Large and High Power Cylindrical Batteries - Analysis of the Battery Pack Temperature Distribution Using the COMSOL Multiphysics® and MATLAB® Simulation Softwares

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Abstract

Nowadays, "green" cars such as the EVs, HEVs or PHEVs allow solving major environmental issues. Although to guarantee their safety and improve their lifetime, a special care has to be brought to the good monitoring of the temperature distribution occurring at the level of their battery packs.

Therefore, to achieve accurate predictions of the heat generation and the thermal response of a battery pack made of large cylindrical lithium-ion batteries, this paper will present two reduced 2D models developed using the COMSOL Multiphysics® and MATLAB® softwares. The battery packs considered in this paper are supposed to be made of cells arranged according to the "in-line" or to the "staggered" configurations.

The first battery pack model is based on a "homogeneous" modelling of the internal region of each cell, whose thermal properties are approached by the mean values of the thermal properties of each layer of the cell. The second model is based on a "cross-sectional" modelling of the internal region of each cell, in which all the different layers of the cells are represented and associated with their respective thermal properties. For each of the two battery pack models, a coupling between the "lithium-ion battery physics" (at the 1D level) and the "conjugate heat transfer physics" (at the 2D level) was implemented. The heat generated by the different layers represented in the 1D lithium-ion battery module, was defined as the "heat source" value associated (in the conjugate heat transfer physics) to each of the battery internal regions or domains. MATLAB® was also used for the post-processing of the simulations results obtained with the models, and for the implementation of the specific volumetric heat generation rate occurring at the level of each of the different layers of the 1D model.

Because of the lower temperature gradient in the longitudinal direction of the cell compared to the radial direction (observed formerly with 3D simulations at the scale of a single cell), the conventional 3D modelling approach of a battery pack can be successfully reduced to the

development of 2D models. The temperature distributions obtained inside the pack at the end of the simulation time of a 5 It (90 A) constant current discharge, without airflow (closed pack) and with airflow, are given by Figures 1 and 2 respectively. Figures 3 and 4 represent the airflow velocity obtained inside a pack associated with an internal staggered and an in-line cells arrangement.

The results obtained with the cross sectional model, and the curves of the temperature time evolution of each cell in both 'in-line" and "staggered" packs will be also presented and analyzed. To find the best and optimum parameters values of a pack and its coolant fluid, a parametric study will be conducted in this paper to find out the most significant design parameters and assess their influences on the temperature distribution obtained. These accurate 2D models developed in this study allow for time and cost reduction regarding the development of improved thermal management systems for battery packs.

Figures used in the abstract

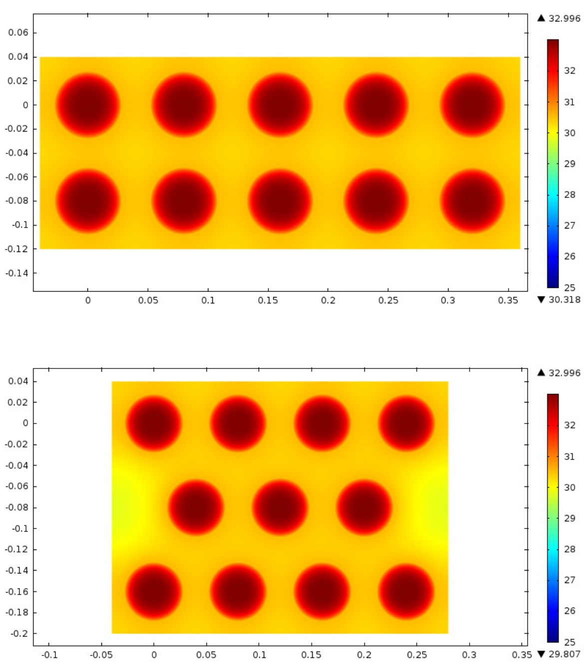

Figure 1

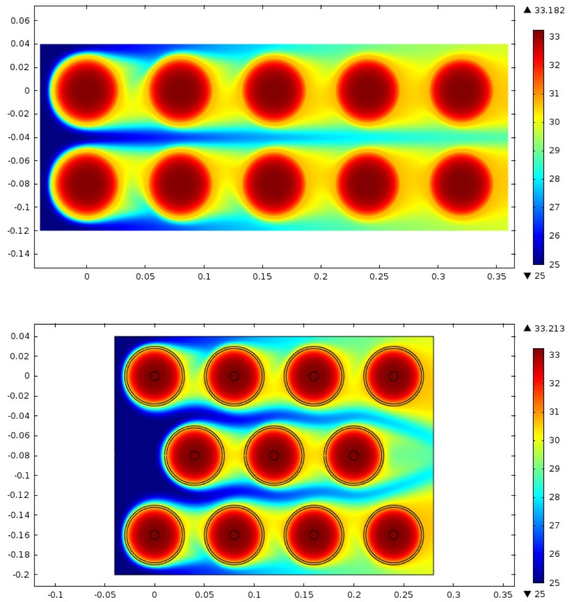

Figure 2

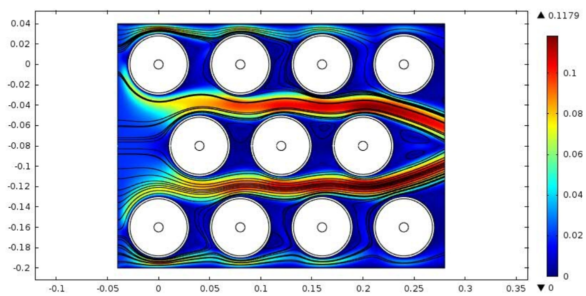

Figure 3

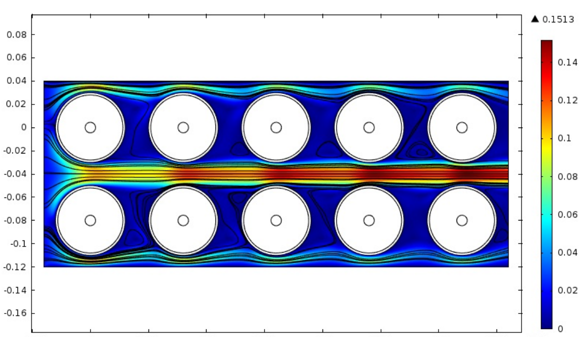

Figure 4