Thermal Analysis on Module Level in an Automotive Battery Package

Z. Wu[1], H. Kemper[1]

[1]Energy Storage Systems, FH Aachen, Aachen, Germany

Abstract

Vehicles with battery as energy storage fascinate more and more people. Meanwhile, more questions are surfaced - How to ensure a safe operation of the battery package? How long could the cycle life of a battery package reach? Can a battery package be operated in any environmental circumstance? All these questions are the driving forces of our work - development of the optimal battery packs for specified automotive mission profiles.

An automotive battery pack can be divided into 3 levels - package, module and cell (Figure 1). Depending on the chosen technologies and cell chemistry, cells in the battery package have their own acceptable operational temperatures. However, the temperature control of a battery package is majorly done on module level. The temperatures of all cells during operation are not monitored, which may lead to severe failures.

During our work, the modelling tools Heat Transfer Module, Batteries & Fuel Cells Module and AC/DC Module of COMSOL Multiphysics® are utilized to analyze the thermal behavior both on the cell level and on the module level. A 3D model of single cell is constructed during the early stage of our work (Figure 2). The simulation results are validated by tests. An agreement between the simulation and test is reached.

Base on the 3D model of single cell, an array of cells are modelled and simulated, which delivers the heating of a module. Figure 3 shows the temperature rise of the module under forced convection. Depending on the position of individual cells in the module and the cooling method, the heating of cells varies. The maximal absolute temperature of all cells shall not exceed their maximal acceptable operational temperature, which is one of the most important criterions in battery package design.

A battery module for automotive application contains not only single cells but also other components. Therefore, we are currently constructing a 3D model on the module level including all indispensable components shown in Figure 4, which will push the thermal simulation of the battery pack to a new level. We are optimistic to accomplish the 3D model on the module level by August 2016. The simulation results will be validated through tests using our battery testing system. Besides, the 3D models constructed in COMSOL plays an important role in planning the battery tests. In other words, the testing plan is primarily designed basing on the simulation results for 2 reasons:
1. Safety. The results of 3D models contribute immensely in minimizing the risks to

surpass the maximal operational temperature of the cells and hence destroy them.
2. Measurement difficulty. Due to the construction of the module, temperature measurements of certain cells in the module during operation is often difficult. In this case, the simulation results offer a good approximation.

For the long term, our goal is to develop an advanced methodology for designing and prototyping automotive battery packages with simulation tools such as COMSOL to utilize the power of numerical analysis to shorten the development procedure and minimized the costs.

Figures used in the abstract

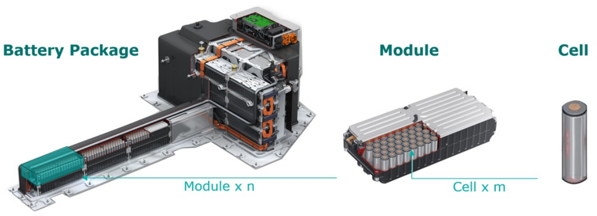

Figure 1: 3 levels of an automotive battery package
[Source: Audi AG]

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Figure 2: Heating of a single cell

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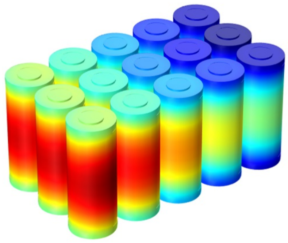

Figure 3: Temperature rise of a 48 V battery module under forced convection

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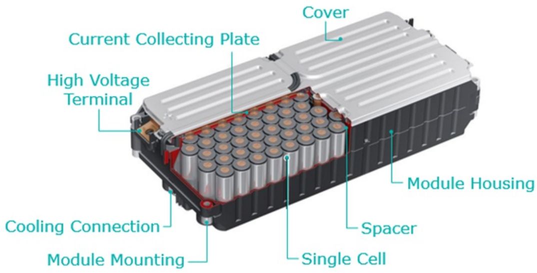

Figure 4: Battery module with all indispensable components

[Source: Audi AG]

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