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USE OF A THERMOELECTRIC DEVICE TO MAINTAIN OPTIMAL AIR TEMPERATURE AT THE INTAKE OF A SPARK-IGNITION ENGINE WHEN OPERATING ON ALCOHOL-CONTAINING GASOLINE

The article deals with the problem associated with increasing the efficiency of operation of a spark ignition engine. Among the alternative fuels for spark ignition engines, ethanol is regarded worldwide as an important renewable energy source Adding ethanol to commercial gasoline reduces harmful air pollutants, greenhouse gases, and production costs. On the other hand, the use of benzoethanol mixtures as a fuel is associated with a lower saturated vapor pressure, which makes starting a cold engine quite difficult, and also leads to deterioration in the fuel-economic and environmental performance of the engine in the warm-up mode. A device with the use of thermoelectric modules is proposed for maintaining the optimal air temperature at the intake of a spark-ignition engine when operating on benzoethanol mixtures in the start-up and warm-up modes of a cold engine. The description of the proposed thermoelectric device, the principle of its functioning and the results of functional tests are presented. Bibl. 9, Fig 4.

Key words: spark ignition engine, benzoethanol mixture, thermoelectric modules, cold engine start and warm-up, intake air heating.

Introduction

Transport has become an integral part of modern life and one of the key sectors in terms of energy consumption. The internal combustion engine (ICE) running on fossil fuel is one of the most efficient and universal sources of mechanical energy used in cars, construction and agricultural machinery, stationary power plants, etc. The instability of world prices for fossil fuels, the reduction of its reserves, problems with transportation force us to look for alternative fuels. The use of alternative fuels should reduce the environmental damage associated with the use of fossil fuels. The development of the alternative fuel market should reduce Ukraine's dependence on oil and contribute to economic growth and reduction of greenhouse gas emissions in transport. Reducing the impact of road transport on atmospheric air pollution is one of the most important priorities of state policy in the field of road transport [1].

Therefore, research on the impact of alternative fuels on the environmental and energy performance of a vehicle engine, as well as determining recommendations for their use, taking into account the operating conditions of the vehicle, is an important scientific task that makes it possible to widely use alternative fuels in the future.

Analysis of previous research

Modern trends in the fuel industry, such as increased environmental requirements for fuel, an increase in the consumption of high-octane gasoline, an increase in the cost of oil production, a deterioration in the quality of produced oil and, as a result, an increase in the cost of its processing, lead to the need to revise traditional approaches to the production of motor fuels. First of all, this concerns the production of high-octane gasolines and the use of fuels and their components alternative to petroleum ones.

One of the ways to solve these problems can be the use of alcohol as an additive to traditional commercial gasoline, and first of all, dehydrated ethyl alcohol (fuel bioethanol) made of biologically renewable raw materials. The use of alcohol-containing gasoline mixtures has become a global trend that allows improving the energy efficiency of internal combustion engines, increasing its operational life, reducing maintenance costs, and most importantly, reducing dependence on fossil fuels [2 – 5].

Along with this, a number of significant drawbacks of the use of alcohol as a motor fuel have been identified, limiting its maximum concentration in benzoethanol mixtures. Thus, the high latent heat of evaporation makes it difficult to start a cold engine (at temperatures below 10°C it becomes practically impossible), the lower heat of combustion compared to the heat of combustion of petroleum fuels requires an increase in consumption by 25...30 %, the lower temperature of the exhaust gases leads to an increase in the time for the catalytic converter to reach an effective mode of conversion of harmful substances in the engine warm-up mode, as a result of which the emission of harmful substances increases, relatively high electrical conductivity in combination with a high oxygen content requires protection of parts of the fuel supply system from corrosion, phase instability of alcohol-containing fuel, unsatisfactory tribological characteristics [6, 7].

To overcome some of the disadvantages of using a benzoethanol mixture as a motor fuel, which will improve the performance of internal combustion engines, there are basically two possible approaches. The first is the introduction of a minimum amount of alcohol into commercial gasoline (up to 20 % in order to avoid problems with the normal operation of the internal combustion engine). The second is to ensure the heating of the intake air to the optimum temperature and stabilization when using a benzoethanol mixture (depending on the concentration of alcohol in the mixture) at low ambient temperatures, in particular, in cold engine start and warm-up modes.

Modern designs of vehicle engine intake systems, through the use of various design solutions, primarily provide a low concentration of harmful substances in the exhaust gas and high economic performance under normal operating conditions, in which there are no factors that impede the implementation of functional or technological processes. As is known, the operational characteristics of a vehicle engine in different modes of its operation depend not only on the improvement of the design of engine systems, but also on operating conditions. Natural and climatic conditions have the greatest influence on the performance of the vehicle engine. The main characteristic of natural and climatic conditions, which significantly affects the operational properties of the vehicle, is the ambient temperature. The ambient air temperature is a determining factor in the formation of the air-fuel mixture due to the effect on the temperature in the intake manifold of the vehicle engine [8, 9].

The formation of the optimal composition of the air-fuel mixture, the speed and completeness of its combustion during engine operation in various modes, including at low ambient temperatures, to a large extent depends on the physicochemical properties of the fuel used, determined by a number of indicators, including saturated vapor pressure (SVP) characterizing the volatility of the fuel. The value of SVP can be used to judge the starting properties of the fuel (Fig. 1).

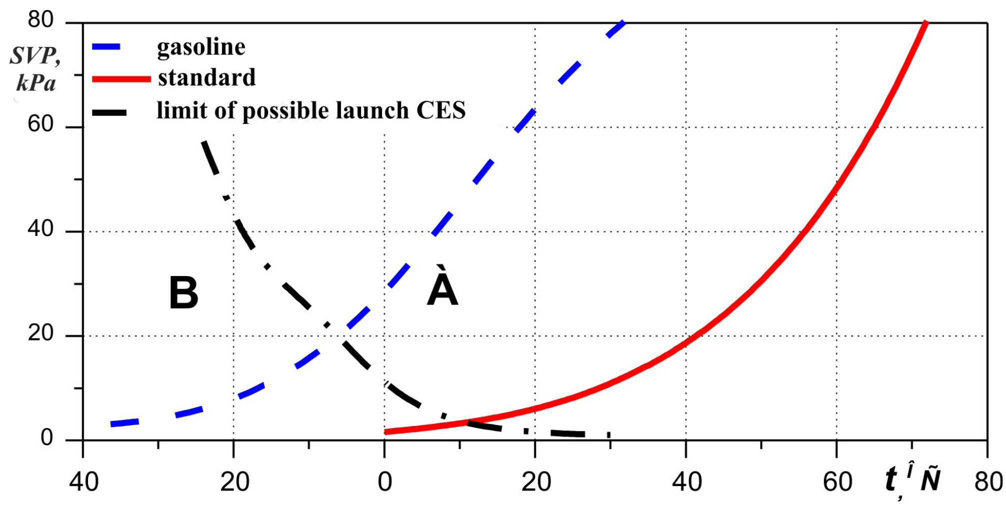


Fig. 1. Dependence of the SVP of gasoline and alcohol on the ambient air temperature and the dependence of possible engine start on their SVP: A – the area where it is possible to start an internal combustion engine; B – area where start-up is impossible

Presented in Fig. 1, graphical dependences obtained from a fairly large number of sources show that with an increase in the ethanol content in the benzoethanol blend, the SVP decreases and reaches a value that makes it impossible to start the engine, especially at low temperatures.

Various methods are used to intensify fuel evaporation at low temperatures, including fuel preheating, intake manifold heating, intake air heating, increased airflow turbulence, and others.

In this regard, the use of a benzoethanol blend, especially with fairly high ethanol content, requires the development of various methods and devices in order to ensure the preparation of an air-fuel mixture of optimal composition and quantity, regardless of climatic conditions and vehicle engine operating modes.

The results of the conducted analysis indicate the relevance and expediency of research aimed at creation and use of devices that ensure the improvement of the operating characteristics of a spark-ignition engine when working on benzoethanol mixtures in the start-up and warm-up modes of a cold engine.

Research results

Taking into account the requirements for minimizing interference in the engine design, systems that ensure its operation and modern technological solutions, the authors proposed a system that ensures automatic maintenance of the optimal air temperature in the intake manifold of the vehicle engine, which consists of an internal combustion engine, an air cleaner, an intake manifold, a thermoelectric device (TED), electronic control unit, air temperature sensor in the intake manifold, load sensor. The thermoelectric device consists of thermoelectric modules, an internal and external heat sink with fans, and an external heat sink temperature sensor (Fig. 2).

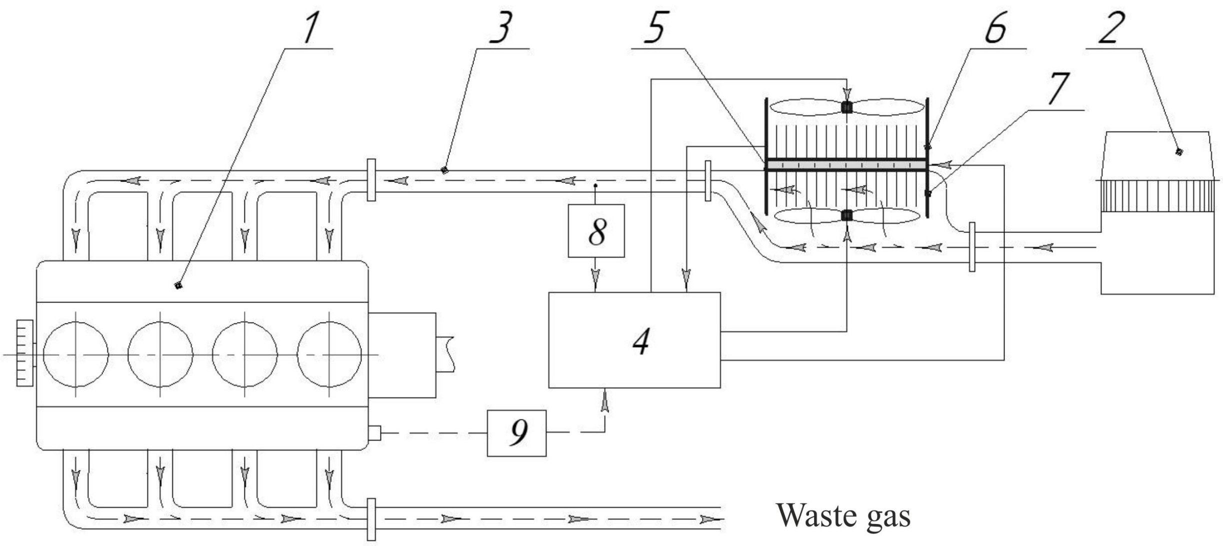


Fig. 2. Structural schematic of the proposed system, which ensures automatic maintenance of the optimal air temperature in the intake manifold of the internal combustion engine: 1 – iternal combustion engine, 2 – air cleaner, 3 – intake manifold, 4 – electronic control unit, 5 – thermoelectric module, 6 – external heat sink with a fan and temperature sensor, 7 – internal heat sink with a fan, 8 – air temperature sensor in the intake manifold, 9 – load sensor.

The main element of the proposed system is a thermoelectric device consisting of thermoelectric modules, the principle of operation of which is based on the Peltier effect (TEC1-12706). The most significant features of thermoelectric modules are: small weight and dimensions, lack of moving parts, fairly high heating speed with low energy consumption, practically no need in maintenance. The use of thermoelectric modules often allows obtaining a simple solution to complex technical problems of thermal energy management and provides significant advantages over alternative technologies.

Functions of the electronic control unit: forms a continuous current and voltage on the thermoelectric modules, measures and stabilizes the intake air temperature, limits the power consumed according to the set value, controls the temperature of the external heat sink of the thermoelectric device and controls its fan, smoothes out pulsations and performs diagnostics of the parts of the proposed system.

A fan is used to intensify the heat exchange (enhance turbulence) of the air flow in the intake manifold with the internal heat sink of the thermoelectric modules. In order to prevent a decrease in the efficiency of the proposed system, the electronic control unit ensures that the fan of the external heat sink is turned on according to the signal level of the external heat sink temperature sensor.

The principle of operation of the proposed thermoelectric system is as follows: during engine operation, the electronic control unit receives signals from air temperature sensors in the intake manifold, the external heat sink, and the load. Depending on the level of these signals, the electronic control unit, by changing the power of the electric current supplied to the thermoelectric modules, ensures the required (optimal) temperature of the internal heat sink (the degree of its heating).

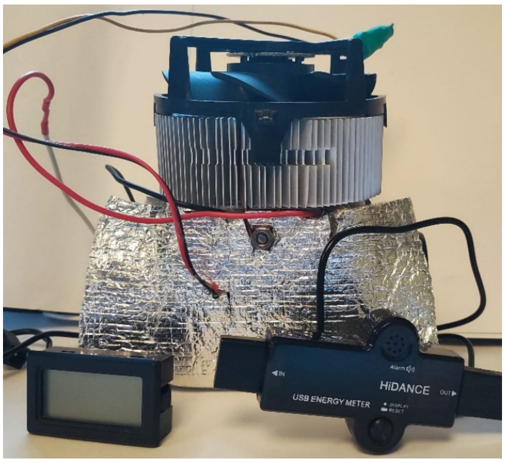
The proposed system provides the following modes of operation:

- under conditions of optimal air temperature in the intake manifold (according to the signal level of the air temperature sensor in the intake manifold), air from the air cleaner through the intake manifold enters the engine cylinders (the thermoelectric device is turned off);
- under conditions when the air temperature in the intake manifold is less than optimal, the electronic control unit connects the thermoelectric modules to the on-board network, which ensures an increase in the temperature of the internal heat sink and, by changing the power of the electric current, ensures the heating of the air in the intake manifold to optimal values.

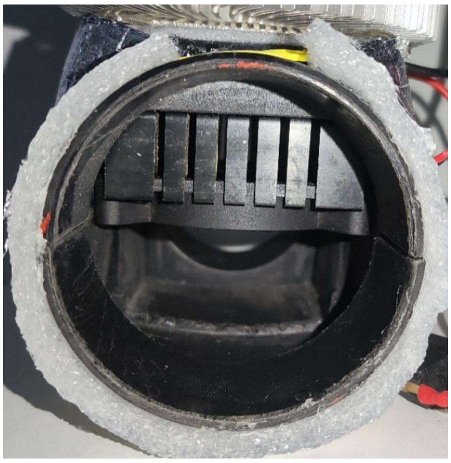
At the Department of Engines and Thermal Engineering of the National Transport University, a working sample of the proposed thermoelectric device was made (Fig. 3) and its functional tests were carried out in order to assess the possible effectiveness of the proposed device for maintaining the optimum air temperature at the intake of a spark ignition engine when operating on benzoethanol mixtures under conditions of low ambient temperatures.

Functional tests of the working sample were carried out at an ambient air temperature of minus 5°C. At the same time, the temperature change at the outlet of the thermoelectric device, the voltage and the current strength at the thermoelectric module were monitored. Based on the analysis of the literature, which is devoted to the features of starting a cold engine, the optimal intake temperature in the start-up and warm-up modes is about +40...60 °C. Taking into account the higher heat capacity of benzoethanol mixtures compared to commercial gasoline, the final intake temperature was chosen to be about + 60 °C.

According to the results of the research, the following was established. The average value of the voltage on the thermoelectric module was 12.7 V, the current strength was 4.1 A. Air temperature after 3 min reached 56.8 °C, while there was a decrease in the rate of increase in air temperature (Fig. 4). This phenomenon is due to a decrease in current power, which is explained by the absence during the research of TED electronic control unit, in particular, managing controller of thermoelectric module. This phenomenon is due to a decrease in the current power, which is explained by the absence of an electronic control unit during the TEC study, in particular, the managing controller of the thermoelectric module. The absence of a thermoelectric module controller led to a decrease in current power by almost 12 % compared to the initial value.



a)



b)

Fig 3. Experimental sample of the proposed thermoelectric device: a) General view of a TED with a remote temperature sensor and a voltage, currentand power consumption tester, b) Internal heat sink with a fan

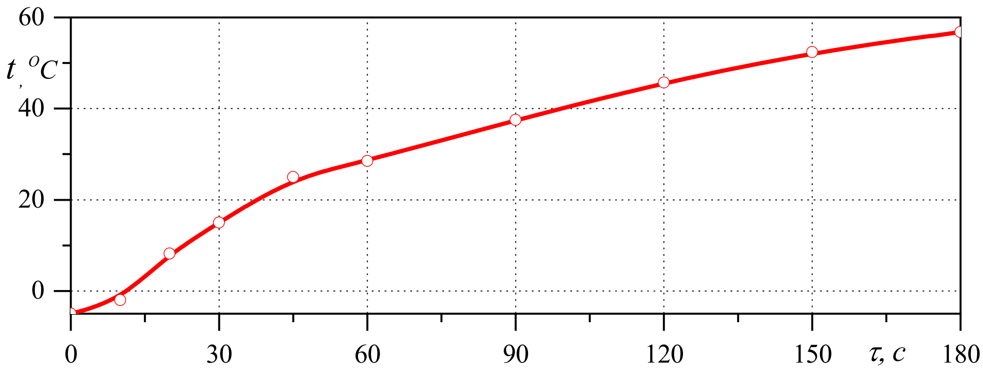


Fig.4. Change in intake air temperature when using TED

Based on the results of functional tests, the possibility and expediency of using devices that ensure the maintenance of the optimum air intake temperature of spark ignition engine in the modes of starting and warming up a cold engine when operating on benzoethanol mixtures, in particular, thermoelectric modules, the principle of operation of which is based on the Peltier effect, have been confirmed. Based on the results of the study, it was established that it is necessary to use a managing controller for a thermoelectric module, the absence of which leads to a sharp decrease in the efficiency of the module (according to some data, up to 30 ... 40 %).

Conclusions

1. Alternative fuels, in particular benzoethanol mixtures, have great potential in solving fuel-energy and environmental problems associated with fossil fuels.
2. The possibility of using thermoelectric devices to maintain the optimal air temperature at the intake of the vehicle engine during operation on benzoethanol mixtures, in particular in the start-up and warm-up modes of a cold engine, was studied.
3. The advantages and prospective directions of the use of thermoelectric devices during the operation of vehicle engines under conditions of low ambient air temperatures are determined. It has been established that such devices can realize the heating of the intake air to optimal values.
4. Functional tests of TED indicate the possibility and expediency of using thermoelectric modules, the principle of operation of which is based on the Peltier effect with a managing controller to maintain the optimal air temperature at the intake of a spark-ignition engine in the start-up and warm-up modes during its operation on benzoethanol mixtures.

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ВИКОРИСТАННЯ ТЕРМОЕЛЕКТРИЧНОГО ПРИСТРОЮ ДЛЯ ПІДТРИМАННЯ ОПТИМАЛЬНОЇ ТЕМПЕРАТУРИ ПОВІТРЯ НА ВПУСКУ ДВИГУНА З ІСКРОВИМ ЗАПАЛЮВАННЯМ ЗА РОБОТИ НА СПИРТОВМІСНОМУ БЕНЗИНІ

У статті розглядається проблема, що пов'язана з підвищенням ефективності експлуатації двигуна з іскровим запалюванням. Серед альтернативних палив, для двигунів з іскровим запалюванням у всьому світі розглядається етанол як важливе відновлюване джерело енергії. Додавання етанолу до товарного бензину забезпечує зниження шкідливих забруднювачів повітря, парникових газів, а також цін на виробництво. З іншого боку, використання бензоетанольних сумішей як палива пов'язано з більш низьким тиском насичених парів, що робить пуск холодного двигуна досить складним, а також призводить

до погіршення паливно-економічних і екологічних показників двигуна в режимі прогріву. Запропоновано пристрій що використовує термоелектричні модулі для підтримання оптимальної температури повітря на впуску двигуна з іскровим запалюванням при роботі на бензоетанольних сумішах в режимах пуску і прогріву холодного двигуна. Наведено опис запропонованого термоелектричного пристрою, принцип його функціонування та результати функціональних випробувань. Бібл. 9, рис. 4.
Ключові слова: двигун з іскровим запалюванням, бензоетанольна суміш, термоелектричні модулі, пуск і прогрів холодного двигуна, підігрів повітря на впуску.

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