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DESIGNING A COOLER WITH NATURAL COLD FOR A 100 KW SEMICONDUCTOR POWER CONVERTER

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ПРОЕКТИРОВАНИЕ ОХЛАДИТЕЛЯ ДЛЯ 100 КВТ ПОЛУПРОВОДНИКОВОГО СИЛОВОГО ПРЕОБРАЗОВАТЕЛЯ

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Abstract. The subject of the study is the design of a cooler with natural cooling capacity for a 100 kW semiconductor power converter. The purpose of this thesis is to design a cooler with natural cooling capability for a 100 kW semiconductor power converter and to evaluate its practical effects. We summarize the demand for power semiconductor devices for new applications in power electronics in recent years. During the study and testing of the cooler for the 100 kW semiconductor power converter, the parameters that became the basis for mathematical modeling were determined. In this paper, we summarize the key issues and the current state of research on power semiconductor modules, including module thermal design and thermal modeling issues. The degree of realization is complete. In the process of developing the experimental device, reduction of energy consumption losses and reduction of explosion and fire hazards in industrial production facilities was achieved, which in turn will increase the efficiency of the invention and reduce its production costs. Development of efficiency — reduction of power consumption losses, reduction of explosion and fire hazards in industrial production facilities due to overheating of power semiconductors.

Аннотация. Предметом исследования является конструкция охладителя с естественной холодопроизводительностью для полупроводникового силового преобразователя мощностью 100 кВт. Целью данной работы является разработка охладителя с возможностью естественного охлаждения для полупроводникового силового преобразователя мощностью 100 кВт и оценка его практических свойств. В ходе исследования и испытаний охладителя полупроводникового силового преобразователя мощностью 100 кВт были определены параметры, которые стали основой для математического моделирования. В обобщаются ключевые вопросы и текущее состояние исследований в области силовых полупроводниковых модулей, включая вопросы теплового проектирования модулей и теплового моделирования. Степень реализации полная. В процессе разработки опытного устройства достигнуто снижение потерь энергозатрат и снижение взрывопожароопасности промышленного производства, что в свою очередь позволит повысить эффективность изобретения и снизить себестоимость его производства. Повышение эффективности — снижение потерь электропотребления, снижение

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взрывопожароопасности промышленных производств из-за перегрева силовых полупроводников.

Keywords: coolers, semiconductors, heat dissipation, heat transfer, cooling efficiency, energy flow.

Ключевые слова: охладители, полупроводники, теплоотвод, теплообмен, эффективность охлаждения, поток энергии.

Introduction

The relevance of the research topic is to design a cooler with natural cooling capacity for a 100 kW semiconductor power converter.

The level of knowledge on the subject. Many scientists, such as Johann Andreas von Segner, Heron of Alexandria, Victor Schauberger, Leopold Shergyue, Richard Clem, have studied the problem of converting the energy of fluid flow into energy, but this problem has not been studied thoroughly. Some problems should be considered and decided to be eliminated.

The goal of this paper is to design a naturally cooled cooler for a 100KW semiconductor power converter. The aim of this work is to improve the energy efficiency of the cooler by using the energy of the compressed flow as a result of its periodic braking.

In this work, the following research methods were used: comparison, generalization, modeling, description, experimentation, graphical analysis. The information base of the research was literary sources and patents, such as A. P. Levtsev, A. Makeev, Ya. A. Narvatov, A. Lysyakov, S. Kudashev, V. M. Ivanov, B. V. Semkin, A. A. Blinov, T. A. Volkova.

The novelty of this research is the design of a cooler with natural cooling capacity for 100KW semiconductor power converters, which will help to reduce power consumption losses and reduce explosion and fire hazards in industrial production facilities, introducing and using this laboratory equipment in practice for facilities requiring high heat, such as industrial sites; logistics centers; all possible use in underground structures where explosive gases may leakage of semiconductor devices, such as IGBTs, etc.

In this paper, the thermal properties are considered, and the experimental characteristics are analyzed. And the model is formalized in mathematical language. A new semiconductor power cooler is developed, and a description of the theoretical calculations is considered, and the theoretical heat dissipation is calculated and simulated for different parameters and the results of the design simulations are analyzed graphically.

Material and research methods

The study was carried out under natural and laboratory conditions in 2022. Laboratory experiments were carried out in the laboratory of the Institute of Mechanical and Power Engineering of the N.P. Ogarev Mordovia State Research University.

The authors analyzed the existing articles and patents on coolers [1-4]. Articles on the subject of research work [5-7] were studied. Amplitude-frequency and phase-frequency characteristics were plotted to determine the most efficient mode of operation, and mathematical energy conversion was performed on the constructed hydraulic circuit. The development of technological solutions for power semiconductor device coolers and the transfer of cooler hydrodynamics and its heat transfer energy were studied. To be clearer the thermal design of the liquid cooler, strength, hydrodynamic calculations and calculation of economic efficiency of the semiconductor devices after their introduction into the cooler. The methodology and scheme of the experiments were developed.

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Further experiments were carried out to formalize the model in mathematical language and to process its data.

Results and discussion

Table shows the calculated results of the amplitude-frequency and phase-frequency functions of the energy loops for three modes of operation at cooler frequencies of 0.5 to 5 Hz.

Table

VALUES OF AMPLITUDE-FREQUENCY AND PHASE-FREQUENCY FUNCTIONS OF ENERGY CIRCUITS

Ω	*A1(jΩ)*	*A2(jΩ)*	*A3(jΩ)*
0.5	207858.1079	207858.1079	207858.1079
1	6249900.02	6249900.02	6249900.02
1.5	1116978.998	1116978.998	1116978.998
2	831484.8052	831484.8052	831484.8052
2.5	743204.0568	743204.0568	743204.0568
3	702630.3868	702630.3868	702630.3868
3.5	680226.0506	680226.0506	680226.0506
4	666429.5895	666429.5895	666429.5895
4.5	657287.9447	657287.9447	657287.9447
5	650900.511	650900.511	650900.511

Based on the values obtained in Table 1, the AFC diagram was drawn.

As can be seen from the amplitude-frequency response plot (Figure 1), when the mass m is reduced to 50 kg and the softness l is reduced to 0.00008ms/N, the amplitude frequency decreases slightly compared to the reference value. When the mass m is increased to 100 kg and the compliance l is increased to 0.001 ms/N, the amplitude increases sharply by a factor of 10 or more. In this respect, this model is the best.

Figure 2 shows a schematic diagram of a laboratory setup with a pulsed circulating coolant.

The principle of operation of the scheme.

When the centrifugal pump 5 is turned on, it will supply the coolant through the natural cold cooler 6 to the heat exchanger 4. Then it returns back to the centrifugal pump 5 through one of the open valves of the shock valve 3. When the speed of the coolant is calculated, the valve of the shock valve 3 will quickly close. For exchange, the left valve. When the left valve is closed quickly, a hydraulic shock will occur, the revest pressure, wave of which will move the diaphragm 2. A portion of another coolant will be supplied to 7 and remove heat from the thyristor.

In a simplified from it includes 5 links: the first is hydraulic, take into account the friction losses of the input path with active resistance r_1 and the mass of water in the character m_1; the second is a convertor, converts the pressure P_2 into force, and the mass flow g into the diaphragm velocity v; the third is mechanical, takes into account the elastic properties of the diaphragm by the pliability T and the friction losses of the diaphragm about liquid active resistance r_2;the fourth-the converter link, converts the force f_1 into pressure P_3, and the linear velocity V_1 into mass flow g_2;the fifth link is hydraulic, take into accent the losses of the loss of the output path the diaphragm pump using the active resistance r_3. As in Figure 3:

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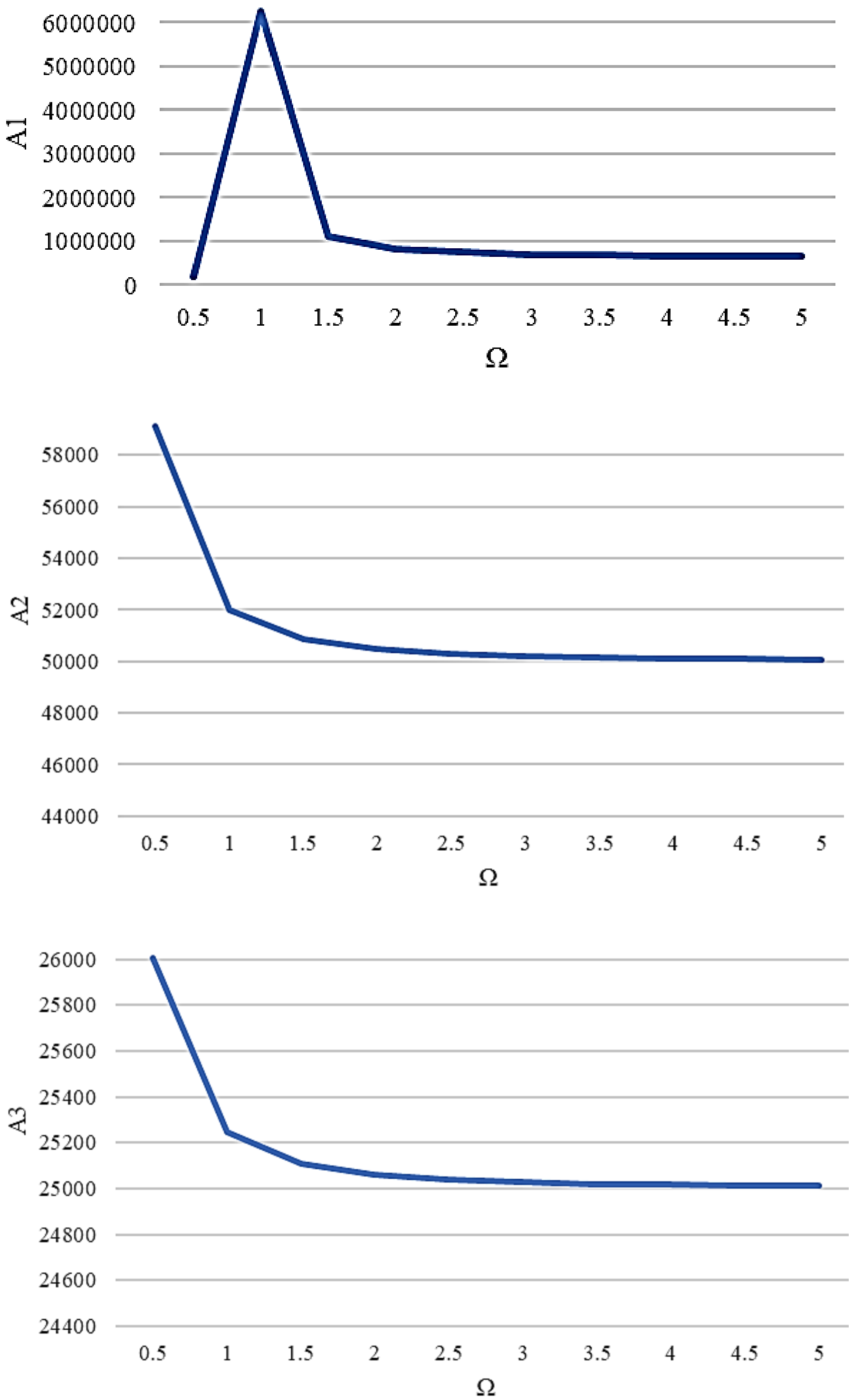

Figure 1. The calculated results of the amplitude-frequency and phase-frequency functions of the energy loop for the three operating modes of the table cooler frequency from 0.5 to 5 Hz are shown in the graph

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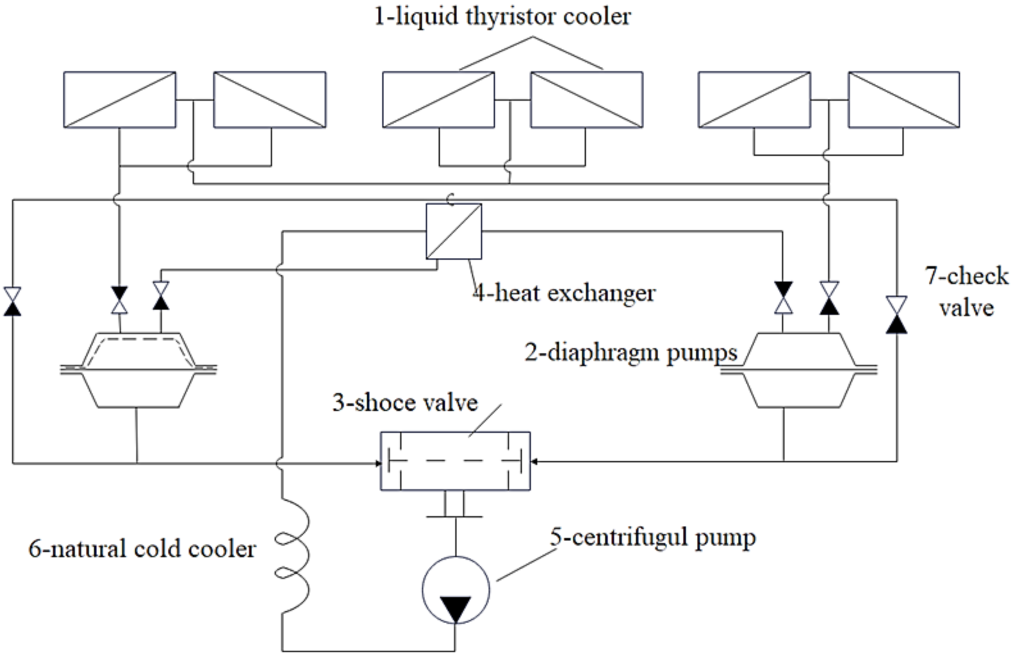

Figure 2. Technological scheme of the cooling unit

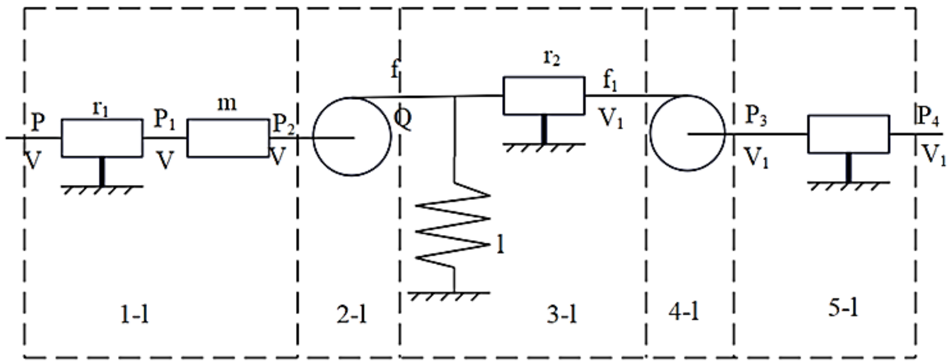

Figure 3. The energy circuit of the diaphragm pump link equation

The calculation method of the micro-tank heat exchanger is studied, and the thermal efficiency is calculated to investigate the relationship between the flow rate and the input temperature, output temperature, heat loss, temperature difference and the related auxiliary quantities P, R. As in Figure 4:

We can conclude that we have obtained a peak which is equal to $\Omega = 4.5$, which means that the design will work best under these conditions.

When considering the dependence of the third energy circuit, we can say that these indicators lead to an increase in efficiency with the growth of the parameters.

If we consider the phase-frequency characteristics, the dependence of all three energy circuits leads to a decrease of these parameters.

Moreover, in the course of this work we have a model on which we can understand which values have a greater influence on the desired value, i. e. the input temperature.

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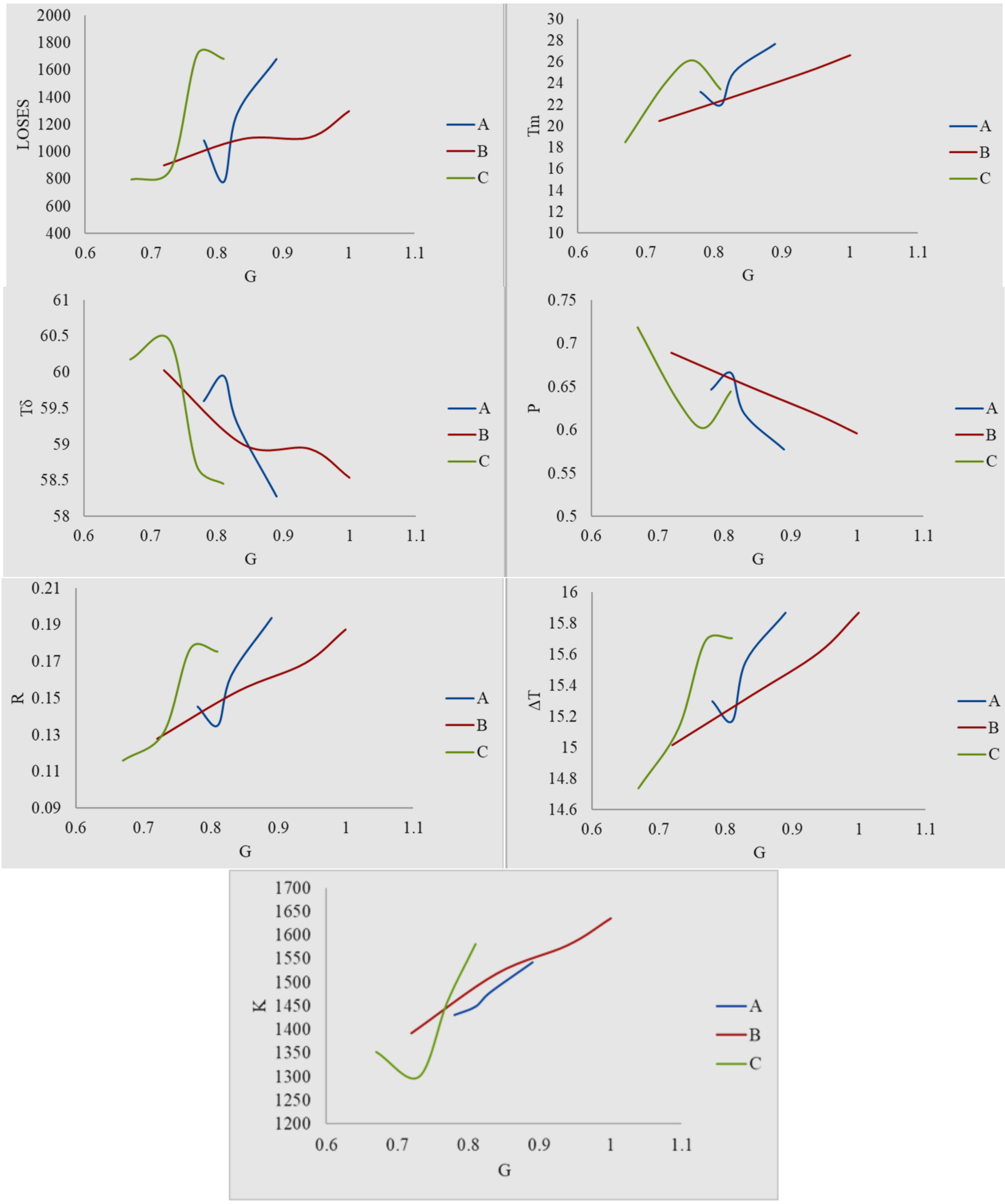

Figure 4. Plot of flow rate versus input temperature, output temperature, heat loss, temperature difference, and related auxiliary quantities P, R, etc.

Conclusions

The aim of this bachelor work is to improve the energy efficiency of 100kW semiconductor power by using the energy of the liquid cooling stream as a result of its periodic suppression.

The integrity of the solution task was evaluated.

- Power semiconductor device heat sink improvement patent analysis, which ensures its ability to effectively improve its thermal performance.

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- Developed and tested calculations for a 100kW semiconductor power converter design a natural cooling capacity cooler.
- The theoretical dependence of heat transfer, energy flow on the design parameters and operation mode of the cooler for a 100KW semiconductor power converter was obtained.
- Developed design documentation for a prototype cooler for a 100kW semiconductor power converter.
- Developed an energy evaluation method for the cooler of a 100kW semiconductor power converter.
- Performed tests of the cooler for a 100kW semiconductor power converter and obtained experimental dependence of heat transfer, energy on design parameters and operation modes.

In the process of developing the experimental device, reduction of energy consumption losses and reduction of explosion and fire hazards in industrial production facilities was achieved, which in turn will increase the efficiency of the invention and reduce its production costs.

During the study and testing of the cooler for the 100kW semiconductor power converter, the parameters that became the basis for mathematical modeling were determined.

In the simulations, the equations for the cooler of the 100kW semiconductor power converter were derived.

Based on the energy circuit dependence diagram of the second stage, we can conclude that we have obtained a peak which is equal to $\Omega = 4.5$, which means that the design will work best under these conditions.

When considering the dependence of the energy circuit of the third stage, we can say that these indicators lead to an increase in efficiency as the parameters grow.

If we consider the phase-frequency characteristics, the dependence of all three energy circuits leads to a decrease in these parameters.

Also, in the course of this work we have a model on which we can understand which values have a greater impact on the desired value, i. e. the input temperature.

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