Study on the Thermal Behaviors of LFP Aluminum-laminated Battery with Different Tab Configurations

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Abstract

Abstract: A 3.2V/10Ah LFP aluminum-laminated batteries are chosen as the target of the present study. A three-dimensional thermal simulation model is established based on finite element theory and proceeding from the internal heat generation of the battery[13]. The study illustrates a three-dimensional relationship among the total internal heat generation rate of the battery, the discharge rate of the battery, and the depth of discharge. The interior chemical reversible heat of the battery is manifested by the endothermic process when DOD is smaller than 0.7 and by the exothermic process when DOD is larger than 0.7. The irreversible heat takes an increasingly dominant role with the increase of discharge rate; under the condition of high-rate discharge, batteries with a single-side tab distribution are generally found to have a non-uniform cell temperature distribution, while those with a double-side tab distribution have improved cell temperature distributions[10-12]. Widening the tabs can also greatly reduce the maximum temperature of the cell.

Introduction

Lithium-ion batteries feature high working voltages, high energy densities, long life spans and low self-discharge rates, and thus have been widely applied in high-power applications. Battery design can be guided by adopting the currently fast-developing computer numerical simulation technology. By combining the related theory of heat transfer and establishing the electro-thermal model of batteries, numerical simulation can shorten the design cycle, by gaining time and cutting costs.

Compared with the traditional experimental verification, numerical simulation has been shown to be unparalleled in its superiority as a battery thermal design technique.

The 3.2V/10Ah LFP aluminum-laminated batteries are chosen as the target of the present study. By establishing a three-dimensional thermal simulation model based on finite element theory and proceeding from the heat generation inside the battery, the study discusses in detail the evolution of different heat generation mechanisms during the batteries' dissipation process, and probes into the cell temperature distributions of batteries with different tab designs.

Model Development

The essence of thermal simulation of the battery is in its internal energy conservation of the battery:

the term of heat source q adopts the expression approach of Thomas K E:

By ignoring the third and fourth terms of Equation (2), we can obtain the Bernardi equation of heat generation:

$$q=I(U_{avg}-V)-IT\frac{dU_{avg}}{dT}$$

$$Q_{hir}=I(U_{avg}-V)=I^2 R_{cell}$$

$$Q_{hr}=-IT\frac{dU_{avg}}{dT}$$

The calculation equation of heat generation rate of tab is as below:

$$q_{(Al, Cu)}=Q_{(Al, Cu)}/V_{(Al, Cu)}=(I^2 R_{(Al, Cu)})/V_{(Al, Cu)}$$

Based on Newton's law of cooling

$$\lambda(\partial T/\partial n)=h(T_{amb}-T_{\infty})$$

Conclusion

A three-dimensional thermal simulation model based on finite element theory is established using 3.2 V/10 Ah LFP as the research object. The thermal behavior of the discharge process can be effectively simulated by coupling the dynamic changes of the battery temperature, internal resistance, and voltage temperature coefficient.

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Figures used in the abstract

Figure 1: Fig. 1. The contrast of contours between infrared imagery and simulated temperature distribution in natural cooling condition (a) 3C discharge; (b) 5C discharge.

Figure 2: Fig. 2 The heat calculation(top) and three-dimensional relationship(down)

Figure 3: Fig. 3. The temperature distributions of the center section under different rates. (a) 1C; (b) 3C; (c) 5C; (d) 10C.

Figure 4: Fig. 4 Temperature variations at the end of discharge at 3C，5C，10C on the MN line of three batteries with different tab distributions