Thermal and Electrical Optimization Design of Pouch Battery Cell Based on Advanced Simulation Tool

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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 such as fast charge and quick acceleration of the vehicles. 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 for optimized thermal management in order to keep the battery in the safety operating range and also 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 behaviours of large size pouch cell. This approach is based on a coupling of the energy balance with a Newman's electrode model [5]. Newman's 1D electrochemical model is often used for small size batteries but not sufficient for large size where significant 3D gradients of temperature, voltage, current and concentration can be observed along the height and the width of 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 simulation tool in order to investigate the impact of tabs localization and size on the thermal and electrical distribution throughout the battery.

2. Methodology

The P2D thermal-electrochemical modeling 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 is used to simulate different constant current charge and discharge ($1I_t$, $3I_t$, $5I_t$) applied on a pouch cell. Then, we compared the model results to the experimental results. After validation step, different tabs localizations and sizes configurations, as shown in Figure 1, are investigated and compared.

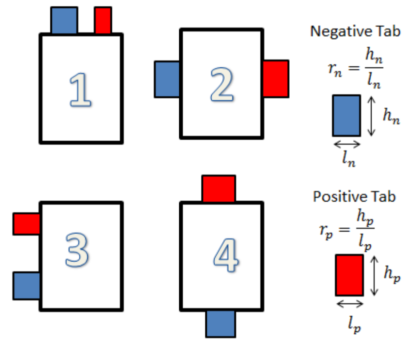

Figure 1: Configurations of Tabs localization and size

3. Results

The simulation results performed at It-rates (45A), as shown in Figure 2, are in good agreement with the experimental results, where the error varies between 0-1°C.

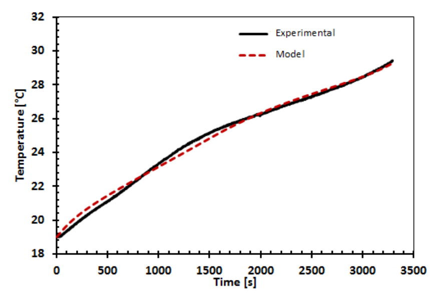

Figure 2: Comparison between experimental and model at I_t

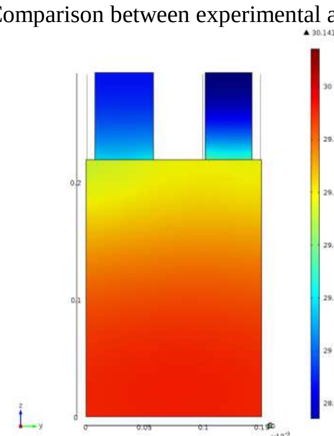

Figure 3: Thermal distribution at the end of I_t charge

Figure 3 shows the thermal distribution where the hottest zone is located at the lower part of the battery.
All remaining results, such as the thermal and voltage distributions as a function of the tabs localizations and sizes, will be include in the final paper in order to determine the best configuration.

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