Statistical Sensitivity Analysis of Li-ion Pouch Battery Cell Dimension and Design

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Abstract

1.Introduction

Lithium-ion batteries play an important role as energy carriers in automobiles area mainly in Hybrid Electric Vehicles (HEVs), Battery Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs)[1-3].
Large size lithium-ion pouch batteries are widely used in HEVs and EVs, and are also generally subjected to heavy demands. These solicitations increase significantly the battery temperature and may cause a non-uniform distribution of temperature, voltage and current [7]. These phenomena lead to a local degradation of the battery, and then reduce its lifetime and performances. To avoid this, there is a need of good battery system designers in term of thermal and electrical distributions.
Multi-Scale and Multi-Dimensional (MSMD) modeling approaches [4-7] have been proposed to simulate the thermal, electrical distributions and concentration behaviors of large size pouch cell. This approach is based on coupling of the energy balance with the Newman's electrode model [5]. Newman's 1D electrochemical model is often used for small size batteries but not sufficient enough for large size where significant 3D gradients of temperature, voltage, current and concentration can be observed throughout the battery.

In this work, an advanced 3D simulation tool, using a Newman's pseudo two dimensional (P2D) model coupled with the heat equation for large format pouch lithium-ion cells (45Ah), has been developed in COMSOL Multiphysics® environment in order to investigate the impact of tabs localization and size on the thermal and electrical distribution throughout the battery.

2.Methodology

The model used in this work is based on the resolution of several equations such as the electrochemical kinetics, the solid-phase lithium transport, the lithium transport in electrolyte, the charge conservation and the energy conservation. The outputs from this model are: solution phase lithium ion concentration, solid phase lithium concentration, solution current, reaction rate, solid

potential, solution potential, heat generation and temperature.
Firstly, the model has been used to simulate the battery behavior at different constant current rates during charge and discharge events (1It, 3It, 5It) applied on a pouch cell (45Ah). Then, the model results have been compared to the experimental results. After validation step, different tabs localizations and sizes configurations, as shown in Figure 1, are investigated and compared.

3.Results

The simulation results performed at 1 It-rates (45A), as shown in Figure 2, are in good agreement with the experimental results, where the error varies between 0-1°C for the temperature and less than 0.1V for the voltage with exception at the beginning of charging process.
Figure 3 shows the results of the statistical analysis of the temperature and voltage distribution for each configuration. The distribution is calculated by the absolute difference between the maximum and minimum and then we took the maximum in function of time. They show that the case 2 present a thermal and voltage distribution more uniform comparing the case 1 where a more heterogeneous behavior is noticed.
All remaining results, such as the thermal and voltage cartography as a function of configurations and also the behaviors of the average voltage and temperature, will be include in the final paper.

Reference

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Figures used in the abstract

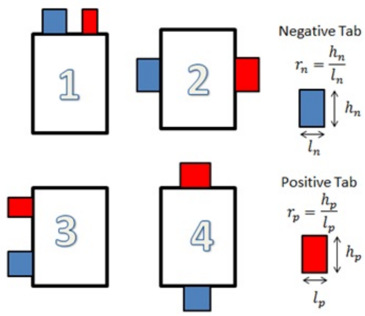

Figure 1: Configurations of Tabs localization and size

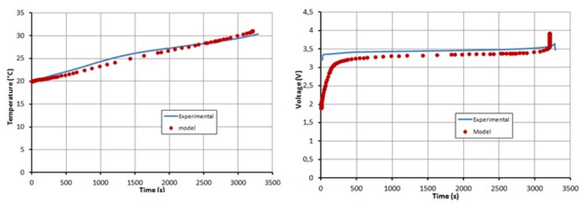

Figure 2: Comparison between experimental and model at 1

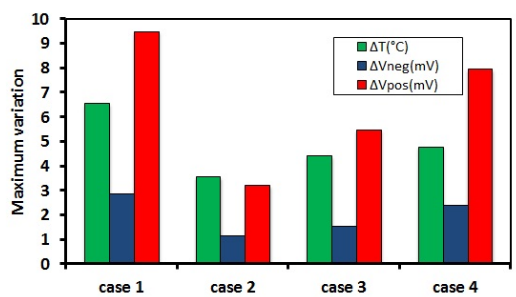

Figure 3: Statistical analysis of thermal and voltage distributions at different configuration