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Research on the Thermal Management System of BEV $LiFePO_4$ Battery Pack

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Abstract

In order to effectively improve the working characteristics of the power battery of BEV, this paper conducts a thermodynamic analysis on the LiFePO4 battery pack, The changes of internal resistance under different discharge rates and ambient temperatures were measured. Three-dimensional thermal effect model of the battery was established, and the thermoelectric coupling simulation analysis was carried out, Compare the simulation results with the experimental results to verify the effectiveness of the model, and analyze the influence of the air inlet angle on the temperature distribution of the battery pack, and optimize the heat dissipation structure. By studying the influence of air flow and its temperature on the temperature distribution of the battery pack, the heat dissipation structure is optimized to achieve the best performance of the battery pack structure.

Keywords

$LiFePO_4$ battery; discharge rates; thermoelectric coupling simulation; heat dissipation structure.

1. Overview

With the continuous advancement of environmental protection and energy conservation and emission reduction, the policy incentives and market demand for electric vehicles are increasing. Power batteries are the most important source of driving force for electric vehicles. Especially for pure electric vehicles, the performance of the battery directly determines the power performance and the length of the driving range of the vehicle.Therefore, the research on power batteries has always been a very critical part of the development of the electric vehicle industry, and it is also the bottleneck that restricts the development of the electric vehicle industry. The working performance of power batteries is closely related to temperature, and the temperature directly affects the power and performance of electric vehicles. safety.The heat dissipation of the power battery pack has become a key issue. At present, the heat dissipation effect of the battery pack is generally through continuous improvement of the cooling structure or new attempts to pack the cooling medium of the battery.Kim G.H. [1]et al. compared the cooling effects of air cooling and water cooling;Sabbah R[2] et al. analyzed the cooling effect of phase change material cooling and forced air cooling through numerical simulation and experiment;Liu Guangming [3]studied the thermophysical parameters of the battery, and based on the thermophysical parameters, analyzed the heat generation of the battery under different environmental conditions.Lai Pengfei [4]et al. used a combination of model simulation and experimental verification to determine model parameters. Compared with the previous simple heating and baking in the furnace, the furnace experiment adds the step of moving the battery outside the furnace to cool. The improved experiment makes the parameters used in the model closer to the real value, and the model simulation can better complete the predictive analysis work.However, in the above-mentioned documents, people only take measures to innovate the heat dissipation structure and the cooling medium.The method is to simplify the battery model as much as possible without

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considering the battery case.In fact, the thermal conductivity of the shell is very poor, which is a large thermal resistance to the heat conduction of the battery. In previous designs and calculations, most researchers believed that the battery pack and the fluid were only convective heat. Therefore, the fluid was calculated separately[5]. As the thermodynamic boundary of the fluid-solid interface is difficult to accurately estimate the heat transfer and the heat transfer of the battery pack, this leads to larger errors in the subsequent temperature field and thermal characteristics analysis.In fact, it is not only the heat transfer in the overall structure of the convection battery pack, but also the heat transfer between metal materials.These two parts are not independent, but a coupled process[6].

According to the structure and thermal characteristics of the battery, this paper has carried out fine modeling and heat dissipation structure design of the battery pack.Based on the fluid-solid coupling heat transfer mechanism, the fluid inside the battery is combined with heat conduction, and the heat flow on the fluid-solid interface is balanced through the energy equation, and the entire battery is thermodynamically analyzed to further optimize the heat dissipation structure.

2. Analysis of thermal characteristics of LiFePO4 battery

LiFePO4 battery is a power battery that uses lithium iron phosphate as the positive electrode material and is wrapped in an aluminum shell or a steel shell. the inside of the battery is composed of main parts such as positive electrode material, negative electrode material, electrolyte, separator and current collector. As shown in Figure 1.

Figure 1. The LiFePO4 battery

The charging and discharging of lithium-ion batteries is actually the insertion and insertion of Li+ on the positive and negative electrodes of the battery, and the round-trip migration of the same amount of electrons between the positive and negative electrodes. According to the working principle of the lithium iron phosphate battery, the charging and discharging of the battery is the process in which lithium ions and electrons move in the internal and external circuits respectively, and each link generates heat. The heat generated by the lithium-ion battery in the working process will be exchanged through three methods: heat conduction, heat convection, and heat radiation. According to the heat generation principle of the battery, combined with its resistance characteristics, different discharge rates and ambient temperature will affect the inside of the battery. The impact of resistance. When the SOC is between 0.3 and 1, the internal resistance hardly changes with the change of the discharge rate and the ambient temperature; when the SOC is 0.3, the decrease of the discharge rate and the decrease of the ambient temperature will increase the internal resistance of the battery, so it should be avoided as much as possible The battery works at low temperature and low discharge rate.

3. Study on thermodynamic simulation of lithium iron phosphate battery cells

The thermal model of the square lithium iron phosphate battery cell is established, and the temperature rise simulation under different conditions is performed in ANSYS/Fluent to simulate the heat generation and heat dissipation during the discharge process of the lithium ion battery.

Select the BYD model battery size as 130×30×220mm, and use SolidWorks to build a three-dimensional model of this battery cell. Because the internal structure of the lithium battery is

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relatively complex, in order to ensure the quality of the grid and reduce the difficulty of simulation, the structure of the lithium battery is reasonably simplified, and only the core, anode, and cathode of the battery are modeled. Import the assembly into Fluent/Mesh. Since the model has a regular structure and less difficulty in meshing, the method of automatic meshing is adopted to generate corresponding nodes and elements.

4. Simulation analysis of the temperature field of the prismatic lithium iron phosphate battery cell

When the initial environment is set to 25 ℃, the lithium-ion battery is discharged at a discharge rate of 1C, and the graph of the temperature rise of the battery at this discharge rate is shown in Figure 2. At 1C discharge rate, the temperature rise of the single cell in the initial and late stages of discharge is faster, and the temperature rise in the middle stage is relatively gentle. This is because the internal resistance of the battery is relatively small at the beginning of the discharge, and the battery heats up slowly at this time, and the temperature will quickly be higher than the ambient temperature after starting to work.

When the initial environment is 25°C, the lithium battery cells are discharged at a discharge rate of 1.5C. The temperature rise of the battery when the discharge rate is 1.5C is drawn as shown in Figure 3. Through the comparison of the two sets of data, it can be seen that the battery's The heat generation increases with the increase of the discharge rate, and the battery temperature rises accordingly, and at the same time, the temperature difference on the surface of the single battery is increased. It can be seen from the figure that the temperature change trend of the battery cell under1.5C discharge rate is basically the same as that under 1C.

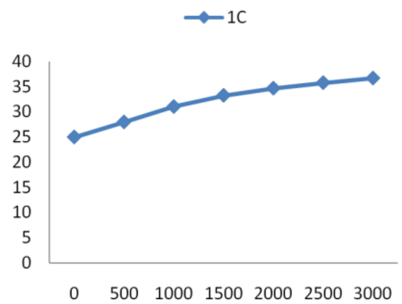

Figure 2. Broken line diagram of temperature rise of battery surface at 1C discharge rate

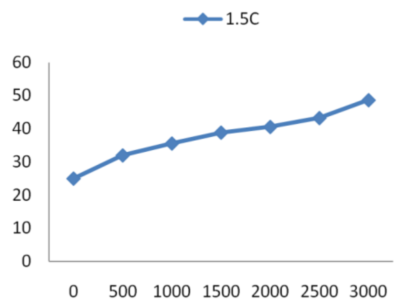

Figure 3. Broken line diagram of temperature rise of battery surface at 1.5C discharge rate

From the results of the single battery simulation, the battery temperature is increasing from the edge to the center of the core. This is because heat is generated inside the battery. The heat at the edge of the battery is dissipated quickly, while the heat at the center of the core is radiated and transferred to the outside. The speed is slow, causing heat to build up.

5. Thermal management system heat dissipation structure and parameter optimization

The heat dissipation effect of the forced air cooling method is directly related to the flow rate of the cooling gas. Increasing the wind speed within a reasonable range can increase the rate of heat exchange, thereby enhancing the heat dissipation effect. In addition, structural parameters should be optimized in terms of battery arrangement spacing and gas inlet angle. When the initial temperature is 25℃, keep other parameters unchanged, and adjust the flow rate of the cooling gas from 4m/s to 5m/s, 6m/s, 7m/s for simulation calculation. The simulation results under different gas flow rates are shown in the figure 4 shown. Comparing the simulation results under different wind speeds, the inlet wind speed is selected as 6m/s.

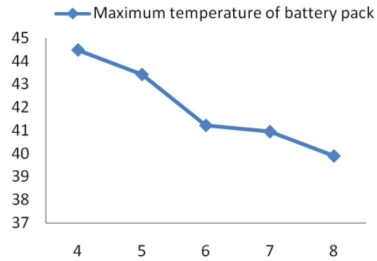

Figure 4. Maximum temperature variation diagram of battery pack under different flow rates

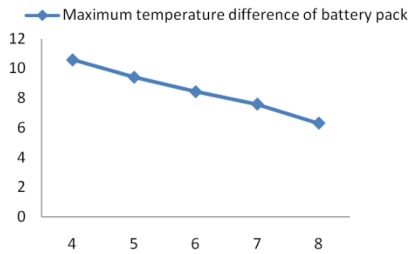

Figure5. Variation diagram of maximum temperature difference of battery pack under different flow rates

By optimizing the battery arrangement spacing, gradually increasing the airflow channels between battery cells with poor heat dissipation effect, which improves the heat dissipation effect and significantly improves the temperature inconsistency between the batteries. By optimizing the battery arrangement spacing, gradually increasing the airflow channels between battery cells with poor heat dissipation effect, which improves the heat dissipation effect and significantly improves the temperature inconsistency between the batteries.

6. Conclusion

The temperature distribution of the battery pack directly affects the performance of the battery. This paper conducts an in-depth thermodynamic analysis of the lithium-ion battery pack, proposes a fine model of the battery, optimizes the heat dissipation structure of the battery pack, and studies the influence of the heat dissipation structure parameters and process parameters on the temperature distribution of the battery pack. The simulation results show that the overall temperature of the battery pack decreases with the increase of the channel spacing and inlet angle. However, if the airflow path is too large and the intake angle is too large, serious backflow will occur, which will affect the heat dissipation effect. Therefore, as the gas flow rate decreases, the maximum temperature of the battery pack will not decrease linearly. When the wind speed is greater than 6m/s, the temperature distribution of the battery pack does not change much, so the best wind speed is 6m/s. The simulation results show that after optimizing the heat dissipation structure, the overall temperature of the battery pack is reduced and the heat dissipation performance is improved.

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