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DEVELOPMENT OF A METHOD AND TOOLS FOR STUDYING THE EFFICIENCY OF THE ENGINE PRE-START HEATER

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ABSTRACT

This article describes the need to engine pre-start heaters at low temperatures. The classification and description of the designs of existing devices for preheating engines are given. The methodology and description of the stand for testing electric engine pre-start heaters are presented. An example of calculating the economic efficiency of two models of electric engine pre-start heaters is given.

Keywords: vehicle, internal combustion engine, motor oil, engine pre-start heater, viscosity, friction, starting properties, wear, operation.

INTRODUCTION

At low ambient temperatures, the efficiency of vehicle operation is significantly reduced for a number of reasons. Fuel costs are significantly increased, which are associated with an increase in the time of starting and warming up the engine. There is a high probability of failure of diesel engines due to the formation of ice or air locks in the fuel system. The reliability of some hydraulic braking systems is reduced due to the possibility of freezing of brake fluids. The most unfavorable reason for the decrease in the efficiency of equipment operation at low temperatures is expressed in the change in the properties of the lubricants used, leading to an increase in the wear of parts. Increased wear reduces the reliability of components and assemblies, and ultimately leads to an increase in vehicle repair costs.

The most expensive units in terms of cost and maintenance in vehicles include an internal combustion engine and a gearbox. Increased load with high viscosity of lubricants are the reasons why the main components, parts made of metal, rubber and plastic wear out and lose their properties. Figure-1 shows the failures of engines and gearboxes throughout the year [1].

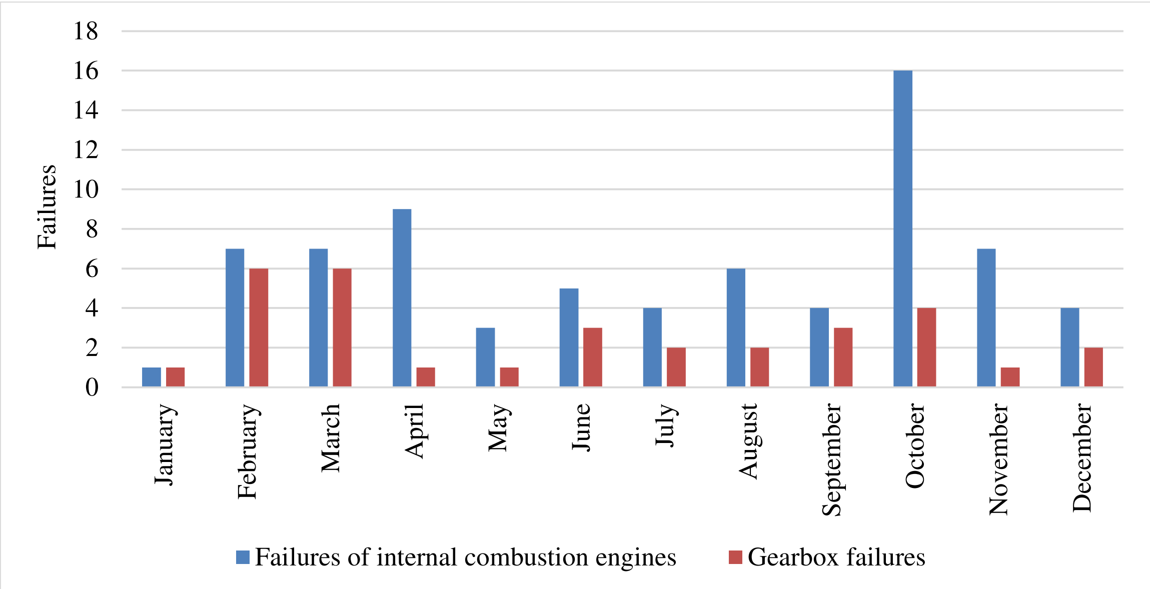

Figure-1. Failures of engines and gearboxes.

Figure-1 shows that engine failure occurs more often than gearbox failures. As noted in a number of studies at low ambient temperature, there is a change in the most important operational properties of motor oils: viscous, anti-wear, antioxidant, dispersing, corrosive. An increase in the viscosity of the motor oil leads to increased engine wear. The viscosity properties of the oil in the engine directly depend on its ability to provide liquid, hydrodynamic friction in the bearings, and therefore their normal operation. The viscosity of the motor oil affects the wear of the crankshaft necks and bearing liners. In the first three seconds of engine operation, when the rubbing parts of the engine are just starting to move relative to each other, there is a high probability of the formation of

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scoring and turning of the engine crankshaft liners. Figure-2 shows a graph of the dependence of the coefficient of friction on the temperature of the motor oil in the engine.

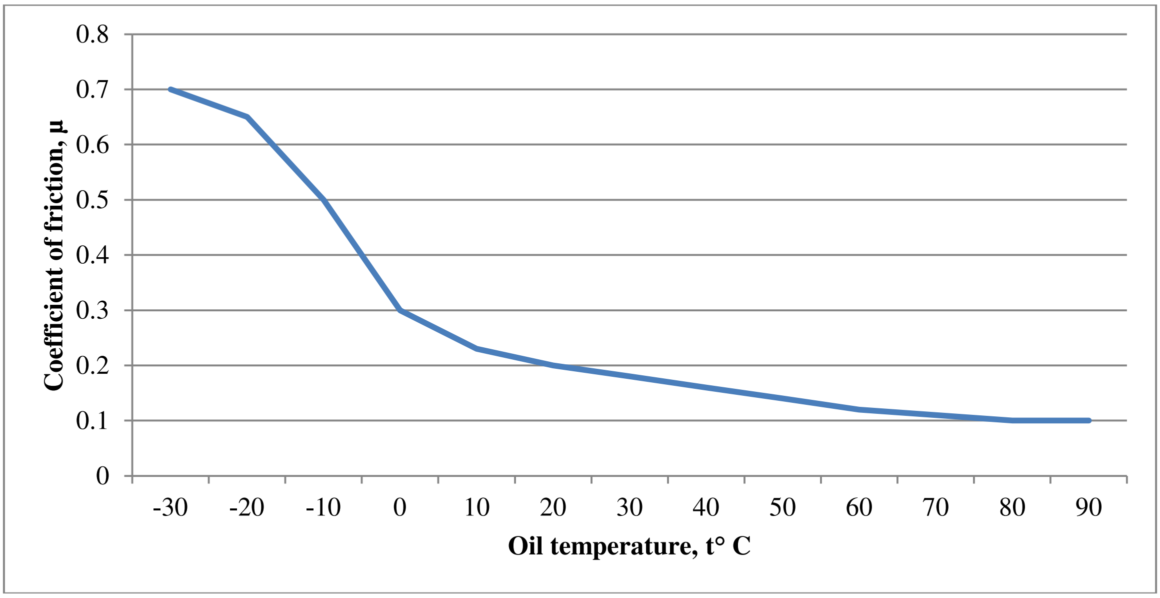

Figure-2. The dependence of the coefficient of friction on the temperature of the motor oil in the engine.

As can be seen from the graph in Figure-2, heating of the motor oil is necessary to reduce the coefficient of friction, and therefore the wear of engine parts.

MATERIALS AND METHODS

A large number of works performed in various industries where vehicles are operated are devoted to the development of effective means of pre-start preparation and facilitating the start of engines at low temperatures. So, according to the results of many studies and widespread opinion, the wear of engine parts in starting modes is 50...75% of the total wear during the period of operation before repair[2].

The issue of reducing start-up wear is inextricably linked with the choice of a method and means to facilitate the start of engines in winter. Due to the lack of clear criteria and reasonable recommendations, quite often subjectively proposed, and often used a variety of design means of preheating using various coolant and energy (hot air, gas-air mixture, steam, hot water, electricity, etc.). At the same time, the main attention is paid to the cost of the start-up itself and the energy consumption for pre-start preparation of the engine is not taken as a criterion. However, due to the need to save fuel and energy resources, the recommended means of thermal preparation of engines before start-up should be evaluated primarily by their thermal efficiency and economy.

The classification of existing devices that facilitate starting the engine at low temperatures is shown in Figure-3.

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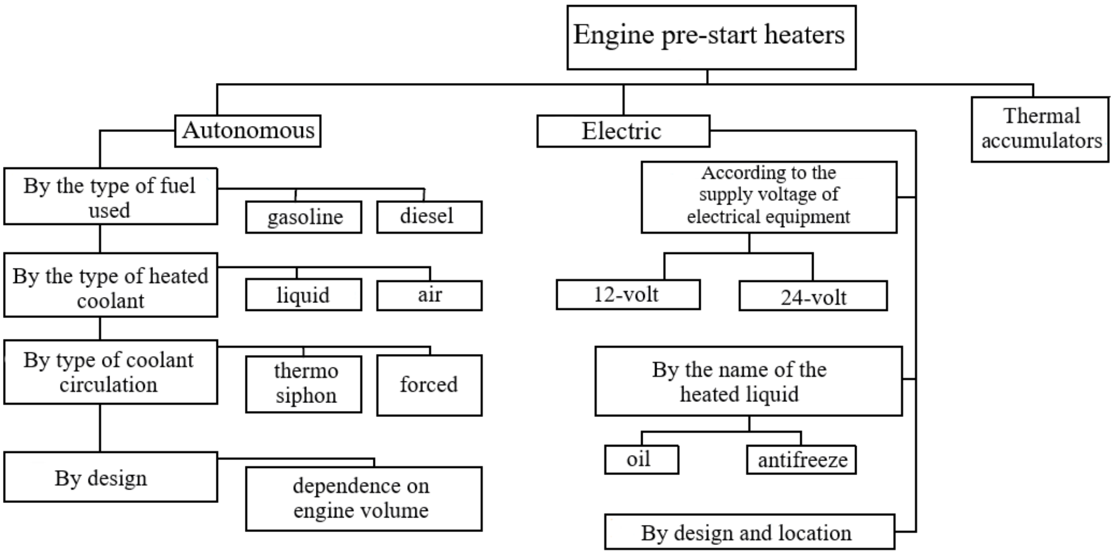

Figure-3. Classification of engine pre-start heaters.

The design of autonomous enginepre-start heaters is the most functional, since it does not depend on connection to external energy sources, but their cost is higher than electric ones. To install autonomous heaters, it is necessary to have technical skills and sufficient experience, besides, the independent installation of such high-tech devices can lead to the loss of the warranty on the vehicle.

The principle of operation of the thermal accumulator is as follows. When the vehicle is moving, hot antifreeze is periodically pumped into the heat accumulator by a special pump of the cooling system. After the engine stops, there is a hot antifreeze in the heat accumulator, which cools down over time. However, even after a day, the temperature of the antifreeze remains sufficient so that its heat can warm up the engine. Before starting a cold engine, the heat accumulator is discharged, in which the antifreeze stored in it is pumped into the engine by an electric pump. As a result, the engine warms up. But such a system is ineffective when the vehicle is parked for a long time[3].

The simplest technically and most cost–effective way to preheat a diesel or gasoline engine before starting in winter is to install an electric heater. The pre-start electric heater, made in the form of a plug for draining motor oil from the engine pan, is a heating element of small size and power. The choice of the product depends on the specific engine model. Figure-4 shows one of the variants of a pre-start electric heater in the form of a plug.

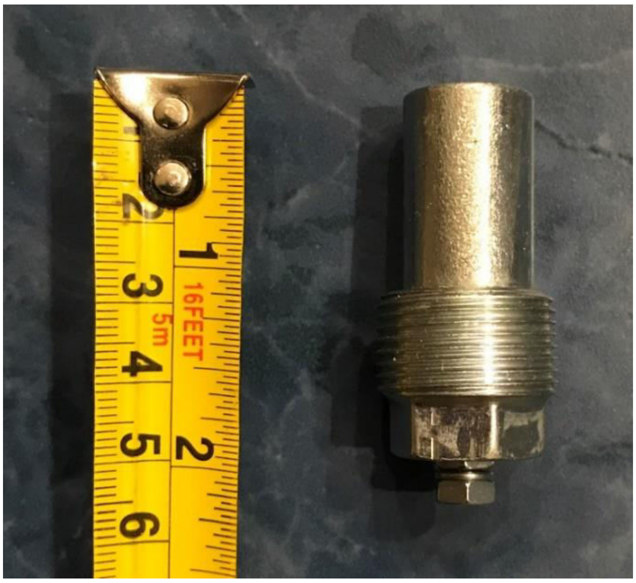

Figure-4. Engine pre-start heaters in the form of a plug.

The positive properties of the engine pre-start heaters in the form of a plug are simplicity of design, reliability, the possibility of installation without additional equipment, low cost of the product, fire safety. The operating voltage of this heater is 12 V, so the device can be connected to the vehicle battery. The disadvantages of the engine heater in the form of a plug include a small temperature range during heating, which is limited by the battery capacity, as well as a small area of the heated surface.

To facilitate the start of the internal combustion engine at low temperatures, it is possible to use electric heaters in the form of a plate. The electric heating plate [4], shown in Figure-5, is mounted on two studs in the sump of the engine crankcase.

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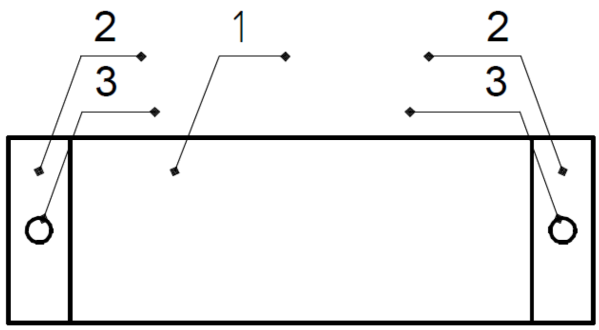

Figure-5. Engine pre-start heaters in the form of a plate: 1 - heat-generating surface; 2 - current leads; 3 - mounting holes.

During operation, the temperature of the heat-generating surfaces reaches plus 80° C, while additional control devices are not required, since a thermal equilibrium is established between the arrival and loss of the released heat into the environment. With an operating voltage of 12 V, the power of the device is 170-200 watts. Depending on the size of the sump pan of the engine, the overall dimensions of the electric heating plate can be 130 × 50 mm or 200 × 50 mm.

Due to the low cost and relatively simple installation, electric heaters are the most common and widely popular.

RESULTS AND DISCUSSIONS

The existing regulatory documents [5, 6] mainly define the requirements for the design and test methods for liquid systems of thermal preparation of an internal combustion engine. A new methodology and test program have been developed to study the efficiency of electric engine pre-start heaters. At the stand, the scheme of which is shown in Figure-6, tests were carried out, including: visual inspection, installation, verification of operability and basic characteristics, as well as dismantling of the heating device.

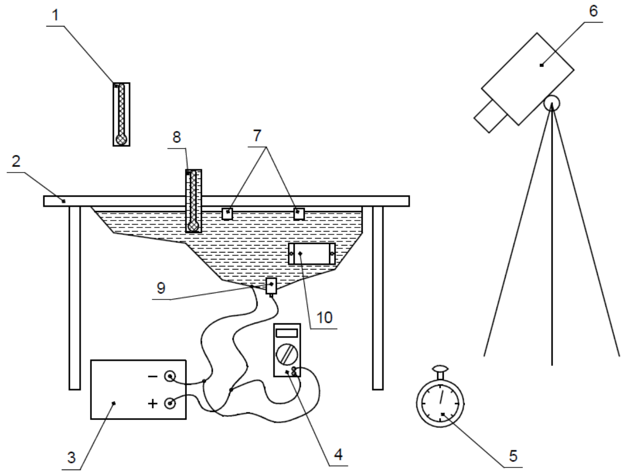

Figure-6. Scheme of the stand for testing electric enginepre-start heaters:
1 - thermometer for measuring ambient temperature; 2 - sump of the engine crankcase; 3 - power supply; 4 - multimeter; 5 - stopwatch; 6 - video recording equipment; 7 - floats; 8 - thermometer for measuring engine oil temperature; 9 -heater in the form of a plug; 10 - heater in the form of a plate (not connected to a power source).

During visual inspection, the surfaces and connections of the heating device were examined for defects that could worsen the quality of the tests.

When installing the heating device on the test stand, the start and end time of the work was recorded as shown in Figure-7.

Figure-7. Test bench for electric engine pre-start heaters.

To check the operability of the heating device, motor oil was poured into the sump of the engine crankcase with the heating device installed in it, after which two floats were placed on its surface, shown in Figure-8.

ARPN Journal of Engineering and Applied Sciences

Figure-8. Floats based on cork material.

After turning on the video recording equipment, the stopwatch was started, and the heating device was connected to the power source. During the tests, the readings of thermometers, multimeters and the positions of floats were recorded with a certain frequency. When the motor oil reached a temperature of plus 40° C according to the thermometer in the sump, the stopwatch stopped and the end time of the tests was recorded. The performance test of the heating device was carried out under normal climatic conditions, as well as in the climate chamber at ambient temperatures from plus 10° C to minus 20° C.

After testing at various ambient temperatures, the heating device was dismantled from the sump, while the time of the work carried out was recorded.

The data obtained from the test results made it possible to calculate the economic efficiency of heating devices in the form of a plug and a plate. The electricity costs of each heater were calculated using the following formula:

$$S_p = N_p \times n_h \times P$$

Where N_p is heater power consumption, kW; n_h is number of hours worked, h; P is cost of one kilowatt of energy, RUB/kWh.

In addition to the cost of electricity, the calculations took into account the cost of installation and dismantling, as well as the retail cost of the heating devices themselves. According to the results of calculations, a greater economic efficiency of using a heating plate compared to a heater in the form of a plug has been established.

CONCLUSIONS

The developed methodology and testing tools can be used to select the optimal design of the engine pre-start heaters, calculate its economic efficiency, as well as in the educational process of technical universities.

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