

OPTIMIZATION APPROACHES FOR BATTERY PACK LAYOUT AND INTEGRATION: A REVIEW OF METHODS, TOOLS, AND RESEARCH GAPS

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Keywords: battery pack optimization, battery module packaging, electric vehicle batteries, multidisciplinary design optimization, battery pack integration, simulation-based optimization

Abstract

Electric vehicle (EV) battery packs play a critical role in determining vehicle performance, safety, and energy efficiency. As EV adoption continues to grow, the design of battery packs has become an important research topic in both academia and industry. This paper presents a comprehensive review of optimization approaches used in electric vehicle battery pack design, covering structural, thermal, electrical, and system-level optimization methods. Existing research studies are analyzed to identify common design objectives, optimization algorithms, simulation tools, and emerging research trends in the field. The literature shows that most existing studies focus on structural optimization of battery enclosures, thermal management systems, and electrical sizing of battery packs using simulation-driven methods such as finite element analysis and evolutionary optimization algorithms. Moreover, many studies treat battery packs as simplified systems and do not consider spatial packaging constraints within the vehicle structure. Furthermore, integrated multidisciplinary optimization frameworks that simultaneously consider mechanical, thermal, electrical, and packaging constraints are still limited in the current literature, with most studies addressing these aspects separately rather than within a unified system-level design approach. Similarly, the use of AI-assisted design tools, such as machine learning models, surrogate-based optimization, and intelligent decision-support systems, remains relatively unexplored for supporting early-stage battery pack architecture design and layout optimization. The review highlights the lack of studies addressing three-dimensional battery module placement and vehicle envelope packaging optimization. These gaps indicate significant opportunities for developing intelligent optimization frameworks capable of integrating geometric packaging, system-level performance, and multidisciplinary design constraints in future electric vehicle battery pack design.