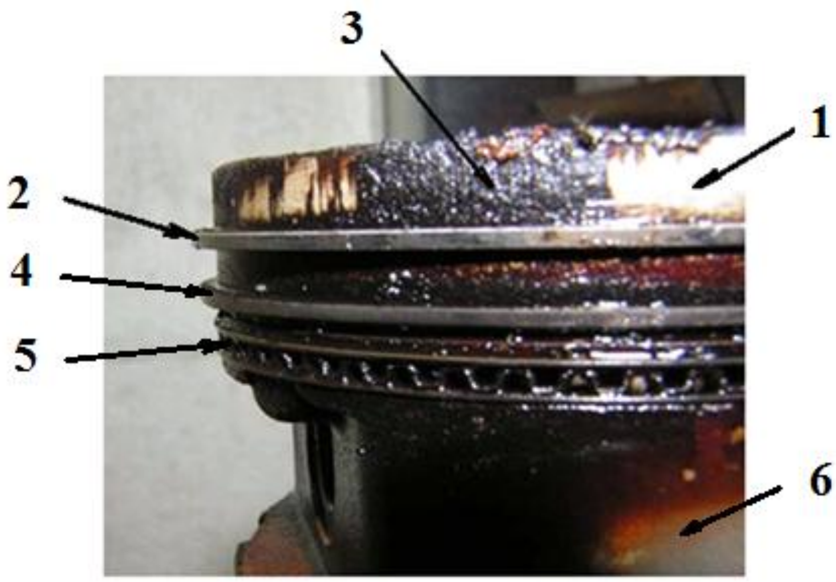

1 - piston head; 2 - the first compression ring; 3 - carbon deposits; 4 - the second compression ring; 5 - oil scraper ring; 6 - piston skirt

Fig. 1. Appearance of a carbon-coated piston

Due to the low quality of motor fuel, especially diesel fuel, the heavy hydrocarbon fractions contained in it due to low volatility are poorly burned in the combustion chamber of the engine. Therefore, on the parts of the cylinder-piston group and the gas distribution mechanism, tarry varnish-coke deposits form in the form of hard soot over time (see Figure 1). Sludge contains a whole complex of substances with varying degrees of oxidation and carbonization. Over time, these substances accumulate in the form of soot on the bottom, head and skirt of the piston, in the grooves of the piston rings, on the valves and the inner walls of the combustion chamber. All this leads to the fact that there is a decrease in heat transfer from parts to the cooling circuit, that is, they overheat and expand further. Then the piston rings lie, which leads to a decrease in compression in the ICE cylinders and an increase in oil consumption, due to the oil scraper passing the oil into the combustion chamber, where it is burned, forming an additional deposit on the parts. Ultimately, all this leads to a decrease in the efficiency of the internal combustion engine, an increase in fuel and oil consumption by it, glow ignition from incandescent particles of carbon appears and engine power is sharply reduced.

Therefore, resinous-varnish-coke deposits (in the form of hard soot on the details of ICE) not only worsen the performance of the ICE , but also cause its premature wear and also reduce its life before overhaul. In this regard, during seasonal technical maintenance (STO) of automotive vehicles, it is necessary to carry out work related to the removal of soot from the walls of parts of the cylinder-piston group and the gas distribution mechanism. These operations require complete disassembly of the engine, therefore they are not performed during service stations, but are performed only during major or current repairs. Performing the cleaning of parts from carbon deposits during service stations, when its layer is not yet large, will significantly increase the volume of the combustion chamber, provide better sliding of the piston rings along the cylinder mirror, increase compression in ICE cylinders and restore its operating parameters to the required ones.

It should be noted that the formation of 1 mm carbon deposits on the piston bottom increases its heating by 30 ... 40 ° C. And during the operation of automotive vehicles on average over 100 ... 150

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thousand km of run on the piston, about 3 mm of hard soot is formed. As a result, the equipment crashes faster (for a long period) and requires expensive repairs. Work carried out during service stations and maintenance of automotive equipment does not include the removal of soot from the surface of engine parts. Therefore, the soot layer only increases over time and the engine resource decreases sharply, as a result of which expensive repairs are required.

The developed in-place methods for cleaning ICE parts from soot involve filling the cleaning agent into the fuel tank. In this case, the minimum amount of added agent depends on the thickness of the deposit, which is judged by the diagnostic examination of the internal combustion engine using a video endoscope. Such cleaning compounds are commercially available under various brands, but their cost is very high, and as shown by the tests in the magazine “Driving”, their effectiveness is very low. The composition of these cleaning agents mainly includes highly active substances that can adversely affect the details of ICE. Therefore, their use can lead to irreversible consequences for ICE parts and, ultimately, to expensive repairs.

The main disadvantage of these cleaning agents is that they do not allow for complete cleaning of ICE parts, in particular, cleaning the piston ring and grooves for them, since fuel is not accessible to this area. These agents also do not have the ability to remove old deposits accumulated in the grooves under the piston rings, since these deposits are acidic in nature. Therefore, commercially available cleaning compositions do not provide complete removal of soot and, accordingly, restoration of compression in the ICE cylinders.

In order to extend the ICE resource by cleaning the parts of the cylinder-piston group from soot, without using disassembly of the engine, a cleaning method is proposed by working on a water-fuel emulsion (VTE). This emulsion can be prepared on a special installation and fed into a standard ICE power supply system, both stationary and directly on automotive vehicles without putting it out of operation.

The method of in-place cleaning of parts of the cylinder-piston ICE group from soot consists in the restoration of engine performance by cleaning the parts of the cylinder-piston group and engine gas distribution mechanisms by supplying a mixture of fuel and water of high dispersion, in which the droplet size is about 3 ... 5 microns. In a combustion chamber, water droplets boil at high temperature and randomly move, hit a carbon deposit, and gradually destroy it. At the same time, the sizes of the split particles of the soot are so small that they are easily removed from the combustion chamber through the exhaust system without consequences for ICE components.

Water-fuel mixtures consist of two insoluble liquids, of the dispersed phase - water, which in the form of small drops is distributed in a dispersion medium, that is, in fuel. Thus, the formation of such emulsions during mechanical dispersion is explained as follows. Under the influence of external force, the droplets of the dispersible phase are stretched and take a shape close to cylindrical. When the length of such a cylinder becomes equal to the circumference of its section, then it splits into many droplets. This process occurs repeatedly: large drops are again stretched into threads to a certain length and break up into smaller ones. At the same time, the smaller the droplet size, the more stretching and disintegration it is. The stability of the emulsion is determined by its dispersion, a slow process - coagulation. The main factors on which the quality of the emulsion depends: particle size; component content; viscosity. The analysis showed that for use in ICE it is necessary to use the “reverse” VTE. The advantage of “reverse” VTE is that the drops of the aqueous phase in the fuel medium cannot significantly affect the corrosion process of parts of the cylinder-piston group and the exhaust system
ICE (15).

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At low concentrations of the aqueous phase in the fuel (up to 20%), its effect on the main indicators of the physicochemical composition of hydrocarbon fuel is insignificant. In this case, the cetin numbers of diesel fuels are reduced due to a decrease in the temperature of the spray jet of diesel fuel caused by evaporation of water.

Water in the combustion chamber at a temperature (T ≥ 100 ° C) turns into steam, which, moving randomly, contributes to a uniform distribution of the combustible mixture throughout the volume of the chamber. Drops of vehicles with a smaller size (less than 50 microns) than drops of ordinary fuel in the combustion chamber of an internal combustion engine are more evenly distributed. Therefore, the average distance between the surfaces of the droplets decreases, that is, they become closer to each other and at such small distances, that is, less than the width of the zone of the laminar flame front, such droplets merge and, when they burn, form a common powerful flame front. Under such conditions of VTE combustion, the conditions of heat transfer and, accordingly, diffusion increase significantly.

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A drop of a water-fuel emulsion consisting of water inside having a gas bubble and outside coated with heavy fractions of hydrocarbon fuel in the combustion chamber is heated due to high temperature (up to 600 ° C). In this case, the inner part of the water drop turns into superheated steam, and the VTE drop shell, consisting of heavy fractions of hydrocarbon fuel, continues to remain in the liquid state since their boiling point is higher than 200 ° C. Therefore, at a temperature above 100 ° C, a drop of the aqueous phase rapidly boils in the combustion chamber, its transition to a gaseous state, while the vapor strikes the soot surface at high speed, gradually softening and destroying it. This feature of burning VTE contributes to the destruction of soot due to microexplosions. The resulting "microexplosion" of a water drop (see Figure 2) crushes the outer shell of VTE particles consisting of heavy fractions of liquid hydrocarbon fuel that adversely affect the combustion process. Then, due to the random motion of the vapor droplets, secondary atomization and crushing of the liquid hydrocarbon fuel fractions occurs, which improves the process of mixing fuel and air and increases the completeness of combustion of the fuel mixture in the engine cylinders.

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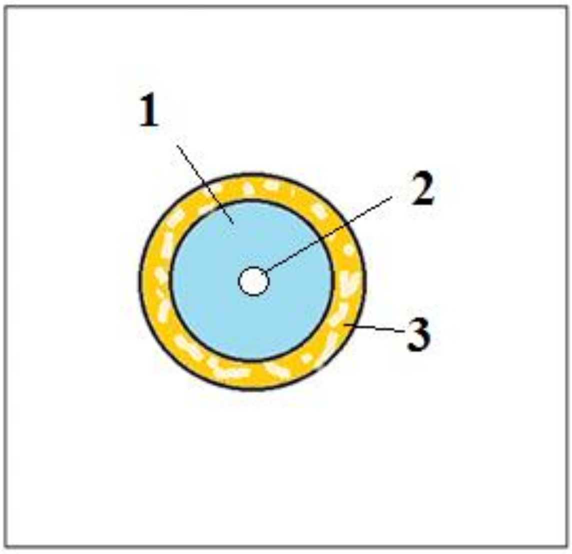

1 - water; 2 - a gas bubble; 3 - heavy fractions of hydrocarbon fuel
Fig. 2. Appearance of a VTE drop

Chipped particles of soot are removed from the engine cylinder through the exhaust system. Also, during the operation of ICE at VTE, the content of harmful substances contained in the exhaust gases is reduced. The operating time of ICE at VTE depends on the thickness of the deposit on engine parts, the greater the thickness of the deposit (which depends on the mileage of the car), the greater should be the water content in VTE and longer its duration on it.

Studies have shown that water is a very cheap component for VTE, allowing to reduce not only the cyclic pressure indicators in the cylinder, but also significantly reduce the temperature in the combustion chamber. In this regard, the following chemical reactions occur in the engine cylinders:

$$m\,H_2O + C_mH_n + Q = \left(\frac{2m+n}{2}\right) H_2 + mCO. \qquad (1)$$

The chemical activity of the aqueous phase is also manifested, which is expressed by the following chemical reactions.

The first case in which the coefficient of excess air α> 1:

$$C + 2H_2O = CO_2 + 2H_2, \qquad (2)$$

The second case, in which the coefficient of excess air α <1:

$$C + H_2O = CO + H_2. \qquad (3)$$

It should be noted here that the heat expended during combustion on the heating process of VTE droplets and directly water is compensated by the combustion energy of the resulting H2 as additional fuel for ICE. Therefore, when adding up to 20% of water, there is no decrease in the power of the internal combustion engine.

It should be noted that during the combustion of 1 kg of liquid hydrocarbon fuel, about 1.17 kg of water vapor is formed, which are discharged through the exhaust system.Carbon monoxide pollution is a global concern (4).Also, per kilogram of fuel, about 0.4 kg of water vapor (at an air humidity of up to 96%) enters the engine cylinders together with atmospheric air, where the size of water droplets can be about 20 microns. Under normal operating conditions of vehicles with an air humidity of about 60%, about 0.2 kg of water vapor enters the ICE cylinders.

Thus, the addition of up to 0.20 kg of the aqueous phase does not significantly affect the operation of the internal combustion engine and the course of chemical reactions occurring in the

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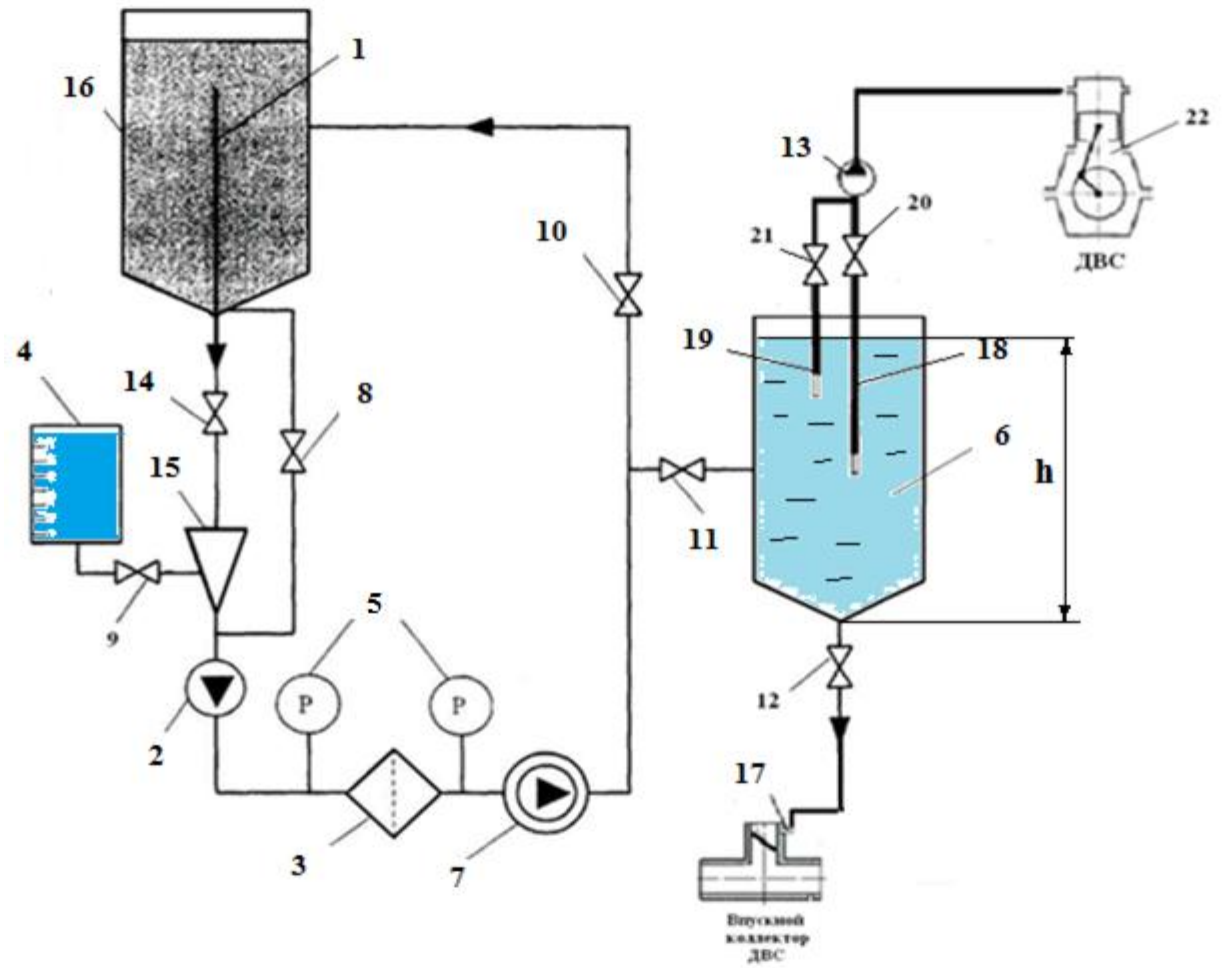
engine cylinders. Therefore, all of the above can serve as evidence that the addition of water to the combustion chamber of an internal combustion engine in the form of VTE does not significantly affect the operation of the engine and the processes associated with corrosion of parts of the cylinder-piston group, the gas distribution mechanism and the elements of the exhaust system of the internal combustion engine (8).

Based on all of the above, a method for preparing VTE with the further supply of such fuel to the ICE power supply system was developed. The developed method is implemented using devices, the layout of which is shown in Figure 3.



1 - intake pipe; 2 - pump; 3 - filter; 4 - water tank; 5 - instrumentation; 6 - settling tank for VTE; 7 - rotary pulsation apparatus, 8, 9, 10, 11, 12, 14, 20, 21 - valves;13 - regular fuel pump; 15 - mixer; 16 - tank with fuel;17 - jet; 18, 19 - intake pipes; 22 - engine power system

Fig. 3 .Layout of devices for cleaning ICE parts from soot

Into the tank 16 with motor fuel is vertically mounted intake pipe 1 with radial holes around the entire circumference. In the tank-sump 6 at different heights installed intake pipes 18, 19 at different heights. Further, these intake pipes are connected to a standard fuel pump 13 of the internal combustion engine power supply system 22, thus, VTE is taken from different levels, which is regulated by valves 20, 21.

In the settling tank 6, VTE is also stratified into three fractions and the excess water is discharged from the lower part of the tank through the valve 12 and the nozzle 17 into the intake manifold of the internal combustion engine.

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The developed scheme works as follows.

The motor fuel used for the internal combustion engine is poured into the tank 16, then through the perforated pipe 1 with the valve 14 open, it enters the input of the mixer 15. In the mixer, the fuel mixes with the water supplied to the mixer from the tank 4 through valve 9. The specified amount of water is set the design of the pre-mixer, and can also be controlled by valve 9. The pumping and circulation around the VTE are carried out by pump 2, which passes the entire volume of the mixture through filter 3 and feeds it to the input of the rotary pulsation apparatus 7, which is prepared by finely VTE. Then it through the valve 10 returns to the tank 16 for reprocessing(8).

After the entire amount of water is consumed from the water tank 4, the valve 9 closes and the mixture circulates in a circle until the entire VTE volume is driven several times through the rotary pulsation apparatus. After that, the valves 8 and 10 are closed, at the same time open the valve 11 and with the help of the pump 2 pumps the entire VTE into the tank-settler 6.

In the sump tank, the prepared fine VTE is divided into the following fractions:

- refined motor fuel with improved Physico-chemical properties;
- reverse VTE with sizes of water droplets of about 5 microns,
- excess aqueous phase with heavy fractions of hydrocarbon fuel (formed at the bottom of the tank).

After the separation of the VTE, it is then taken by a regular fuel pump 13 from the settling tank 6 into the ICE power supply system 22. Through the upper intake pipe 19, the cleaned engine fuel is sampled from the level (0.85h) in the engine start and warm-up mode. Through the intake pipe 18 from the level (0.5h), the VTE is sampled with water droplet sizes of about 5 microns in the mode of average and maximum ICE loads. And the mixture of the excess aqueous phase with heavy fractions of hydrocarbon fuel, which is formed at the bottom of the tank 6, is discharged through the open valve 12 into the intake manifold of the engine 22.

The proposed method is universal and suitable for both gasoline and diesel ICEs and can be implemented directly on the vehicle without a significant change in the design of the standard power supply system and its engine power characteristics (9, 6).

It is also proposed that VTE with the addition of an aqueous phase be prepared without the use of an expensive emulsifying system directly on the vehicle itself, to immediately use it up without allowing it to exfoliate. In this case, the developed samples of devices are mounted in any free space in the engine compartment of the vehicle and are connected by flexible rubber fuel lines. Standard water tanks can be used as water tanks.

Consequently, the use of developed devices for field-free cleaning of the engine piston group cylinder parts in the field during the operation of automotive tractor equipment will increase the engine and fuel equipment resource by reducing the formation of solid particles (carbon deposits) and varnish films on the parts in the combustion chamber and high-pressure fuel pump. This becomes relevant due to the high cost of engine parts for automotive vehicles and especially high-pressure fuel pumps.

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