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THERMOELECTRIC AIR CONDITIONERS FOR VEHICLE SEATS

The paper discusses the prospects of thermoelectric air conditioning of vehicle seats, which can be used to save energy resources and improve the temperature conditions of a person's stay in a vehicle. To determine the most rational options for using these air conditioners, their classification was carried out depending on the method of thermoelectric air conditioning. Bibl. 30, Fig. 4.

Key words: thermoelectric air conditioner, thermoelectric heat pump, air conditioning, thermal conditions.

Introduction

General characterization of the problem. In recent decades, the number of vehicles is growing rapidly. According to the analytical company Navigant Research, today their number has exceeded 1.2 billion units, and by the end of 2035 the figure could reach 2 billion [1]. At the same time, due to the intensity of traffic, people spend more and more of their time in it. For this reason, there is a need to ensure optimal thermal comfort of the person while in the vehicle, and hence the need to create air conditioners.

In [2-8], various methods of air conditioning in vehicles are considered, each of which has its own advantages and disadvantages. Thus, in [8], a comparison was made between the use of compression and thermoelectric air conditioners and the advantages of each were shown depending on climatic conditions. Despite the different methods of air conditioning, it is common that air conditioning occurs for the entire volume of transport. This leads to increased electricity costs and the problem of airflow distribution, as drivers or passengers feel comfortable for those parts of the body that are directly facing the air outlet. In so doing, ordinary seats will act as an insulator, reducing the cooling of the body, preventing the evaporation of sweat and raising the skin temperature in contact with the seat surface [9].

To solve these problems, it is advisable to use local air conditioning, namely air conditioning of the vehicle seat. This option will provide a comfortable environment with lower energy costs and solve the problem associated with the distribution of airflow.

In the literature, there are various options for air conditioning of vehicle seats [10 - 15], among which air conditioning with the use of thermoelectric converters has become widespread. This is due to the presence in such converters of a number of advantages, namely: high reliability, the ability to provide cooling and heating, the absence of harmful refrigerants, low maintenance cost, possibility of temperature control in a wide range [16]. In so doing, of particular interest is the possibility of using thermoelectric air conditioning for operators of armored vehicles, including tanks, which will optimize the thermal conditions for the stay of tankers during combat operations.

Based on the foregoing, it seems important to consider the known methods of thermoelectric conditioning of transport seats in order to highlight the most rational options. The latter is reduced to the study and analysis of the known options of thermoelectric air conditioners for vehicle seats and their classification according to the thermal scheme.

Analysis of the literature. Active work is underway to create thermoelectric air conditioners for car seats in many countries around the world. Thus, in [17] a temperature controlled seat was developed, powered by an exhaust thermoelectric heat recovery system. A series of experiments, including bench and real vehicle tests, showed that the thermoelectric system was able to reduce the temperature of the seat surface by 14.59% after the temperature controlled seat was operated for 10 minutes.

In [18], a thermoelectric system was created, which was used for climate control of car seats. Experimental results showed that the system reduces the temperature of the air pumped to the seat by about 9 ° C at a performance factor of about $\varepsilon = 0.41$, while the results of the heating mode showed that the device can increase the air temperature by about 34 °C at $\varepsilon = 1.34$.

In [19], a thermoelectric device for regulating the temperature of the surface of a car seat was modeled and designed. The test results showed that at a voltage of 12 V, the thermoelectric system can reduce the seat temperature by about 18 °C in cooling mode and increase it by 22 °C in heating mode.

In [20], an automated seat cooling system for cars using a thermoelectric device was developed, which is aimed at preventing the death and injury of young children left unattended in parked cars at high ambient temperatures. An experimental series of tests has shown the high efficiency of the system.

In [21], a seat with variable temperature was developed and tested using a thermoelectric cooler to increase thermal comfort and reduce fuel consumption. Experimental results have shown that at an ambient temperature of 27 °C, such a system can remove approximately 33.3 watts of power from the conditioned air pumped to the seat.

In [22], the authors applied an optimal design method to develop thermoelectric air-liquid conditioning and managed to obtain a performance factor of 1.68 at the same input power. This optimal design method used dimensional analysis to optimize the applied current and the geometric ratio of the thermocouple (or the number of pairs of thermocouples) simultaneously for a given set of fixed parameters.

In [23], a thermoelectric system for regulating the temperature of a car seat was developed and tested to provide rapid cooling and heating. Experimental tests have shown that the thermoelectric system has the advantage of accelerating the cooling of the car seat from 50 °C to about 6 °C with a significant response time.

All of the above listed thermoelectric options for air conditioning of vehicle seats have their own strengths and weaknesses. Considering that the need for further research related to the use of thermoelectric air conditioning will only grow, it is necessary to classify and systematize the known options of such air conditioning with the subsequent determination of more rational ones.

The purpose of the proposed work is to analyze the known options of thermoelectric air conditioners for vehicle seats and determine the most rational ones.

Companies engaged in the production of serial samples of air conditioners for car seats

One of the leaders in the field of thermoelectric air conditioning of transport seats is the American company *Gentherm Incorporated*, formerly *Amerigon*. The company has created the world's first system of seats with thermoelectric heating and cooling for the automotive industry. The developed system was named "Seat Climate Control" and was first adopted by the *Ford Motor Company* as an option for the *Lincoln Navigato 2000*. Today this system is available in more than 50 vehicles, such as Ford, General Motors, Toyota (Lexus), Kia, Hyundai, Nissan (Infinity), Range Rover, Jaguar, Land Rover, etc.

In one of the company's patented technology, the climate control system includes a thermoelectric device based on a metal plate that heats up on one side and cools down on the other [14]. The heat exchange between the heat generated or absorbed by the Peltier element and the air transferred from the fan is due to the heat exchangers. The housing, which accommodates the Peltier elements and the heat exchanger, includes special parts that are connected to a tube for supplying air from the fan to the seat temperature controller and for connection to the exhaust pipe.

Today, *Gentherm Incorporated* is not only the world's leading company in thermoelectric cooling and heating of car seats, but also one of the best among its competitors that use other ways of air conditioning. The company cooperates with almost all well-known automotive manufacturers, therefore, as the case requires, it has a variety of options for its products. The company currently owns many patents for thermoelectric cooling / heating of car seats.

The Indian company *Dhama Innovations* has developed a thermoelectric temperature control system for car seats [25]. The product is called *Dhama Comfort* and is a temperature-controlled seat that connects to the car's battery. The user can adjust the temperature level in any mode. *Dhama Comfort* is based on *Climacon* technology, which is a small unit consisting of a thermoelectric module and specially designed heat sinks. These units are placed in the seat to provide thermal comfort anywhere. Today, *Dhama Innovations* seats are installed in many cars and trucks. Studies have shown that the use of such seats creates optimal temperature conditions. Moreover, drivers feel less tired, which allows them to drive longer.

The use of special covers (cushions) for car seats has become widespread. Such products do not require significant costs and are suitable for all types of car seats. The products of the Beijing company *Huimao Cooling Equipment Co., Ltd* are in the greatest demand among cushions [26]. The company has been working in the global market since 1996. It specializes in the research, development and manufacture of thermoelectric cooling modules and components.

The American company Arizon Line-X is also developing seat cushions for drivers [27]. Their developments allow reducing fuel consumption. The companies estimate that such savings in the future may even offset the cost of purchasing a seat cushion. There is also an AC power adapter included so that you can use it in the office or at home.

Another American company, *Tempronics*, was founded with the invention of the **Climate Ribbon** [28]**.** Initially, it focused on the development and patenting of technology, and then moved to the market. The main product is the Tempronics personal climate system, PCS 200. This thermoelectric technology allows one to maintain a comfortable temperature in the form of a personal cover used in the cars for cooling or heating.

Classification of thermoelectric air conditioners for vehicle seats

In the proposed work, the classification of thermoelectric air conditioners for vehicle seats is based on two main features: the method of cooling or heating (air or liquid) and the method of removing unwanted waste heat (in the car or outside the vehicle).

Scheme A. The first classification option is shown in Fig. 1. Considered is thermoelectric seat conditioning using air cooling while removing unwanted waste heat into the car cabin.

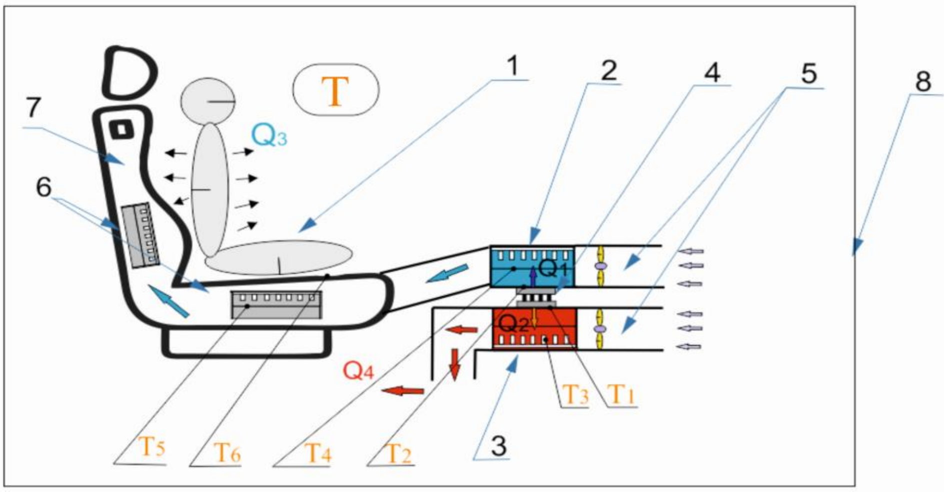

Fig.1. Option of thermoelectric air conditioning of a seat with the use of air cooling when removing heat to a car cabin: 1 – schematic image of a passenger, 2 – cold loop radiator, |3 – hot loop radiator, 4 – thermoelectric modules, 5 – air fans, 6 – air radiators, 7 – schematic image of a transport seat, 8 – schematic image of a car cabin.

Scheme A works in cooling mode. To switch to heating mode, you only need to change the direction of electric current supply to the thermoelectric modules. In this mode, the fans 5 inject air through the radiators 2 and 3, which dissipate the cold and hot heat flow from the thermoelectric modules 4. The cooled air passes through a system of air ducts to the seat 7, where it exits via the radiators 6 through the seat surface thus cooling the passenger. The heated air is discharged through a special duct system directly into the cabin. In this case, the temperature inside the cabin will not change significantly, and the cooling or heating effect will only take place for the people who are on the seat.

In [13 – 15], the described method of seat conditioning was used, but with certain variations in the very design of the thermoelectric system. Thus, for instance, [11] describes a scheme consisting of a rear seat heat pump that regulates the temperature of the air passing through the seat back and a lower seat heat pump for air conditioning passing through the lower part of the seat. These two pumps contain a thermoelectric device, a main heat exchanger and heat exchangers for waste heat. Attached to one end of each main heat exchanger is an outlet from the main fan, which is used to transfer conditioned air to the back or lower part of the seat. The outlet end of each main heat exchanger is connected to an air duct, which in turn is connected to the corresponding air inlet in the rear seat or the air inlet in the lower part of the seat. Attached to one end of each waste heat exchanger is an outlet from a fan that serves to transfer unwanted waste heat to the outside. Temperature sensors are attached to the side of the main heat exchanger in each heat pump. Each temperature sensor can contain an electric thermocouple.

Scheme B. Another classification option is shown in Fig. 2. Thermoelectric air conditioning of the seat with the use of air cooling during the removal of unwanted waste heat to the environment outside the vehicle is considered.

The operating principle of scheme B is similar to scheme A and differs only in that the unwanted waste heat is not removed in the middle, but outside the car. Also, on the inlet side of the air duct for unwanted heat it is possible to place the inlet for air supply outside the vehicle. The advantage of this method is that the temperature inside the vehicle can change, as unwanted heat will be released into the environment. Despite this, in the literature reviewed, very few works use this conditioning scheme. This is mainly due to the complexity of the implementation of additional holes.

In [29], a thermoelectric air conditioner for a vehicle seat using circuit B is described. One of the main parts of such an air conditioner includes an electric fan and a thermoelectric unit. An air duct and a fan are provided. On the inlet side of the air duct there are inlets for air supply outside the vehicle and internal inlets for air supply inside the vehicle. The ratio of mixing the external and internal air is switched by the corresponding dampers. The described air conditioner is controlled by a control unit, which receives signals from temperature sensors. In one aspect of the invention, the removal of unwanted waste heat outside the vehicle is provided.

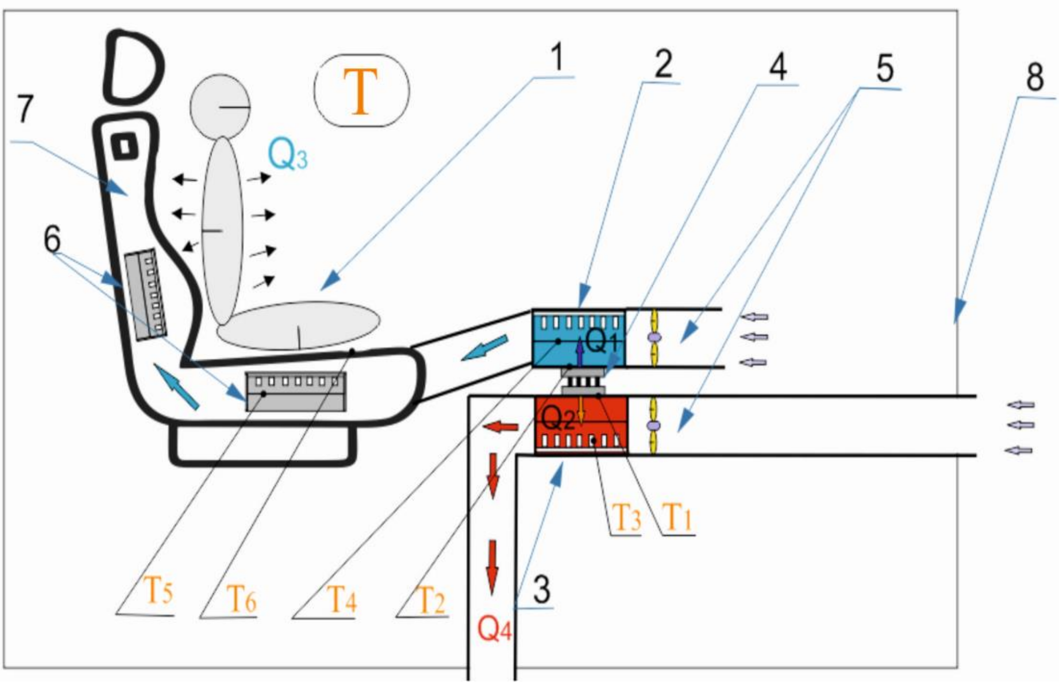

Fig.2. Option of thermoelectric air conditioning of a seat with the use of air cooling when removing heat to environment outside the vehicle;
1 – schematic image of a passenger; 2 – cold loop radiator;
3 – hot loop radiator; 4 – thermoelectric modules;
5 – air fans; 6 – air radiators; 7 – schematic image of a transport seat; 8 – schematic image of a car cabin

Scheme C. The next classification option is shown in Fig. 3. The paper considers thermoelectric seat conditioning using liquid cooling while dissipating unwanted waste heat into the vehicle cabin.

The difference between the operating principle of such air conditioning and those discussed earlier, is the presence of a liquid cooling system. Thermoelectric modules cool (or heat) the liquid, which circulates through a closed system by means of a liquid pump. The cooled (or heated) liquid passes through the seats creating the necessary temperature conditions for drivers or passengers. Unwanted heat is dissipated in the cabin of the car.

Ref. [30] describes a special heating and cooling system for the seat, which works in a similar way. The system consists of a thermoelectric device that selectively cools or heats a liquid-filled heat exchanger. The liquid is sucked in by the pump through the reel on a seat. The coil transfers heat by passing it through the seat to the passenger. The controller allows one to select the heating or cooling temperature. The switch determines the polarity of the voltage applied to the thermoelectric device.

Scheme D. The last classification option is shown in Fig. 4. Considered is thermoelectric seat conditioning using liquid cooling while dissipating unwanted waste heat to the environment outside the vehicle.

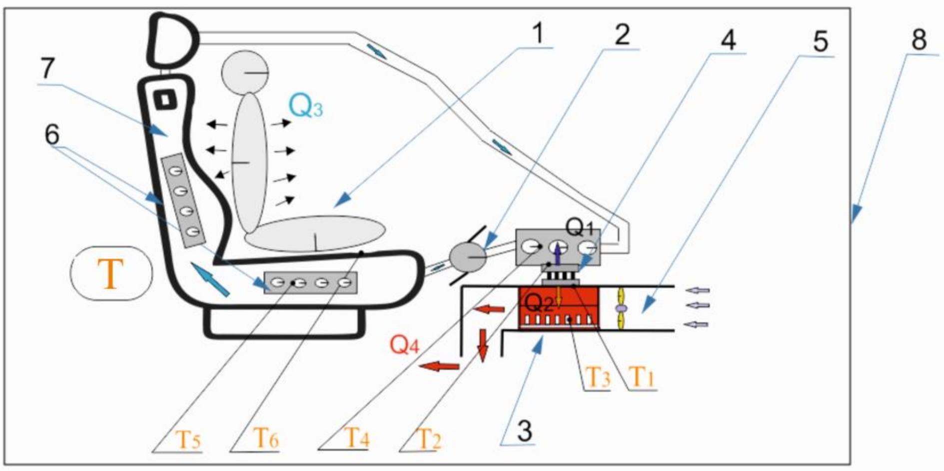

Fig.3. Option of thermoelectric air conditioning of a seat with the use of liquid cooling when removing heat to a car cabin: 1 – schematic image of a passenger, 2 – liquid pump, 3 – hot loop radiatory, 4 – thermoelectric modules, 5 – air fan, 6 – cooling system elements, 7 – schematic image of a transport seat, 8 – schematic image of a car cabin.

The operating principle of scheme D is similar to that of scheme C and differs only in that the unwanted waste heat is removed outside the car. Also, on the inlet side of the air duct for unwanted heat it is possible to place the inlet for suction of air outside the vehicle. This option of air conditioning is hardly considered in the scientific literature, despite the fact that it is the most effective in air conditioning. This is mainly due to the complexity of the implementation process.

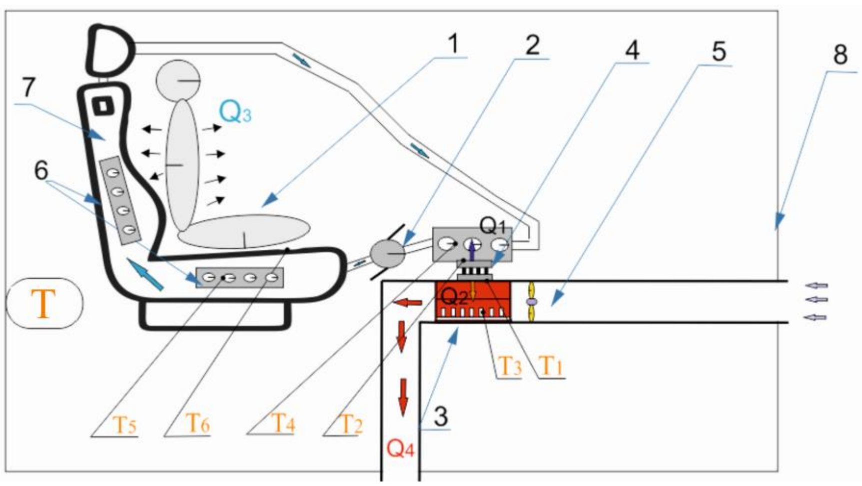

Fig.4. Option of thermoelectric air conditioning of a seat with the use of liquid cooling when removing heat to environment outside the vehicle: 1 – schematic image of a passenger, 2 – liquid pump, 3 – hot loop radiator, 4 – thermoelectric modules, 5 – air fan, 6 – cooling system elements, 7 – schematic image of a transport seat, 8 – schematic image of a car cabin.

Analysis of the most rational options of thermoelectric air conditioners for vehicle seats

A number of important conclusions can be drawn from the literature analysis and classification of thermoelectric air conditioning schemes described in the previous section. The most widespread is the option of scheme *A* – thermoelectric air conditioning of the seat using air cooling with heat dissipation in the car cabin. This is due to the simplicity of this scheme, as such a thermoelectric air conditioner is universal and autonomous and does not require additional changes in the design of the car. However, this scheme has its drawbacks. The largest of these is that the overall cooling efficiency will be lower than in the options of schemes *B* and *D*, because the waste heat will not be dissipated into the environment, but will lead to a small increase in the overall temperature inside the car.

The air conditioner which works according to the option of scheme *D*, has the highest efficiency. Its advantage over the option of scheme B is the removal of waste heat outside the vehicle, and the advantages over the options of scheme **A** and *B* is the greater efficiency of the selected method of cooling. Moreover, this option is the most difficult to implement, since special holes for waste heat must be provided in addition to the overall liquid cooling system. Therefore, today such a method of conditioning has not been implemented commercially, although research is underway to introduce it into production.

Depending on the process of implementing thermoelectric air conditioning for car seats, there are two most appropriate options. If the priority in the production of such an air conditioner is its autonomy and lack of binding to a particular vehicle design, then scheme *A* is the best option. In this case, it is necessary to understand the losses in the efficiency of such an air conditioner.

The most appropriate in terms of energy efficiency is the option of scheme *D*, but in this case it is necessary to design and optimize the thermoelectric air conditioner in conjunction with the development of the vehicle itself.

Conclusions

1. The most rational options of thermoelectric air conditioners for vehicle seats are determined.
2. Using the option of scheme A is the most rational in the development of autonomous and universal air conditioning system, which can be used for any seat of an existing car. This will ensure the mass use of such air conditioners.
3. The most appropriate in terms of energy efficiency is the option of scheme D, but in this case it is necessary to design and optimize the thermoelectric air conditioner in conjunction with the development of the vehicle itself.

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ТЕРМОЕЛЕКТРИЧНІ КОНДИЦІОНЕРИ ДЛЯ СИДІНЬ АВТОТРАНСПОРТУ

У роботі розглядаються перспективи використання термоелектричного кондиціонування сидінь автотранспорту, якими може бути здійснена економія енергетичних ресурсів та покращення температурних умов перебування людини у транспортному засобі. Для визначення найбільш раціональних варіантів використання даних кондиціонерів здійснено їх класифікацію в залежності від способу термоелектричного кондиціонування. Бібл. 30, рис. 4.

Ключові слова: термоелектричний кондиціонер, термоелектричний тепловий насос, кондиціонування, теплові умови.

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ТЕРМОЭЛЕКТРИЧЕСКИЕ КОНДИЦИОНЕРЫ ДЛЯ СИДЕНИЙ АВТОТРАНСПОРТА

В работе рассматриваются перспективы использования термоэлектрического кондиционирования сидений автотранспорта, при помощи которого могут быть осуществлены экономия энергетических ресурсов и улучшение температурных условий пребывания человека в транспортном средстве. Для определения наиболее рациональных вариантов использования данных кондиционеров осуществлена их классификация в зависимости от способа термоэлектрического кондиционирования. Библ. 30, рис. 4.
Ключевые слова: термоэлектрический кондиционер, термоэлектрический тепловой насос, кондиционирование, тепловые условия.

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