Modelling Thermal Runaway Propagation In A Lithium-ion Battery Module Using COMSOL Multiphysics

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Abstract

Thermal runaway (TR) is a critical safety hazard in lithium-ion battery systems, particularly in large energy storage installations and electric transportation applications. TR occurs when the cell temperature exceeds a certain threshold value, triggering a series of exothermic decomposition reactions and processes within the Li-ion cell. Once TR begins, the temperature rises rapidly and continues until the battery burns out, or in the worst case, it may explode.

This paper presents a thermal runaway model for a simplified prismatic lithium-ion battery module, developed using COMSOL Multiphysics®. The model presented in this paper is developed to have a good balance between simulation complexity and availability of parameters. The internal structure is modeled using a large jellyroll with anisotropic thermal conductivity and simplified current collectors. An external heat source is applied to one of the outer walls of the module to create an abuse condition and trigger TR.

The model uses COMSOL's Event interface to simulate the onset and progression of exothermic reactions through discrete, indicator, and implicit events. Electrochemical heat generation is excluded to isolate thermal effects. The Heat Transfer Module is used to simulate conduction, convection, and heat generation within the module. The fan is modeled as an outflow condition airflow, representing active cooling present in the actual battery module.

This model can be used to study how key design parameters, such as module geometry, insulation materials, and airflow conditions affect the initiation and propagation of thermal runaway. The developed model also helps in identifying strategies to mitigate or reduce the impact of TR events.

Figures used in the abstract

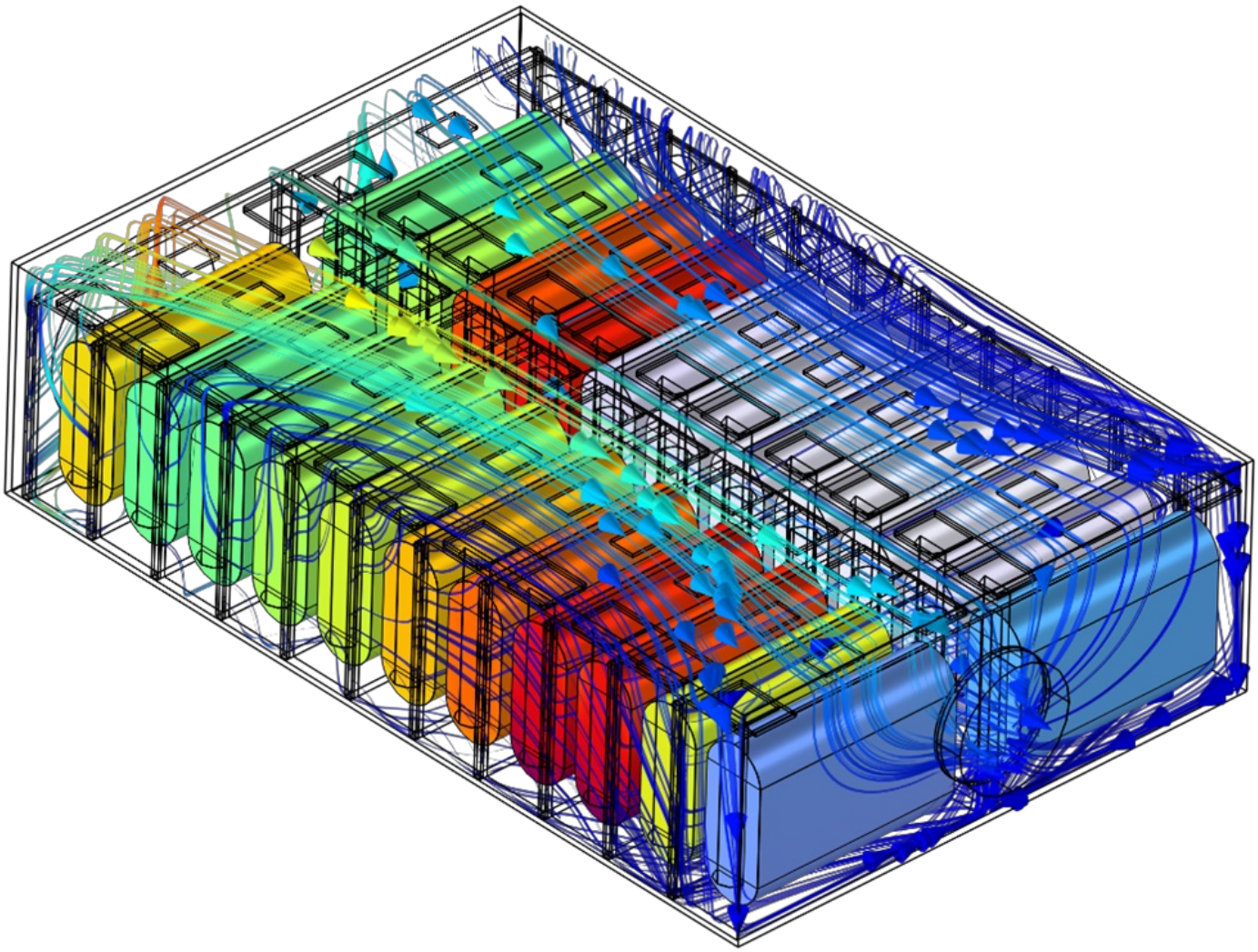

Figure 1 : Temperature distribution in battery cells during thermal runaway, with airflow streamlines