IAV's Multi-purpose Coupling Solution For Electro-physicochemical Battery Models Via COMSOL®-API

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Abstract

Automotive battery development faces complex challenges requiring time- and cost-efficient progression. One critical issue is the limited availability of physical prototype cells at various stages of design, chemistry, age, and health. However, a highly integrated model-based developing process can enhance engineering effectiveness across all phases by allowing performance optimizations towards typical requirements of automotive applications.
Electro-physicochemical modeling (EPCM) addresses the need for independence from assembled cell prototypes by providing high-fidelity simulated cell data. These models can be used for benchmarking different cell chemistries, designs, or performances, supporting development and optimization of functions, cooling concepts, or layouts as well as evaluating safety topics. To fully leverage EPCM's, the data must be seamlessly accessible across other existing tools chains to foster acceptance and applicability within model-based development.
Our presentation focuses on coupling pseudo-two-dimensional (P2D) cell models in COMSOL® Multiphysics with other vehicle simulation environments such as GT-SuiteTM or SIMULINK®. By doing so, it becomes feasible to investigate the impact on the electrochemical behavior (performance, aging) of these cells at a system level while considering interactions over dynamic boundaries (e.g. temperature, coolant flow, balancing). We demonstrate this coupling solution's utility through two specific application examples. First object focuses on early detection of cell anomalies in a module by modeling different internal short circuit resistances to mimic a faulty cell. The second example is placed on thermal management of a battery and cooling system containing two substantially different next-gen cell chemistries: sodium-ion and solid-state lithium-ion cell in a "Twin Battery" concept.
We accomplished this by integrating cell models into simplified 3D partial battery packs including thermal models and cooling circuits - if required. Utilizing the COMSOL tools Application Builder and Compiler™, the models are packaged into customized apps and then optimally compiled. Subsequently, COMSOL API and Java® code couple these compiled apps with vehicle simulation environments in third-party software for co-simulation, defining model inlets and boundary conditions (e.g., inlet current, coolant inlet temperature and mass flow, heat rates at boundary surfaces and initial conditions). The COMSOL App returns voltage, SOC, temperatures, and power dissipation and makes all internal cell states available for interpretation as required.
Our approach significantly enhances the capabilities in using customer specific COMSOL® battery models for automotive system development within the existing tool chains.
This presentation is based on published works presented at the International Vienna Motor Symposium (Vienna, AUT) in 2023 and the International Battery Seminar & Exhibit (Orlando, USA) in 2024.

Figures used in the abstract

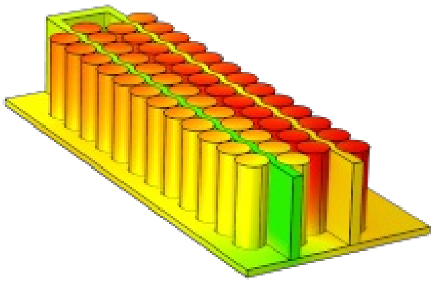

Figure 1