DEVELOPMENT AND RESEARCH OF TEMPERATURE CONTROL SYSTEM OF A HIGH-VOLTAGE BATTERY OF A PERSPECTIVE ELECTRIC VEHICLE

РАЗРАБОТКА И ИССЛЕДОВАНИЕ СИСТЕМЫ ТЕРМОСТАТИРОВАНИЯ ВЫСОКОВОЛЬТНОЙ АККУМУЛЯТОРНОЙ БАТАРЕИ ПЕРСПЕКТИВНОГО ЭЛЕКТРИЧЕСКОГО ТРАНСПОРТНОГО СРЕДСТВА

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Abstract: *The development of temperature control system of high-voltage batteries is an actual and important task in the development of modern electric and hybrid vehicles. There are a large number of designs and types of temperature control systems. In this article, we propose to consider a temperature control system based on a liquid cooling system and designed for both cooling and heating the battery in a wide range of ambient temperatures. In the development process of temperature control system for high-voltage batteries were carried calculations, 3D modelling of the design and tests.*

Keywords: VEHICLE, ELECTRIC VEHICLE, TEMPERATURE CONTROL SYSTEM, COOLING SYSTEM, HIGH-VOLTAGE BATTERY

1. Introduction

The development of electric transport in the European Union has become one of the three priority areas of the European economy, and in Russia energy efficiency is declared the main direction of the country's development in the coming years. According to the forecasts of the Subcommittee on Strategic Innovations in the Automotive Industry of the Chamber of Commerce and Industry of the Russian Federation, by 2025 at least 50% of the world's produced vehicles will be on electric traction [1, 4]. Already, all major automobile plants are developing or producing such vehicles. Developments in the field of electromobile transport are engaged in the largest universities, scientific organizations, and enterprises of the Russian Federation. However, in our country now, electric vehicles is not very popular. This is due not only to the underdeveloped infrastructure, but also to climatic conditions. In the greater territory of the Russian Federation is prevailed the cold climate [3, 4, 5 and 6]. Studies show that the mileage of electric vehicles depends strongly on the temperature conditions of the high-voltage battery, which is one of the main elements of the functioning of such vehicles. At low temperatures, the mileage of electric vehicles falls sharply (to 30…40%), and at high temperatures, the high voltage battery can overheat, which can lead to degradation of battery cells. Thus, the task of thermostating high-voltage battery is very important for our country.

Consider the design of high-voltage batteries with thermostating systems of commercially produced vehicles on electric traction.

The Chevrolet Volt T-shaped lithium-ion high-voltage battery, shown in Figure 1, is installed under the car and passes through the central tunnel and under the rear seats.

Fig. 1 *T-shaped lithium-ion high-voltage car battery Chevrolet Volt with aluminum cooling plate.*

Through the quick-release couplings, the coolant enters into the of the high-voltage battery. Inside the housing of battery, there are thermal channels that allow the coolant to flow through the cooling plates between the flat cells of the lithium-ion batteries. These channels allow cooling or heating of the cells depending on operational requirements. If the temperature of the battery is lower than the operating temperature, the heating element located on the input channel of the cell is activated directly from the 360 V of lithium-ion battery.

The high-voltage battery of the hybrid Toyota Prius, shown in Figure 2, is located in the trunk above the rear axle of the car. Battery in the car has an air cooling. This type of cooling has a disadvantage, since in this case the air must be cleaned. Therefore, the battery is located inside the car and the air intake comes from the cabin.

Fig. 2 *High-voltage car battery Toyota Prius.*

The high-voltage battery of the Audi A3 e-tron PHEV-20, shown in Figure 3, has a complex liquid cooling system in which four cooling plates regulate the temperature of the eight modules. Cooling is carried out using a separate controlled low-temperature circuit. To warm up the battery using a thermoelectric heating element and gasoline preheater.

Fig. 3 *High-voltage car battery Audi A3 e-tron PHEV-20.*

The high-voltage battery of the Tesla Model S, shown in Figure 4, is arranged under the bottom of the car and consists of 16 battery modules with liquid cooling system. As a coolant in the cooling system, a solution of glycol is used. The battery module consists of a flat curved tube with battery cells, as shown in the figure, which evenly distribute the coolant between the cells. Further heat is diverted to the cooling circuit and is used by the climate system to heat the car's cabin.

Fig. 4 *High-voltage car battery Tesla Model S.*

Based on the analysis of the thermostating systems for high-voltage batteries produced vehicles, we can conclude that the liquid cooling system is mainly used. In addition, the thermostating system is influenced by the type and design of the battery cells used in the car.

2. Solution of the examined problem

Now, FSUE NAMI conducts research on the topic «Creation of new technologies and systems in the field of increasing the level of use of alternative energy sources for vehicles, based on the introduction of new scientific and technical solutions aimed at the use of electric and renewable (solar) energy for the movement of vehicles». As a model of an electric vehicle, the Russian electric vehicle LADA Ellada was used. This car uses the air-cooling system of the high-voltage battery (Figure 5) (the incoming airflow to the battery housing is supplied through the front bumper and radiator). On this vehicle, there is no battery heating system.

Fig. 5 *High-voltage car battery LADA Ellada.*

One of the main tasks of the project was the development of a high-voltage battery with thermostating system, which allows increasing the temperature range of vehicle operation and maintaining the temperature of the high-voltage battery in the operating range. The operating range of the battery cell without a significant decrease in its life 0 ... 50 ºC. Such a temperature range is most suitable for the careful operation of the battery [2, 5, 7 and 8]. With the existing form of battery cells and the limited layout space, an air-water thermostating system for a high-voltage battery was developed. In addition, it was required to rework the concept of a system for the thermostating of a car. The result is shown in Figure 6.

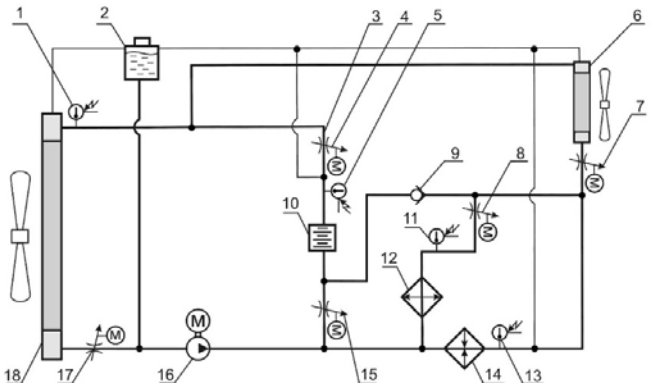

Fig. 6 *Schematic diagram of the thermostating car LADA Ellada.*

A schematic diagram of the car thermostating system comprises an electric pump 16 for supplying coolant from the radiator 18 along the pressure main to the housing of the high-voltage battery 10. To regulate the flow of the pump 16, the system has valves 4, 7, 8, 15, 17 with an electromechanical drive, which are controlled respectively by temperature sensors 1, 5, 11 and 13. The thermostating system has a cooler 12 and an electric heater 14, from where, depending on the operating mode (cooling or heating), the coolant flows through the check valve 9 to the battery housing 10 and then through the drain line 3 to the radiator 18. Also in the thermostating system there is a heater 6 and an expansion tank 2.

3. Results and discussion

The main stages in the development of a high-voltage battery with a thermostating system were:

- 3D modeling;

- calculation of heat and mass transfer.

Based on the car's engine compartment (Figure 7), and technical requirements for the high-voltage battery, it was decided to use 26 cells Winston WB-LYP90AHA as the battery cells.

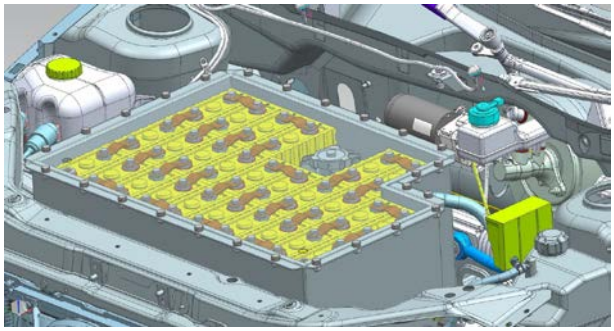

Fig. 7 *The layout of a high-voltage battery in the car's engine compartment.*

The high-voltage battery is a closed box with a thermal insulation layer, which significantly reduces the temperature effects of the environment. The housing of high-voltage battery has two sections. In the upper section, where the battery cells are located, there is a system of air circulation inside the closed volume (Figure 8). The movement of air inside the volume of the high-voltage battery is organized as follows. In the upper cavity of the closed volume, a depression is created, and in the lower cavity, a zone of increased pressure is obtained. These cavities are connected by channels formed by the shape of battery cells. The pressure difference is explained by the use of the fan SPAL VA32-A101-62S. The position of the high-voltage battery cells and the characteristics of the fan have been optimized to ensure sufficient air circulation inside the volume of the high-voltage battery.

In the lower section, there is a heat exchanger, which is a curved tube with many copper plates.

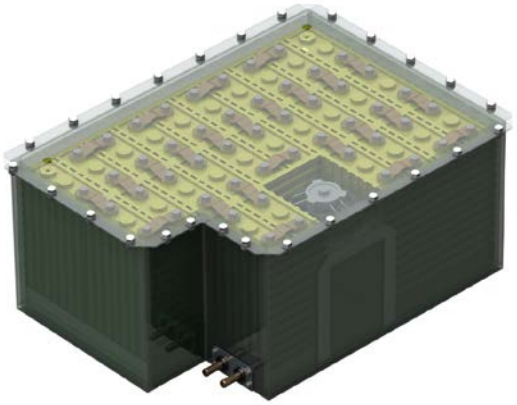

Fig. 8 *3D-model of high-voltage battery.*

The calculation of the efficiency of the system of thermostating of a high-voltage battery was carried out in two modes:

1) Loaded battery operation mode. The ambient temperature is + 40 ° C.

2) The battery is inactive. The ambient temperature is -25 ° C.

The main task of the calculations was to determine the flow rate and temperature of the coolant through the heat exchanger, to provide the target temperature values of the battery cells (0…50°C).

Figures 9-10 show the results of calculations for the first mode.

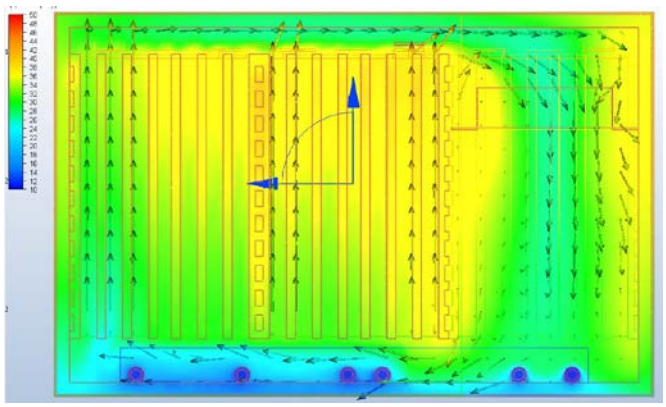

Fig. 9 *Distribution of airflow and temperature in the battery.*

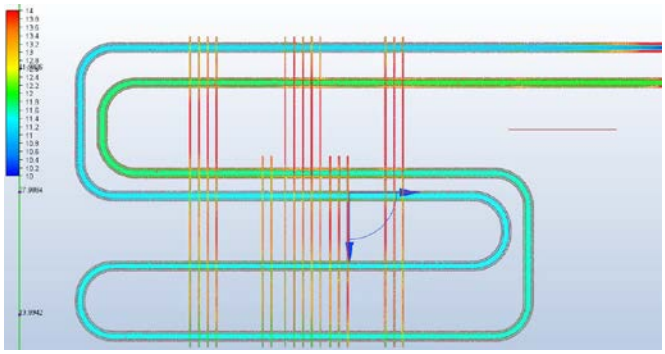

Fig. 10 *Section through a radiator.*

Figures 11-12 show the results of calculations for the second mode.

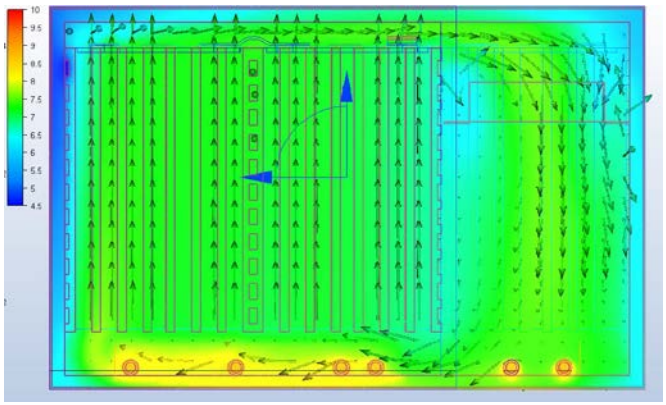

Fig. 11 *Distribution of airflow and temperature in the battery.*

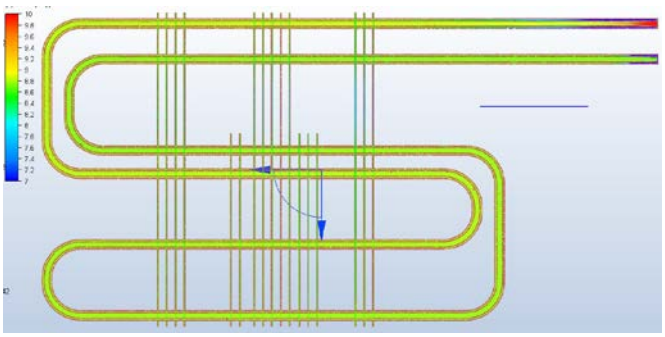

Fig. 12 *Section through a radiator.*

According to the figures, it can be seen that the developed thermostating system has optimal characteristics and allows maintaining the temperature inside the high-voltage battery within operating limits. This design of thermostating system of the high-voltage battery requires a small flow of coolant through the heat exchanger 3 l / min. The coolant temperature measured at the inlet to the heat exchanger + 10 ° C is constant both during cooling and heating. This shows a good level of thermal insulation of the battery volume from the environment.

After the manufacture of a high-voltage battery with a thermostating system, tests were carried out in the temperature test chamber of FSUE NAMI. Tests showed that in a loaded high-voltage battery at a temperature of + 40°C inside n the temperature test chamber and a coolant temperature of + 10°C, which is supplied to the heat exchanger of the battery housing with a flow rate of 3 l/min, a temperature of + 49°C is maintained.

In turn, at a temperature of -25°C inside the temperature test chamber and a coolant temperature of + 10 ° C, which is supplied to the heat exchanger of the battery housing with a flow rate of 3 l / min, the cells of the high-voltage battery warm up above 5°C. This is enough for quickly heat the internal volume of cells of battery, safely activate the car and charge the battery when the car is parked.

A sufficient accuracy of the calculated results with the results of laboratory studies is obtained.

4. Conclusion

Currently, the car with a developed high-voltage battery with a thermostating system is preparing for road tests, which must confirm the effectiveness of the developed design.

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