INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
*(Volume 11, Issue 3 - V11I3-1390)*
Available online at: https://www.ijariit.com

# Optimization of Battery Thermal Management System using Fin Spacing and Fin Count Parameters in Electric Vehicles

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## ABSTRACT

***Efficient battery thermal management is pivotal for ensuring the safety, performance, and extended lifespan of electric vehicle (EV) batteries. This study presents a comprehensive Computational Fluid Dynamics (CFD)-based analysis on the influence of fin geometry, spacing, and quantity on heat dissipation efficiency. Thermal simulations were conducted using ANSYS Fluent, allowing evaluation of radiator models under varied fin geometries and boundary conditions to observe temperature uniformity and heat removal performance. Emphasis was placed on comparing different fin shapes (square, circular, curved), spacings (5 mm to 12.5 mm), and fin counts. Results indicate that 7.5 mm spacing provides optimal thermal efficiency regardless of geometry, and increasing fin number beyond a threshold yields diminishing returns. Copper showed superior thermal performance over aluminum, though cost and weight favoured aluminum. The findings provide practical insights into radiator fin optimization for advanced BTMS design.***

**Keywords-***Battery Thermal Management System (BTMS), Electric Vehicle (EV), Computational Fluid Dynamics (CFD), Fin Spacing, Fin Geometry, Heat Dissipation*

## 1. INTRODUCTION

With the global push towards sustainable transportation, electric vehicles (EVs) are gaining significant traction. A crucial factor limiting EV performance and safety is the temperature regulation of lithium-ion battery packs. Overheating can trigger thermal runaway, leading to catastrophic failures, while suboptimal temperatures reduce efficiency and shorten battery life. The battery thermal management system (BTMS) serves to maintain optimal operating temperatures by dissipating excess heat generated during charging/discharging cycles.

Modern BTMS architectures utilize air cooling, liquid cooling, or phase change materials. However, fin-assisted radiator designs are emerging as lightweight, passive, and efficient methods. This research explores the influence of fin geometry, material selection, and spacing on BTMS efficiency using CFD simulations. Particular attention is given to understanding how the number and spacing of fins affect thermal gradients within EV battery modules.

## 2. METHODOLOGY

To evaluate the thermal performance of various fin geometries and configurations, a series of simulations were conducted using ANSYS Fluent. The analysis followed a structured approach encompassing geometry modelling, meshing, boundary condition application, and post-processing of results.

Three primary factors were varied: fin shape (square, circular, curved), fin spacing (5 mm, 7.5 mm, 10 mm, 12.5 mm), and fin count. Fin materials considered were copper and aluminum. A fixed heat source temperature of 130°C was used to simulate battery-generated heat, with air as the cooling medium. The airflow velocity was maintained at 0.5 m/s.

Each simulation included static temperature contour plotting and heat flux analysis. Mesh independence checks were conducted to ensure solution accuracy. The efficiency of each configuration was compared based on minimum surface temperature, average temperature drop, and uniformity of heat distribution.

## 3. RESULTS AND ANALYSIS

The CFD simulations yielded insights into the impact of fin configuration on heat dissipation. Curved fins consistently outperformed square and circular variants, especially at mid-range spacing (7.5 mm). Beyond this, increasing spacing decreased cooling efficiency due to reduced surface area.

Temperature contours revealed that 7.5 mm fin spacing resulted in the most uniform thermal gradient, minimizing hotspots. Increasing the number of fins improved dissipation initially, but benefits diminished after a saturation point due to airflow obstruction. Among the tested materials, copper provided superior thermal conductivity characteristics; however, its increased density and higher material expense make it less favourable for lightweight or cost-sensitive designs

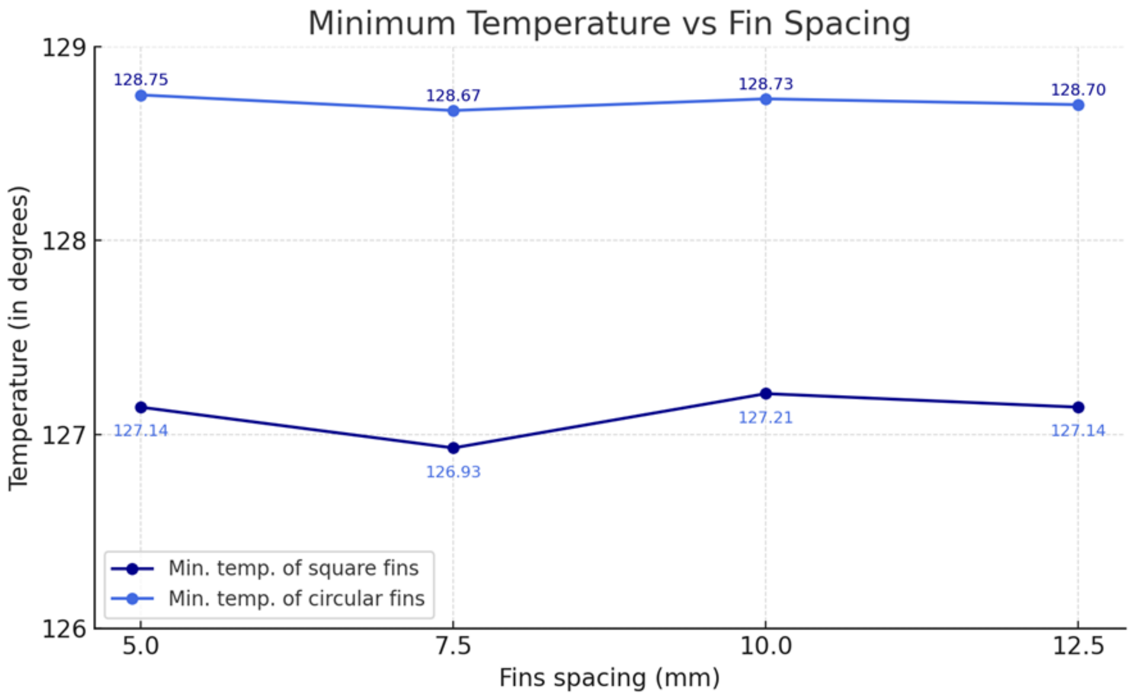


***Chart-1: Temperature vs Fins spacing graph for different shaped fins***

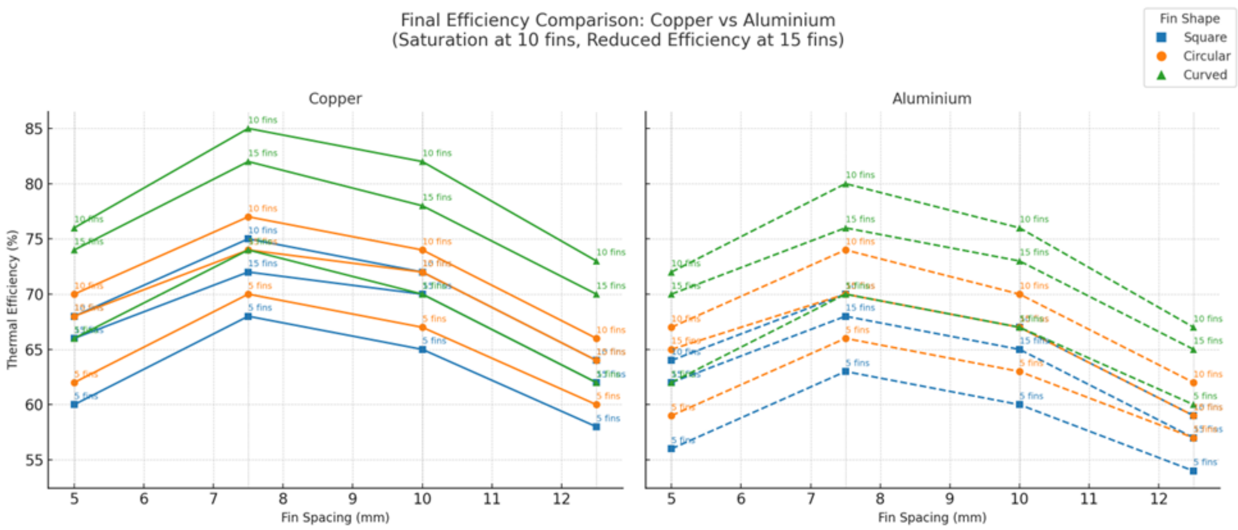


***Chart-2: Final comparison of thermal efficiency for Copper and aluminum fins across shapes, spacing, and fin counts. Peak efficiency is observed at 10 fins and 7.5 mm spacing with curved copper fins.***

The optimal configuration was found to be curved copper fins with 7.5 mm spacing and moderate fin density, offering the best trade-off between performance and practicality.

## 4. CONCLUSION

This study demonstrates the critical role of fin geometry, spacing, and quantity in optimizing battery thermal management systems for electric vehicles. Using ANSYS-based CFD simulations, we established that a 7.5 mm spacing between curved fins provides superior cooling performance across multiple metrics. While copper demonstrated enhanced heat dissipation capabilities compared to aluminum, its greater mass and cost pose limitations for certain EV applications.

The results highlight a balanced design approach incorporating material selection, geometry optimization, and spacing calibration as key to effective BTMS implementation.

## 5. FUTURE SCOPE

Further research can explore hybrid fin materials such as copper-aluminum alloys to balance thermal efficiency and economic feasibility. Integration of machine learning models for real-time thermal control based on usage patterns could improve adaptive BTMS response.

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