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ON THE PROSPECTS OF USING THERMOELECTRIC COOLERS TO MAINTAIN OPTIMAL AIR TEMPERATURE IN THE INTAKE MANIFOLD OF INTERNAL COMBUSTION ENGINE FOR IMPROVING ITS PERFORMANCE CHARACTERISTICS

The paper deals with the problem associated with increasing the efficiency of the operation of road transport in conditions of high ambient temperatures, substantiates the need to take special measures to maintain the optimum air temperature at the engine inlet. According to the results of the analysis, it is established that the ambient temperature has a significant impact on the efficiency of the internal combustion engine. The use of a thermoelectric system is proposed, which makes it possible to maintain the optimum temperature in the intake manifold in order to improve the performance of the engine. Descriptions of the proposed thermoelectric system and the concept of its operation are presented. Bibl. 11, Fig. 4.
Key words: internal combustion engine, natural and climatic factors, thermoelectric cooler, performance characteristics.

Introduction

The transport industry is one of the basic sectors of the Ukrainian economy, has a developed network of roads, which creates the necessary prerequisites to meet the needs of transport users in the provision of transport services and the economic development of the national economy of the country. The current state of the transport industry does not fully meet the modern requirements for the effective implementation of energy-saving technologies and ensuring the priority of environmental safety requirements, which is due to the low level of implementation of modern technologies and the implementation of innovative policies in the transport industry. In this regard, the problem of increasing the efficiency of road transport operation is one of the most significant, which is confirmed by the National Transport Strategy of Ukraine for the period up to 2030 [1].

Analysis of previous research

Modern designs of intake systems of internal combustion engines (ICE) through the use of various design solutions, first of all, provide a low concentration of harmful substances in the exhaust gas and high economic performance. At the same time, the performance indicators of internal combustion engines have faded into the background, which is caused by the strengthening of international standards for

environmental safety and fuel efficiency for road transport. As you know, the performance of internal combustion engines in different modes of operation, environmental and economic indicators depend not only on improving the design of the engine, but also on the efficiency of combustion of fuel-air mixture in engine cylinders, which in turn is determined by its qualitative and quantitative composition.

The effect of intake air temperature on the performance characteristics of internal combustion engines is widely covered in [2–6].

In works [7 - 9], based on the results of research work carried out to determine the optimal air temperature in the engine intake manifold, it is noted that the air temperature at which the optimal parameters of the engine operating cycle are provided is 40...60°C. In real conditions of vehicle operation, maintaining such a temperature regime of air at the inlet is practically impossible due to the influence of various changing factors, primarily climatic and road, as well as loading, speed and thermal modes of operation of the internal combustion engine. In addition, the turbocharger and other technology that boosts the engine also contribute to the increase in temperature under the hood of a modern engine. In this regard, the air temperature at the inlet of the internal combustion engine, depending on the operating conditions and the number of additional equipment, can vary widely, which significantly affects the work process (the filling of the cylinders with the air-fuel mixture and its quality deteriorate) and the heat balance of the engine.

It should be noted that the electronic engine control systems of modern cars equipped with various sensors to ensure the optimal composition of the air-fuel mixture, despite their technical excellence, do not fully take into account the influence of variable factors that manifest themselves during the operation of the car. For example, in hot climates, the temperature of the air in the intake manifold during engine operation at idle and partial loads rises to 80 ° C and above [10]. An analysis of changes in global temperature in relation to the average temperatures of 1951-1980 shows that the duration of periods of abnormally high temperatures has increased significantly on average over the past decades due to global climate trends (Fig. 1).

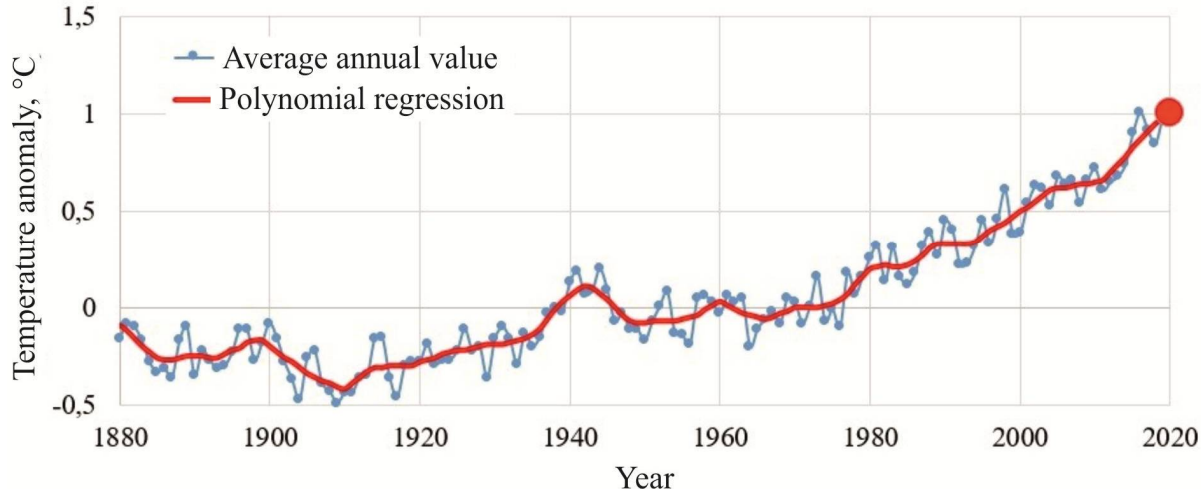

Fig.1. Global land and ocean temperature index [11].

Air cooling, in particular for turbocharged diesel engines, is widely used to improve engine volumetric efficiency by increasing air density and improving cylinder filling. This is usually done due to the air/air heat exchanger. Ambient air is used as a cooling medium (coolant), and therefore the degree of cooling of the air entering the engine is strictly related to the ambient temperature. Record-breaking high ambient temperatures in recent years lead to a significant decrease in the efficiency of the standard heat exchanger and, as a result, to a significant increase in intake temperature, which leads to a decrease in the

efficiency of road transport operation (including its energy performance).

Therefore, one of the promising ways to improve the performance of road transport in high ambient temperatures is to ensure optimal air temperature at the intake of the internal combustion engine.

In this regard, there is a need to develop methods and devices, taking into account modern technological solutions, to ensure the optimal temperature of the incoming air to the engine, in order to ensure the preparation of the optimal composition of the air-fuel mixture and its quantity, depending on its operating modes.

To solve this problem, the authors proposed an air-to-air thermoelectric system (Fig. 2), which automatically maintains the optimum air temperature in the engine intake manifold when the vehicle is operated at high ambient temperatures or high engine load.

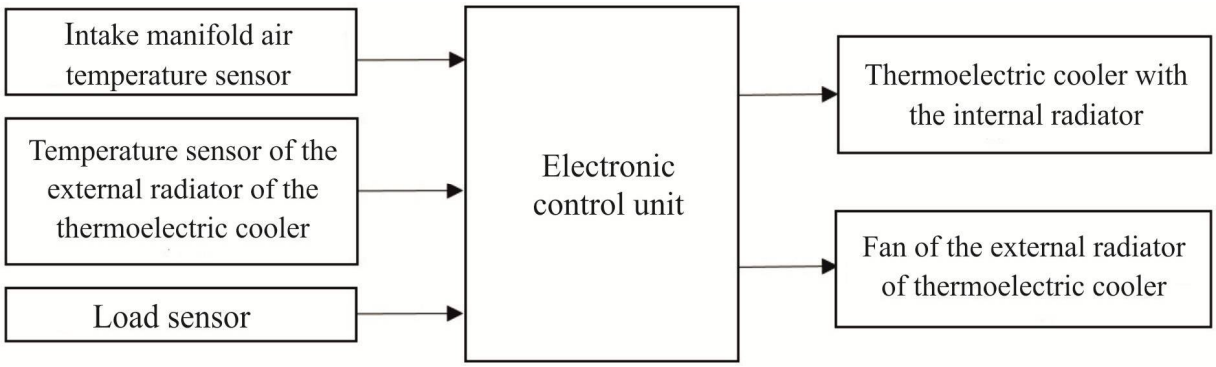

Fig. 2. Block diagram of the proposed thermoelectric system

The electronic control unit provides maintenance (stabilization) of the optimum air temperature in the intake manifold by controlling the thermoelectric cooler (TEC - Thermoelectric Cooler) and the fan of the external radiator of TEC with simultaneous monitoring and display of operating status and system parameters. Temperature stabilization is carried out by changing the electric power supplied to the TEC.

Research results

The proposed thermoelectric system (Fig. 3) consists of an internal combustion engine, an intake manifold, an air cleaner, an electronic control unit, a thermoelectric converter with internal and external radiators, an external radiator temperature sensor, an external radiator fan, an air temperature sensor in the intake manifold, and a load sensor.

The main element of the proposed thermoelectric system is a thermoelectric module consisting of a thermoelectric converter, the principle of operation of which is based on the Peltier effect. The most important features of thermoelectric cooling modules are: the ability to cool the object below the ambient temperature, fairly accurate temperature control and small size. The use of thermoelectric modules often offers a simple solution to complex technical problems of thermal energy management and provides significant advantages over alternative technologies.

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 and external radiator of the thermoelectric cooler and load sensor. Depending on the level of these signals, the electronic control unit smoothly changing the power on the thermoelectric converter provides the required temperature of the internal (cooling) radiator.

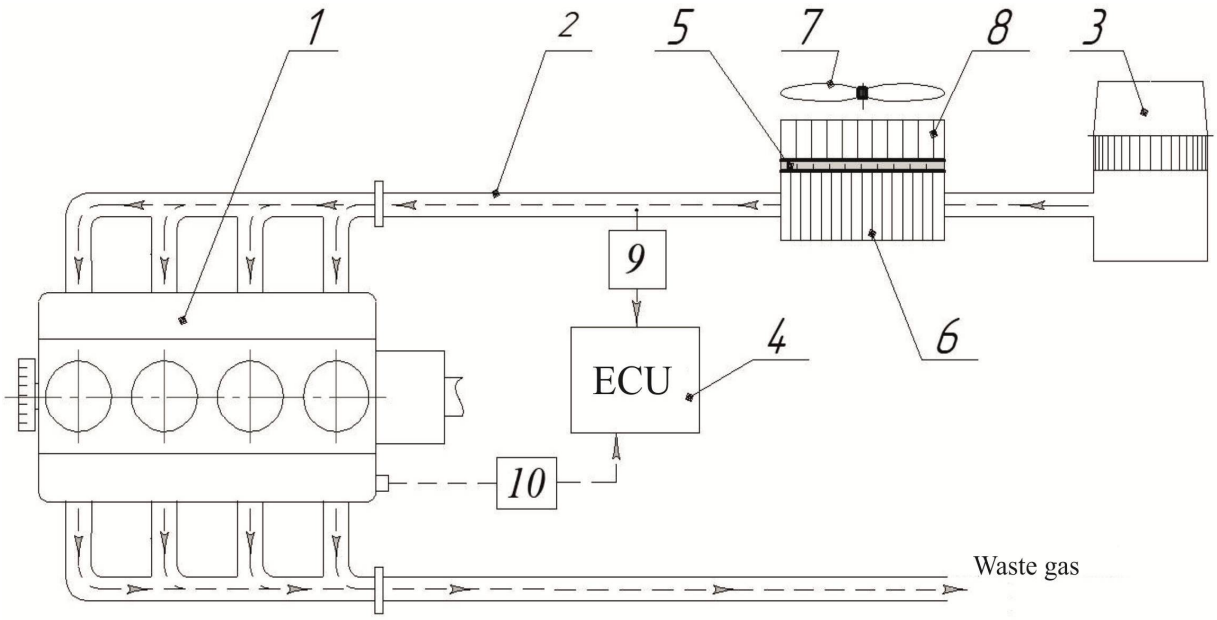

Fig. 3.Block-diagram of the proposed thermoelectric system:
1-ICE, 2-intake collector, 3-air cleaner, 4-electronic control unit, 5-thermoelectric converter,
6-internal (cooling) radiator, 7-external radiator fan, 8-external radiator with temperature sensor,
9- air temperature sensor in the intake collector, 10- load sensor.

In order to prevent a decrease in the efficiency of the thermoelectric system, the degradation of the thermoelectric module and its failure when exceeding the allowable heating temperature of the hot side of the thermoelectric converter, the electronic unit controls the fan of the external radiator (on and off), which facilitates the transfer of heat from the hot surface of the TEC in the underhood of the car.

The proposed thermoelectric system provides the following modes of operation:

– under conditions of optimal air temperature in the intake manifold, air from the air cleaner enters the engine cylinders through the disconnected thermoelectric converter and the intake manifold;

in conditions of exceeding the optimum air temperature in the intake manifold or in acceleration and full load modes, the electronic control unit connects the thermoelectric converter to the on-board network, which leads to a decrease in the temperature of the internal radiator, while the air temperature in the intake manifold decreases due to heat exchange of air from the air cleaner with the internal radiator of thermoelectric converter. Depending on the signal level of the air temperature sensor in the intake manifold, the electronic control unit, smoothly changing the power on the thermoelectric converter, provides the required temperature of the internal radiator, which leads to an improvement in the performance of the internal combustion engine.

At the Department of Engines and Heat Engineering of the National Transport University, an experimental sample of the proposed thermoelectric device (Fig. 4) was made and its functional tests were carried out to assess the possible effectiveness of the proposed approach to solving the above problem.

Functional studies to ensure the optimum air temperature at the engine inlet at high ambient temperatures were carried out in the engine test laboratory of the National Transport University. The experimental setup (Fig. 4) consists of a VW BBY engine installed on a brake test bench, a working sample of the proposed thermoelectric device, electronic thermometers with remote sensors, and a ceramic-metal heating element that heats the air at the inlet to about 60°C.

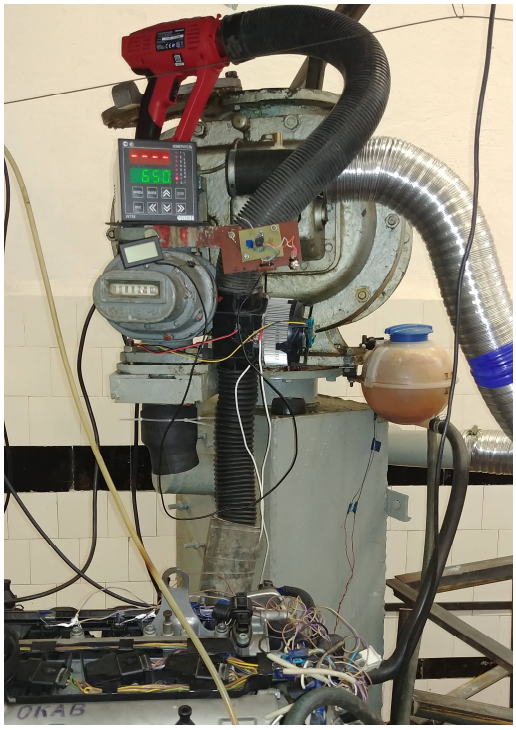

Fig. 4. Experimental sample of the proposed device mounted on a VW BBY engine

Based on the results of the first stage of experimental studies, the possibility of applying the approach proposed by the authors to the implementation of energy-efficient technologies in road transport was confirmed. The use of a thermoelectric system, the operation of which is based on the Peltier effect, makes it possible to reduce and maintain the set air temperature in the intake manifold.

In the future, it is planned to carry out computational studies in order to determine the number of thermoelectric modules and the required area of air heat-dissipating radiators of the thermoelectric module to ensure the required air temperature in the intake manifold and experimental studies in order to determine the expected efficiency of using the proposed device to improve the performance of internal combustion engines at high ambient temperatures and full loads.

Conclusions

1. Based on the results of the research, a thermoelectric system is proposed that ensures the stabilization of the optimal air temperature in automatic mode in the engine intake manifold when the vehicle is operated at high ambient temperatures or high engine load.
2. Based on the requirements for temperature control systems, such as automatic maintenance of a given temperature in a given volume with a certain accuracy, regardless of its change in the environment, small weight and size, short time to enter the operating mode, low power consumption, the authors proposed the use of thermoelectric coolers, the operation of which is based on the Peltier effect.
3. The proposed device has a compact form factor compared to other technologies, is easy to implement and capable of providing the necessary design and operational characteristics, is environmentally friendly and does not require maintenance.
4. According to the results of functional tests of a working sample manufactured at the Department of Engines and Thermal Engineering of the National Transport University, the possibility of using the proposed thermoelectric system to reduce the air temperature in the intake manifold under conditions of

high ambient temperatures was confirmed.

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ПРО ПЕРСПЕКТИВИ ВИКОРИСТАННЯ ТЕРМОЕЛЕКТРИЧНИХ ОХОЛОДЖУВАЧІВ ДЛЯ ПІДТРИМАННЯ ОПТИМАЛЬНОЇ ТЕМПЕРАТУРИ ПОВІТРЯ У ВПУСКНОМУ КОЛЕКТОРІ ДВИГУНА ВНУТРІШНЬОГО ЗГОРАННЯ З МЕТОЮ ПІДВИЩЕННЯ ЙОГО ЕКСПЛУАТАЦІЙНИХ ХАРАКТЕРИСТИК

У статті розглядається проблема, пов'язана з підвищенням ефективності експлуатації автомобільного транспорту в умовах високих температур оточуючого повітря, обґрунтовується необхідність прийняття спеціальних заходів для підтримання оптимальної температури повітря на впуску двигуна. За результатами аналізу встановлено, що значний вплив на ефективність роботи двигуна внутрішнього згорання здійснює температура оточуючого повітря. Запропоновано використання термоелектричної системи, яка дозволяє забезпечити підтримання оптимальної температури у впускному колекторі з метою підвищення експлуатаційних характеристик двигуна. Наведено опис запропонованої термоелектричної системи та принцип її функціонування. Бібл. 11, рис. 4.
Ключові слова: двигун внутрішнього згорання, природно-кліматичні фактори, термоелектричний охолоджувач, експлуатаційні характеристики.

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О ПЕРСПЕКТИВАХ ИСПОЛЬЗОВАНИЯ ТЕРМОЭЛЕКТРИЧЕСКИХ ОХЛАДИТЕЛЕЙ ДЛЯ ПОДДЕРЖАНИЯ ОПТИМАЛЬНОЙ ТЕМПЕРАТУРЫ ВОЗДУХА ВО ВПУСКНОМ КОЛЛЕКТОРЕ ДВИГАТЕЛЯ ВНУТРЕННЕГО СГОРАНИЯ

В статье рассматривается проблема, связанная с повышением эффективности эксплуатации автомобильного транспорта в условиях высоких температур окружающего воздуха, обосновывается необходимость принятия специальных мер по поддержанию оптимальной температуры воздуха на впуске двигателя. По результатам анализа установлено, что большое влияние на эффективность работы двигателя внутреннего сгорания оказывает температура

окружающего воздуха. Предложено использование термоэлектрической системы, позволяющей обеспечить поддержание оптимальной температуры во впускном коллекторе с целью повышения эксплуатационных характеристик двигателя. Представлено описание предлагаемой термоэлектрической системы и принцип ее функционирования. Библ.11, рис.4.

Ключевые слова: двигатель внутреннего сгорания, природно-климатические факторы, термоэлектрический охладитель, эксплуатационные характеристики.

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