Simulation analysis of air cooling for vehicle power battery

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Abstract. Because of its high voltage, strong storage and circulation ability, no memory effect, high safety, low environmental pollution, Lithium ion batteries are the most widely used as power battery in the electric cars, but its heat dissipation problem cannot be ignored. When the power battery is working, the heat is accumulated. If it cannot be discharged in time, it will seriously affect the normal operation of the battery and even cause danger. As a heat dissipation medium, air can give good consideration to heat dissipation effect and cost. In this paper, CFD software was used to simulate the flow field of the power battery when working. Specific research method of this article is that the heating characteristics of lithium ion battery are studied, by studying thermal field distribution of the battery pack, and the battery pack is optimized to improve. Finally the temperature of the battery pack was kept a reasonable range.

1. Introduction

As the most important component of electric vehicle, the battery pack of electric vehicle is good enough to determine the performance of the vehicle. At the same time, heat dissipation problem is also not to be ignored. Higher capacity density will inevitably bring more heat generated, so heat dissipation problem needs to be taken seriously. Air cooling is the most widely used method in electric vehicle power system. Aiming at the parallel hybrid power connection mode, H.J. Jiao et al [1] developed the air-cooled heat dissipation device by using MH-NI battery in natural convection heat dissipation mode. They put 24 battery modules in two horizontal rows, air flowed into the battery modules in parallel way from the bottom of the battery pack. H. Liu et al [2]. Arranged 16 batteries in sequence and installed triangular baffles at the front of the battery to increase the air flow between the battery gap. The influence of the cooling structure of the battery on temperature and flow field distribution was studied by using CFD software simulation. X. Z. Li et al [3] used 10 Ni-MH batteries to form battery pack, the battery pack was tested for charge-discharge and high-temperature forced cooling. The temperature inside and on the surface of each battery was monitored, it was found that the best heat dissipation effect of the battery pack was achieved by using the insulated grating structure.

This paper mainly studied the thermal field of single battery of electric vehicle power battery and its battery pack. Firstly, by studying the structure and working principle of monomer battery, the thermogenesis of monomer battery is mastered. Then, on the basis of studying the single battery, the thermal field distribution of the battery pack was further studied. CFD software was used to simulate the flow field distribution of the battery pack.
2. Thermal simulation analysis of power battery pack

2.1. Thermal simulation of single battery

Single battery, as the smallest battery unit in the battery pack, is the smallest heating unit in the battery pack. In order to simulate the heat dissipation problem of the battery pack, it is necessary to study the heat generation of a single battery. According to the three dimensional parameters of the battery, some software was used to build the three dimensional model. Based on the three dimensional model, it was imported into CFD software to conduct grid division and further simulation. Fig.1 (a) is the three dimensional model of the battery, and (b) is the picture after the cell was divided into grids, and materials and boundaries were set for each part respectively.

![Battery three dimensional model and grids.](image)

The shell thickness of the battery is 3mm, the material inside the battery in the shell is regarded as uniform heating, the heat generation rate of the battery is 4749.15W/m$^3$ when the battery is discharged at 0.5C. The model of single battery was imported into CFD software, and the material parameters of the battery, the battery heating rate, the boundary conditions, the solver, the iteration steps, was set and calculated. The simulation results are shown in Fig. 2, and Fig.2 (a) is the overall temperature cloud diagram of the battery, andFig.2 (b) is the temperature distribution diagram of the battery surface.

![Overall temperature cloud diagram of the battery and surface temperature cloud diagram](image)

It could be seen from the simulation results that when the battery was discharged at 0.5C, the heat inside the battery would be generated and spread outwards, with the maximum temperature difference approaching 26K. By monomer battery simulation it could be seen that the highest temperature of the
surface of the battery was 47.05 °C, and the lowest temperature was 34.25 °C, the difference of the temperature of was 12.8 °C, and the temperature difference of 12.8 °C was more than reasonable temperature difference of 5 °C battery pack. Therefore, it was necessary to install the cooling system when the battery works in the battery pack.

2.2. Heat dissipation simulation of battery pack
On the basis of simulating the single battery, the heat distribution on the single battery was understood, and the necessity of cooling the battery was determined. Battery pack was the place where batteries were concentrated, and the 100 batteries accumulated heat in the battery pack. If the heat was not discharged in time, there would be danger, so the battery pack was simulated.

There were 100 battery cells in the battery pack. A battery module was consisted of 5 individual batteries, and a battery module was consisted of 5 individual batteries, and a total of 20 battery modules were arranged in series in the battery pack. Fig.3 was that five individual batteries were closely aligned to form a battery module.

![Figure 3. A battery module consisting of 5 single cells](image)

The influence on the heat dissipation for the arrangement of the battery pack in the battery box, that is to say, the distance between the battery modules, was studied. The space was set as 10mm, 15mm, 20mm, 25mm and 30mm, respectively. The distance between the battery pack and the battery box wall was 30mm. The diameter of the inlet was 100mm, and the inlet wind speed was 2m/s. The five clearance structures were shown in Fig. 4 (a) (b) (c) (d) (e), and (f) was the battery box structure.

![Figure 4. Battery pack structure of 5 kinds of clearance and battery box](image)
The pressure, velocity and temperature cloud maps of the five layout forms were obtained by simulation respectively. Fig. 5 showed the temperature cloud diagram of 5 groups of simulation, and (a), (b), (c), (d) and (e) were temperature clouds of simulation, and the spaces between battery modules were 10mm, 15mm, 20mm, 25mm and 30mm respectively.

![Temperature cloud diagram of 5 structures](image)

**Figure 5.** Temperature cloud diagram of 5 structures

As can be seen from the temperature cloud diagram, the temperature at the front of the battery box decreased significantly, and most battery packs at the back still showed high temperature. The interstitial wind speed in the middle of the battery pack was high, and the wind speed on both sides was almost zero. Due to the low inlet wind speed, the overall cooling effect of the battery box was not good.

In order to improve the heat dissipation effect of the battery pack at the back of the battery pack, the influence of wind speed on the heat dissipation of the battery pack was studied. The inlet wind speeds of 1m/s, 2m/s, 3m/s, 4m/s, 5m/s, 6m/s and 7m/s were respectively set, and the inlet diameter was 100mm. The space between the battery pack was 20mm. CFD software was used for simulation analysis and the simulation results were compared. After simulation, the temperature cloud maps of the battery pack in the battery box were shown in Fig.6 (a), (b), (c), (d), (e), (f) and (g), and the temperature cloud maps of the inlet wind speed of the battery pack were 1m/s, 2m/s, 3m/s, 4m/s, 5m/s, 6m/s and 7m/s.
Figure 6. Temperature cloud diagram of battery pack under 7 wind speeds

With the increase of inlet wind speed, the average pressure in the battery box was increased. The increase of wind speed was beneficial to the circulation of air and enhanced the cooling effect, and the maximum temperature of the battery pack in the battery compartment was decreased gradually. As the wind speed continued to increase, the temperature was decreased steadily and the cooling effect was decreased gradually.

3. Conclusion
By setting a reasonable gap between the battery modules, the air could flow more smoothly when it entered the battery box, which could speed up the flow of air and took away the heat generated by the battery pack. The faster the wind speed, the more air flew through the battery's surface, speeding up heat exchange. In addition to accelerating heat exchange, the uniformity of battery temperature in the battery pack should be considered. By increasing the number of inlet and arranging the position properly, air could flow evenly through each battery pack.

This paper provides a theoretical basis for the design of battery pack through the simulation of wind cooling and heat dissipation of electric vehicle power battery. But the accuracy of simulation is limited, at the same time, the influence of other circuit, mechanical structure and control chip on temperature and flow field is not considered, and the simulation of the real situation is not perfect. Therefore, the research on this problem needs to be further improved.
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