Discussion on the Application of New Thermal Insulation Materials for Power Batteries of New Energy Vehicles Based on Computer Analysis

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Abstract. With the widespread use of battery insulation systems, there are many optimizations for the size of the battery space in the box, the arrangement and combination methods, but there are few optimizations for the design of the battery inlet and outlet. This paper analyzes the battery insulation materials, builds a power battery heat generation analysis model, and analyzes the battery air outlet angle flow analysis, the air inlet angle material comparison analysis, and the FLUENT software is used for numerical simulation analysis to obtain the overall smooth characteristics and partial Flow rate and temperature distribution range. Finally, through the analysis of the experimental results, it can be known that for batteries with the same structure, the use of battery insulation materials can effectively improve the battery performance and extend the service life.

Keywords: New Energy Vehicle, Power Battery, Temperature Field, Heat Preservation, Fluent

1. Introduction
As the energy part of new energy vehicles [1, 2], power batteries have an important impact on the performance of the whole vehicle. At present, new energy vehicles on the market are mostly used with high specific energy, high specific power, long life and less pollution. Power batteries are driven by batteries, especially nickel-metal hydride batteries and power batteries [3, 4]. Among them, power batteries are affected by their high voltage, small size, high specific energy, good cycle performance, small self-discharge and no memory effect. The attention of many automobile manufacturers. Under normal circumstances, the space left for power batteries in car design is very limited. At the same time, lithium-ion power batteries for vehicles will be accompanied by a large heat flow during the charging and discharging process. If they are not kept warm in time, it is easy Causes the accumulation of heat in the battery, which affects the performance and safety of the battery. If the heat preservation is uneven [5, 6], it will cause a large temperature difference in the battery. The uneven temperature field of the battery will cause the performance of each battery module and each single battery Imbalance will ultimately affect the performance and reliability of the entire battery. Therefore, in order to enable the power battery system to perform better while ensuring safety, it is necessary to optimize the design of the battery insulation scheme.
Prior to this, many researchers have conducted systematic experimental simulation studies on the overall layout of power batteries, and have also proposed various optimization schemes. Among them, the parallel air cooling method is due to its higher heat preservation efficiency and better heat preservation uniformity. And the lower cost is widely used, this article further discusses the thermal insulation performance of parallel ventilation.

2. Heat production model of power battery

The power battery is mainly composed of positive electrode, negative electrode, electrolyte and separator. The negative electrode of the battery is made of carbon materials, such as graphite, etc.; the positive electrode is lithium-containing transition metal oxide and its doped compounds, and the main source of heat for power batteries. The heat of reaction QT, heat of side reaction QS, Joule heat Qj, and polarization heat Qp generated internally during the working process. There is resistance inside the battery, which is mainly composed of the electrode material and the internal resistance of the diaphragm. When current flows, it will generate Joule heat, which is the main source of battery heat. The expression of the total heat Q of the battery is as follows:

\[ Q = Q_t + Q_p + Q_j + Q_s \approx Q_j \]  

The heat source of the single battery body can be calculated by the above expression, and the heating rate per unit volume:

\[ q = \frac{Q}{V} = \frac{I^2R}{V} \]

In the formula: q is the heat source of the battery body; I is the charge and discharge current of the li-ion battery; generally the internal resistance of the battery; V is the volume of the single battery.

Assume that the lithium ion battery model meets the following content: the battery heat source is a stable heat source; the battery material is uniform inside, that is, the specific heat capacity and thermal conductivity are constant, and the thermal conductivity is the same in the same direction. Where the battery, air, and battery box are the same. The thermophysical parameters are shown in Table 1.

| Parameter               | \( \rho/(kg \cdot m^{-3}) \) | \( C/(J \cdot kg^{-1} \cdot K^{-1}) \) | \( k/(W \cdot m^{-1} \cdot K^{-1}) \) | \( \mu/(kg \cdot m^{-1} \cdot s^{-1}) \) |
|------------------------|-----------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| Battery                | 2898                        | 1010.00                                | 0.95                                   | 2.73                                   |
| Air                    | 1.225                       | 1006.43                                | 0.242                                  | 1.789 \times 10^{-5}                  |
| Battery box            | 2719                        | 871.00                                 | 202.4                                  | -                                      |

3. Establishment of calculation model

3.1. Modeling the research object

Establishing a mathematical model of the power battery system is a necessary condition for computational fluid dynamics (Computational Fluid Dynamics, CFD) simulation. This paper selects a typical vehicle-mounted power battery as the research object for modeling. In order to save computing resources and improve the speed of calculation, Under the premise of ensuring that the internal flow field characteristics are truly reflected, the model is partially simplified, and only one of the battery packs is taken as the simulation object. The simplified model established is shown in Figure 1 (this article selects a certain 18A \( \cdot \)h power battery. The battery cell size is 18mm \( \times \) 65mm \( \times \) 150mm, the gap is 4mm, and a battery pack contains 10 batteries).
3.2. Governing equation for CFD calculation

This article involves the heat conduction of solids and the heat conduction and convection of fluids, and the following control equations are required:

1. Solid heat conduction control equation with internal heat source

\[
\frac{\partial T}{\partial t} = \frac{\lambda}{\rho c} \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + \frac{Q}{\rho c} \tag{3}
\]

2. Control equations of cooling air, including: mass conservation equation

\[
\frac{\partial \rho}{\partial t} + \text{div}(\rho \mathbf{u} \mathbf{U}) = 0 \tag{4}
\]

4. Analysis of the internal temperature field of each plan

4.1. Choice of air inlet angle

In this paper, the method of parallel ventilation and cooling is adopted. Under the condition of the same inlet and outlet conditions, the temperature field distribution corresponding to various air inlet angles \( \theta \) shows that the heat preservation effect of the battery does not simply increase with the increase of the air inlet angle. The distribution map of the battery temperature field, select the point where the internal temperature of each battery is close to the highest value as the observation point for analysis, the temperature point selection is shown in Figure 2, and the 10 circles shown in the figure are the corresponding monitoring points. Figure 3 is 4 The temperature distribution of each selected measurement point under the angle of the air inlet, it can be seen that the air inlet angle \( \theta \) is 0, and the cooling effect is equivalent at 1 and 2, and only slightly improved at 3, indicating that in the battery used in this article, the angle of the air inlet is not ideal for the improvement of the insulation effect.
4.2. Selection of air inlet flow rate
The temperature of each monitoring point at different air inlet speeds is shown in Figure 4.

![Figure 4](image)

**Figure 4.** The temperature of each monitoring point under different air inlet speeds.

It can be seen from Figure 4 that below 25m/s, the thermal insulation effect of the battery increases significantly with the increase of the air inlet flow rate. After 25m/s, the increase in the flow rate increases the thermal insulation effect less significantly.

4.3. Local optimization of battery insulation scheme
Through the above simulation analysis, it can be seen that under the blast cooling condition, the highest temperature measurement point is on the second battery, so after the partial rounding treatment, the maximum value of the battery temperature is reduced, and the maximum temperature of the measurement point is also lower. The maximum temperature is reduced, and the uniformity is also significantly improved. Figure 5 compares the cases where there is no rounded corner and the rounded corner radius r is 1mm, 2mm, 3mm and 4mm.
Figure 5. The temperature of each point when taking different fillet radii.

It can be seen from Figure 5 that the maximum temperature and uniformity of the rounded corners are significantly improved. With the increase of the rounded corner radius, the temperature of the second monitoring point is significantly reduced. The overall effect is the best when the rounded corner is 1mm, but the battery The overall temperature distribution did not continue to improve as the fillet radius increased.

5. Conclusion
In this paper, under the condition that the battery inlet and outlet structure is unchanged, the side-ventilated battery structure has better warmth retention than the positive-ventilated battery structure. The selection of thermal insulation materials is beneficial to improve the efficiency of electric vehicle batteries. The import and export are mainly a diagonally distributed shape, and the speed of the air flow is relatively large, showing an upward development trend. Therefore, the application of thermal insulation materials to the battery of electric vehicles can significantly improve the performance of electric cars and shorten the import and export. The spacing can promote the lateral air flow speed, make the air distribution in the battery box more uniform, and improve the uniformity of temperature distribution in the battery.

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