Abstract

The dissertation concerns the application of metamodeling and optimization methods to the design of selected structural components of lithium-ion batteries subjected to dynamic loading. The main research problem is the high computational cost of optimization when successive design variants require nonlinear finite element analyses accounting for contact, plastic deformation, and damage evolution.

A hybrid optimization method combining a quantum-inspired evolutionary algorithm, FEM, and metamodeling was developed. Surrogate models were constructed using FEM results to reduce the number of computationally expensive objective function evaluations. Artificial neural networks, Kriging, and polynomial regression were compared, with particular attention to the influence of training dataset size and origin on prediction quality. Separate surrogate models were also applied to regions characterized by different types of mechanical response, particularly cases with and without damage initiation.

The methodology was verified using a parametric model of an integrated lithium-ion battery housing with three geometrical design variables. The numerical model was developed in Abaqus, while Python was used to automate the computational procedure. The reference approach based on FEM objective function evaluations was compared with hybrid variants employing surrogate model predictions.

The results demonstrated that computational time can be significantly reduced while maintaining comparable optimization results. The total time of four optimization runs was reduced from 133 h for the reference approach to 39 h 25 min and 28 h 5 min for the hybrid variants. The most favorable compromise between computational efficiency and solution reliability was obtained when the best solution indicated by the surrogate model was subsequently verified using FEM. The study confirmed that metamodeling can effectively support the optimization of battery structures subjected to dynamic loading.