Thermal Simulation Analysis for Cylindrical Lithium-Ion Cell

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Keywords: Cylindrical lithium-ion cell, Temperature distribution, Uniformity.

Abstract. Because of the excellent temperature stability and temperature uniformity, cylindrical lithium-ion cells are widely used in the field of electric vehicles. In the paper, 18650 cylindrical lithium-ion cell has been simplified in order to analyze the heat dissipation by simulation analysis method, and then the conditions about cell temperature distribution and uniformity has been obtained at different discharge rates.

Introduction

The selection of cell is related to the consistence, the ability of heat dissipation, and the safety for the cell system. Generally speaking, the consistence of the cell is mainly determined by the production process of cell manufacturer, but most cells are artificially controlled and consistence of the cell can’t reach the appropriate level [1]. If the consistence of the cell is not up to the requirements, cell management formed by a large number of batteries in series and parallel will also not allow the performance of each cell to play better. The cooling capacity of the cell is mainly determined by the capacity of the cell, the greater the cell capacity, the higher the energy of the cell. The safety for cell is inversely proportional to the energy stored in the cell. In the application of electric vehicle, with the increase of the volume of the cell, the cooling dissipation performance becomes worse. If the temperature of a cell is too high, the accident will also spread to the module. If the capacity is small, according to the abnormal situation of the accident, the cell or its module will switches off to prevent the spread of the accident [2]. In short, the cell can not be designed too large. In the application of electric vehicle, small capacity cell is usually used in series and parallel to achieve higher capacity, which is also the main reason for the tesla’s selection of 18650 cell [3].

Model Simplification for Cylindrical Lithium-Ion Cell

In this paper, 18650 column lithium-ion cell is selected as the research object, the specific parameters are as follows:

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Mass [g]</th>
<th>Density [kg/m³]</th>
<th>Specific heat [J/kg·K]</th>
<th>Conductivity [W/m·K]</th>
<th>Energy Density [W/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>18650 Li-ion</td>
<td>42.3</td>
<td>2560</td>
<td>1292</td>
<td>λ_r=0.4456</td>
<td>37170</td>
</tr>
<tr>
<td>(3.7V/3.2Ah)</td>
<td></td>
<td></td>
<td></td>
<td>λ_z=6.137</td>
<td></td>
</tr>
</tbody>
</table>

The internal structure of lithium-ion power cell is complicated, so it is necessary to simplify and assume the model of the cell when studying the temperature of the cell body in the natural convection condition. In this paper, Pesaran method [5] is used to simplify the cell which is simplified as the internal and external of the cell. As shown in Figure 2, the heat Q_n released by the internal heat source of the cell flows through the inner cavity to the outside of the cell by means of the heat conduction, and finally, the natural convection heat transfer of the air is carried out in order to achieve the purpose of heat dissipation. The natural convection heat transfer coefficient is 5 W/m²·K, and the ambient temperature is 20°C. The simplified model is mainly for the analysis of the temperature rise and heat dissipation.
dissipation of the cell under the cross flow and limited voltage discharge condition, and the cell operated under different discharge rate can be used in the actual operation of the electric vehicle.

![Figure 1. 18650 Li-ion cell used in this paper.](image1)

![Figure 2. Simplified model of cell.](image2)

**Simulation Analysis for Cylindrical Lithium-Ion Cell**

According to the parameters in Table 1, the geometric model and mesh model of the cell are built by using ICEM, as shown in Figure 3. When the mesh is divided, the structured mesh is suitable for the simple geometry, but it is difficult to generate the complicated mesh for the complex geometric model. However, for complex shape, unstructured grid is a good choice, and the use of a second-order upwind still had a higher accuracy with a better adjustability and controllability. In this paper, the unstructured grid generation method is used to densify outer boundary of the cell.

![Figure 3(a). The geometric model.](image3a)

![Figure 3(b). The mesh model.](image3b)

Through importing the mesh file of the grid model into the FLUENT software, loading internal heat source for center region of model, setting the convective heat transfer coefficient and the iteration step in each running condition etc, the maximum temperature and the minimum temperature were simulated and calculated, and the change of temperature under different discharge rates (1.0C, 2.0C, 5.0C) was compared in the same environment condition \( (h_{\text{out}}=5 \text{ W/(m·K)}, T_{\text{out}}=20 \text{ °C}) \).

**The Temperature Rise of the Cell**

At the same time, the cell’s the highest temperature appears in the position of the center, the lowest temperature appears in the outer wall of the cell, namely the position of contact between cell and air. These results are illustrated in Figure 3, Figure 4 and Figure 5, their instantaneous maximum temperature and minimum temperature of the cell are different under different discharge rates. In particular, the temperature at cell center is 302.35K, the temperature at cell wall is 301.05K at the end of the discharge under 1.0C discharge rate, the temperature at cell center is 321.26K, the temperature at cell wall is 319.35K at the end of the discharge under 2.0C discharge rate; the temperature at cell center is 343.55K, the temperature at cell wall is 338.95K at the end of the discharge under 5.0C discharge rate. Thus the higher the discharge rate, the faster the temperature rise of the cell, correspondingly, the higher the temperature at the end of the discharge.
Comparative Analysis About the Temperature of the Cell

In Figure 7, Figure 8 and Figure 9, the maximum temperature at the center of the cell and the minimum temperature at the outer wall of the cell follow the same change law with the change of time, which are increasing as time increases. The difference is that the temperature differences of the cell are diverse under different discharge rates, which the maximum temperature difference of the cell is 1.1 °C under 1.0C discharge rate, 2.3 °C under 2.0C discharge rate, 4.9 °C under 5.0C discharge rate.

Therefore, not only the cell temperature is not the same, but also the uniformity of the cell is different. The higher the discharge rate, the higher the temperature of the cell, the lower the temperature uniformity of the cell.
Conclusion

Based on the simulation of 18650 cylindrical lithium-ion cell, we can conclude the following for the cell under different discharge rates. The higher the discharge rate, the faster the temperature rising of the cell, correspondingly, the higher the temperature at the end of the discharge. The difference is that the temperature differences of the cell are diverse under different discharge rates: The maximum temperature difference of the cell is 1.1 °C under 1.0C discharge rate, 2.3 °C under 2.0C discharge rate and 4.9 °C under 5.0C discharge rate. The higher the discharge rate, the higher the temperature of the cell, the lower the temperature uniformity of the cell.

References


