Heat Dissipation Design of Power Battery Module Based on Air Cooling - Semiconductor Refrigeration

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Abstract. In order to ensure that the soft package power battery can work stably for a long time under the condition of large discharge rate, the heat dissipation of the soft package power battery module is optimized based on the semiconductor thermoelectric effect. Based on the establishment of a traditional air-cooled heat dissipation model and air-cooled-thermoelectric cooler heat dissipation model and ANSYS simulation comparison, the maximum temperature difference, maximum temperature and average temperature of the battery module are analyzed. The optimized simulation results show that the temperature control of the battery module by air cooling-thermoelectric cooler can effectively reduce the temperature difference and the maximum temperature of the battery module. The method significantly improves the heat dissipation performance of the battery module.

Keywords: Semiconductor refrigeration, power battery, ANSYS -icepak.

1. Introduction

Pure electric vehicles in China have developed rapidly in recent years. Electric vehicles are inseparable from power batteries as energy. The discharge rate of the power battery is larger than that of the ordinary battery, which is matched with the high power of the motor, and the discharge rate is proportional to the output power of the motor. In order to improve the output power of the motor, a larger discharge rate is often required. The higher the discharge rate of the power battery, the more serious its heating. The heating phenomenon is particularly obvious near the tab with the largest current density. For lithium-ion batteries, when the battery temperature rises to a certain extent, it will not only reduce the discharge characteristics of the battery, but also cause thermal runaway of the battery, and even endanger the safety. Therefore, the management of battery temperature is particularly important.

At present, many scholars mainly use air cooling, liquid cooling, phase change material cooling, heat pipe cooling and other methods to study the heat dissipation of battery pack. Farouk Naeim et al [1]. Studied phase change material refrigeration. In this study, focusing on battery cooling, a thermal control unit (TCU) containing metal fins was integrated into the battery. To boost TCU effectiveness, phase change material (PCM) was injected into it. By numerical solution, the temperature distribution in three areas of battery, fins and PCM was determined. A.A. Hakeem Akinlabi et al. [2] studied natural air cooling and forced air cooling. The conclusion is that the natural air cooling is difficult to meet the heat dissipation demand of the battery, and the direct forced air cooling is analyzed. It is found that the forced air cooling can meet the heat dissipation requirements. Gao et al. [3] studied liquid cooling of batteries. The temperature gradient of the coolant along the flow direction has been a barrier for thermal uniformity improvement of the battery module. In this study, a novel design of BTMS based on gradient channels along the flow direction is developed and applied to a cylindrical lithium-ion battery module.

In recent years, research on semiconductor radiators is also following up. Mostly, semiconductor heat sinks are applied to electronic components. There are few studies on the application of semiconductor radiators to power battery modules. Based on the liquid cooling-semiconductor heat dissipation scheme, Qu Shiyang et al. [4] proposed a multi-objective optimization design method to optimize the arrangement spacing and semiconductor cooling capacity of power lithium battery packs.

At present, there are few researches on air-cooled semiconductor heat dissipation. The author takes the battery module used in Formula Student Electric China as an example, and uses ANSYS Icepak to conduct a simulation analysis of the way of air-cooling and semiconductor heat dissipation. At the same time, several control groups are made to facilitate the better heat dissipation performance of the designed cooling system.

2. Thermal Design

2.1. Introduction of battery module structure

In the Formula Students Electric China, the stability of battery placement is required. Six battery modules need to be placed in a relatively sealed box (Fig.1). A single battery module will be placed in marked grid. Therefore, it is feasible to design a heat dissipation system at the top of the battery module.

Each battery module also needs to be placed in a shell before being put into the battery box. The shape of the shell is shown in Fig. 2. The main material of the shell is acrylic, and the battery cells inside are connected to each other by adhesive materials.

2.2. Reasons for arranging heat dissipation elements at the battery lug

For the soft pack power battery, the current density at the battery ear is relatively large during discharge. Therefore, more heat will be generated near the battery pole. In high rate discharge, the heating power of the battery ear is generally about 2w. In addition, experiments show that the use of tab heat dissipation in a relatively sealed environment has the advantages of large ultimate heat dissipation capacity and good battery temperature consistency. [5]

2.3. Principle of semiconductor cooler

Because of the Peltier effect of semiconductor materials, when the direct current through two different semiconductor materials in series into a couple, at both ends of the couple can absorb heat and release heat, can achieve the purpose of refrigeration. It is a refrigeration technology that produces negative thermal resistance. Temperature control is directly related to the input power, so the temperature can also be accurately controlled. On the basis of ensuring heat dissipation, the temperature of the battery can be controlled more accurately.

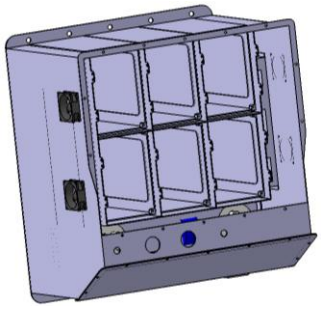


Figure 1. Model of whole battery box

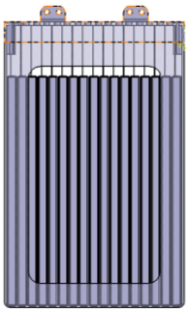


Figure 2. Model of a single battery module

2.4. Advantages of semiconductor cooler

In terms of the complexity of the heat dissipation system structure. Semiconductor itself has no moving parts, high reliability. It is easy to fit closely with radiator, fan and other auxiliary components. Compared with the traditional liquid cooling, which requires a large number of pipes and pumps, the complexity of the heat dissipation system is greatly reduced. Added semiconductor radiator air cooling system and the traditional air cooling system in the structure basically does not increase its complexity. The shape of the semiconductor heat sink is shown below.

In terms of heat dissipation capacity, the remarkable feature of semiconductor heat dissipation is that it can take effect quickly and produce cooling effect quickly. The higher the temperature of the hot end, the worse the cooling effect of the cold end. But at the same time, the higher the temperature of the hot end, the faster the heat exchange with the air. Therefore, after the temperature difference with the air is large to a certain extent, the hot end temperature of the heat sink will not continue to rise. In order to improve the speed of heat exchange with air, the fan and heat sink are added. Later, the simulation of ANSYS -icepak will be used to analyze the steady-state conditions.

3. Ansys-icepak Simulation

3.1. Boundary condition and material parameter

The normal holding period of college students ' electric formula racing car is in November of each year. Taking Xiangyang, Hubei Province as an example, after consulting relevant data, the highest average temperature during the day is 15 degrees Celsius, so the ambient temperature is set to 15 degrees Celsius, Ambient temperature is an important factor for the function of semiconductor radiator, and the heating power of the battery tab is set to 2w.

In this design mainly involved in the structure of the following. The complete design model is shown in Fig 3. The control simulation below is based on this model.

The role of the thermal conductive silica gel is mainly to conduct heat to the top of the module and balance the heat of the pole ear part to avoid overheating of the local pole ear, especially the middle part of the pole ear. The thermal conductivity of thermal conductive silica gel is 3.0w/(m*k). This part is handled in ANSYS and is not shown in the CATIA model.

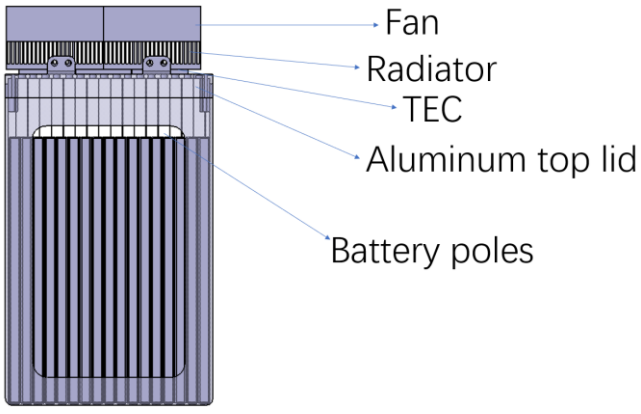


Figure 3. A three-dimensional model of the entire design

TEC refrigeration chip: is the source of low temperature, is also the core component of the heat dissipation scheme. Powering it can make its cold end temperature decrease rapidly, but at the same time, the hot end temperature increases rapidly. The model selected in this design is TEC1-12706. The length and width are 40mm*40mm and the height is 3.5mm.

Radiator: In order to cool the hot end of the refrigeration chip, the radiator and the hot end of the refrigeration chip are tightly bonded. The specific material is Al6063. Thermal conductivity of 201 W/m.K.

Fan: with the radiator with cooling chip hot end heat. Fan selected size is 70mm * 70mm, can be arranged at the top of the battery module two.

3.2. Comparative simulation experiments

In order to study the relationship between the battery heat dissipation module better, three models were made and the temperature after reaching steady state was simulated. The simulation results shown below are models after reaching steady state.

(1) The first

Thermally conductive silicone is filled near the electrode tab. The whole system has no other cooling measures. The system takes away heat completely through the surrounding air.

It can be seen from the Fig.4 that the system without any heat sink can reach a maximum temperature of 99.0 degrees Celsius after reaching a steady state, which is seriously exceeding the normal operating temperature of the battery.

(2) The second

Thermally conductive silicone is filled near the electrode tab. Add cooling fan on top of battery pack. The system uses the circulating air to take away the heat of the electrode tab.

The following data can be obtained from the simulation results as shown in the Fig.5. The highest temperature in the electrode tab is 33.6 degrees Celsius, 18 degrees Celsius higher than the ambient temperature. And most of the areas are in this temperature range. The maximum temperature difference between the battery cells is within 3 degrees Celsius.

(3) The third

Add author names horizontally, moving to a third row if needed for more than 8 authors. Thermally conductive silicone is filled near the electrode tab. Add a semiconductor heat sink to the top of the battery pack. A fan is arranged at the hot end of the semiconductor to take away the heat at the hot end of the semiconductor heat sink.

The following data can be obtained from the simulation results as shown in the Fig.6. The maximum temperature of the battery ear is 18.8 degrees Celsius, and most of the temperature is around 15 degrees Celsius, even some parts of the temperature is colder than the air temperature. The maximum temperature difference between cells is about 3 degrees Celsius. The highest temperature at the hot end of the semiconductor is 50.9 degrees Celsius. Because the semiconductor hot end has a higher temperature, the semiconductor hot end can form a larger temperature difference with the air, which is convenient to take away the heat of the hot end through the radiator and the fan.

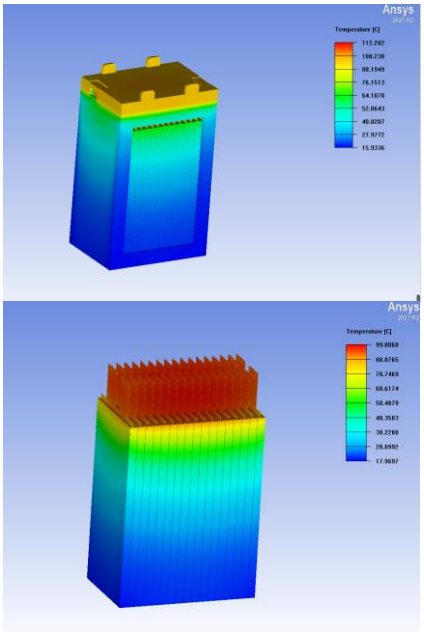


Figure 4. The first heat dissipation system simulation graphics

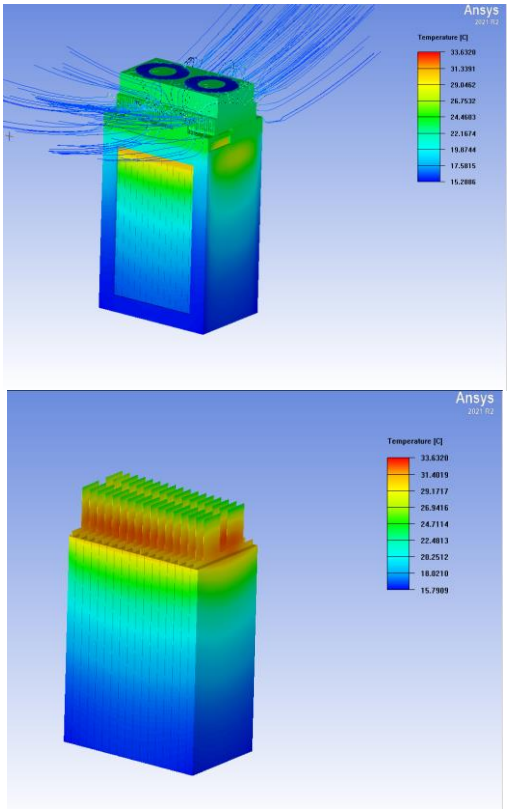


Figure 5. The second heat dissipation system simulation graphics

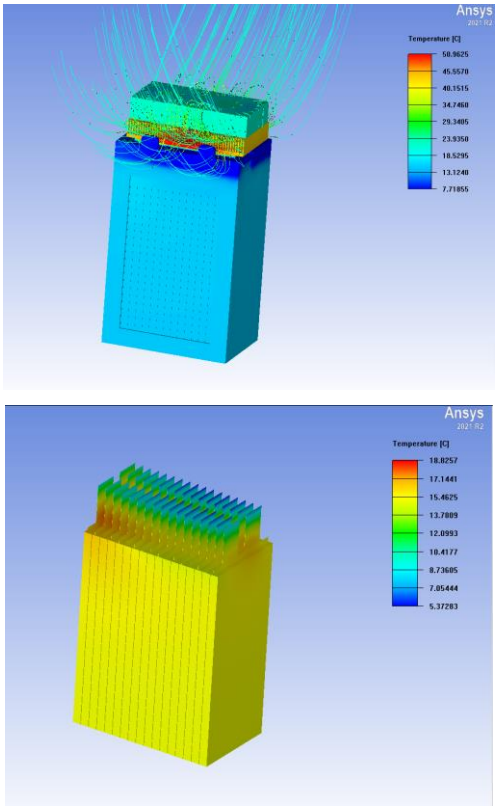


Figure 6. The third heat dissipation system simulation graphics

3.3. Analysis of simulation results

The following conclusions can be drawn by comparing the three sets of simulation results. Fan can improve the cooling effect of the system. This shows the importance of forced air cooling. Under the condition of semiconductor refrigeration chip, the temperature of the battery ear is the lowest. This

shows that the cooling effect is best after adding semiconductor refrigeration chip. The appropriate temperature is provided to ensure the normal working state of the battery.

4. Concluding Remarks

Based on the heat dissipation demand of battery module, a new heat dissipation system using semiconductor thermoelectric effect is designed in this paper. This heat dissipation system combines the forced air-cooled circulating air and the Peltier effect of the semiconductor heat sink. Semiconductor radiator can quickly quantitative controllable heat dissipation at the same time, forced air cooling to solve the problem of heat dissipation system hot end overheating. The above two points can ensure the long-term stable operation of the heat dissipation system. Through the simulation results of ansys-icepak, it can be proved that the heat dissipation system design improves the heat dissipation capacity of traditional air cooling. Since the semiconductor heat sink can control the heat dissipation power through the current size, it can achieve a precise control effect. Low temperature may deteriorate battery discharge performance, and low temperature charging may cause safety problems. It is generally believed that when the lowest temperature of the battery is above 0℃, it can be safely charged and discharged to work normally. By using the reverse current, the cold and hot end of the semiconductor refrigeration sheet can be exchanged, and the semiconductor refrigeration sheet close to the battery side can be heated into the heating end of the battery. In the future, a single-chip microcomputer can be added to design a heat dissipation system with precise temperature control to avoid waste of heat dissipation power.

Acknowledgments

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