A Research of Electro-thermal Coupling Model for Lithium-ion Battery with Multiphysics in COMSOL Multiphysics®

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Abstract

A new method is proposed to study battery thermal behavior under nature convection condition, especially focusing on temperature rising and inhomogeneity of battery. Using porous electrode theory, an electrochemical and homogenization heat source thermal coupling model and an electrochemical-distributed heat source thermal coupling model are established. In the meanwhile, to improve inhomogenity of battery, the tabs layout plans are classified into three types according to electrochemical pole piece model.
In this study, heat source in battery core is assumed to be homogeneous. Firstly, a one-dimensional electrochemical reaction model is established based on battery core, and then heat generation rate is obtained from electrochemical theory. Secondly, to established solid heat transfer model, relevant parameters of battery are consulted, calculated and measured. Thirdly, to build electrochemical and homogenization heat source thermal model for a 40 Ah lithium ion phosphate battery, heat generation and temperature between models are coupled. Finally, temperature sensors are arranged inside the battery to collect the temperature data and to demonstrate the accuracy of the simulation result.
To build electrochemical-distributed heat source thermal model for 40Ah lithium ion phosphate battery, 2C and 3C constant discharge current are selected. And then the current density and temperature distribution inside the battery are measured.
To build electrochemical pole piece model for 8Ah power lithium ion phosphate battery, 15C and 30C constant discharge current are selected. Based on these experiments, current and voltage field in three different tabs layout plans are compared. Afterwards, the result could provide foundations for battery core design and optimization.
An electrochemical and homogenization heat source thermal coupling model could represent overall temperature increasing of battery. However, heat generation rate in battery core relates with current density and voltage distribution. Thus, electrochemical and homogenization heat source thermal coupling model could only be used when current density distribution is homogeny.
Current density distribution and voltage distribution give birth to thermal distribution through analyzing simulation result and theory formula. Besides, state of charge (SOC) and impedance also have impact on thermal distribution. In a word, at the beginning of discharge period, the part close to tabs generates more thermal than other parts. During the middle period, the heat generations between different parts become closer. And at the end, the part close to tabs

generates less thermal than other parts.
When negative tab and positive tab layout on the same side of the pole piece, the voltage distribution of pole piece has bigger difference value. When they layout on the different side, the maximum voltage difference will be decreased.
Tabs layout plans don't take temperature distribution, current density distribution and voltage distribution coupling into account. At the same time, battery impedance change instantly during discharge period. This study doesn't provide properly explanation.
This paper validates thermal model from low dimension to high dimension, single physical field to multiphysics field. And a new method for optimizing battery tabs layout plans is provided, which give a foundation for the establishment of the entire top-down battery thermal model system.

Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4