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ABSTRACT

Constructal Design of a Finned Reservoir Filled with Pcm for Temperature Control of Lithium-Ion Battery Packs

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Constructal Theory is a multidisciplinary view that supports the idea that the configuration/evolution of a flow system - animated or not - does not occur randomly but through a physical principle, the Constructal Law. In the constructal realm, evolution in time is the design change of a system that can freely morph, including the design of engineering systems, where the constructal law is applied through the Constructal Design Method (CDM). The CDM guides the designer (in time) towards flow architectures that achieve progressively higher global performance for the specified flow (fluid flow, heat flow, and others). In engineering, this method has been used to study the geometry of finite-size flow systems, such as the cooling systems of lithium-ion (Li-ion) battery packs, which have a limited volume in electric vehicles (EVs). Therefore, CDM is a suitable tool for the design of Li-ion battery cooling systems, whether they are active, with coolant circulation, or passive, using Phase Change Materials (PCM). This work, through the CDM, aims to investigate the effects of the design parameters of a finned reservoir, filled with PCM - applied to control the temperature of a Li-ion battery pack in a certain range. The proposed problem is addressed numerically through simulations using the finite volume method. The mathematical model consists of the conservation equations for mass, momentum, and energy, along with the enthalpy-porosity model used to model PCM melting. The spatial discretization of the computational domain is performed by applying the two dimensional structured grid meshes, whose uncertainty is determined by the GCI (Grid Convergence Index) method. The results indicate that the number of fins and the spacing between them have a significant influence on the PCM melting and, consequently, on the battery cooling. The maximum temperature reached by the battery is significantly lower with the finned reservoir compared to the finless one, which is considered the baseline geometry.

Keywords: Constructal Design. Lithium-Ion Battery. Battery Pack Temperature. Battery Cooling. Thermal Runaway.