International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 03 | March - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Design of Air-Cooling Battery Thermal Management System

1st Boopalan C
Department of Automobile
Kumaraguru College of Technology
Coimbatore, India
boopalan.21au@kct.ac.in

2nd Gokul selva P
Department of Automobile
Kumaraguru College of Technology
Coimbatore, India
gokulselva.21au@kct.ac.in

3rd Kushalreddy V
Department of Automobile
Kumaraguru College of Technology
Coimbatore, India
kushalreddy.21au@kct.ac.in

Guide – Andrew Pon Abraham J D
Department of Automonile
Kumaraguru College of Technology
Coimbatore, india
andrew.auto@kct.ac.in

***Abstract*—** Efficient thermal management is essential to maintain the performance, safety, and longevity of battery systems in electric vehicles and other energy storage applications. This report investigates the design and optimization of an air-cooled battery thermal management system (BTMS) for an 8-cell battery module using three duct configurations J-type, Z-type, and U type—to enhance cooling performance. Each configuration was analyzed based on parameters including airflow distribution, cooling effectiveness, temperature uniformity, and pressure drop across the system. Computational Fluid Dynamics (CFD) simulations were conducted to assess the thermal and aerodynamic behaviours of each duct design, aiming to identify the optimal configuration for achieving a balanced temperature profile and reducing hotspot formation. Results indicate that the selected duct shape significantly impacts cooling efficiency, with specific configurations offering superior cooling rates and improved temperature uniformity across cells. This study provides insights into the design considerations for air-cooled BTMS and highlights the practical advantages of tailored duct geometries for thermal management in battery modules.

keywords: lithium ion battery pack, CFD simulations.

I. Introduction

The increasing adoption of electric vehicles (EVs) has intensified the demand for efficient Battery Thermal Management Systems (BTMS) to ensure battery safety, longevity, and performance. Batteries generate heat during charging and discharging cycles, and excessive temperature variations can lead to capacity degradation, reduced efficiency, and safety hazards such as thermal runaway. Various BTMS techniques exist, including liquid cooling, phase change materials, and refrigerant-based cooling. However, air cooling remains a cost-effective and lightweight alternative despite its lower heat dissipation capacity. This paper explores the design and optimization of an air-cooled BTMS to enhance thermal performance while minimizing energy consumption.

Several existing cooling techniques are employed in BTMS, each with unique advantages and limitations:

Passive Cooling--Utilizes natural heat dissipation but lacks efficiency under high thermal loads.

Air Cooling--Uses forced or natural convection to regulate battery temperature. It is lightweight and cost-effective but may struggle with high heat dissipation requirements.

Liquid Cooling--Provides superior heat management using circulating coolants but adds complexity and cost.

Phase Change Materials (PCM)--Absorbs heat through latent heat storage but has limitations in prolonged thermal management.

Refrigerant-Based Cooling--Integrates with the vehicle's air conditioning system, offering effective cooling at the cost of increased energy consumption.

Among these, air cooling stands out as an economically viable solution, and this study focuses on optimizing its design for enhanced thermal performance.

II. Proposed System

The proposed air cooling BTMS is designed using Computational Fluid Dynamics (CFD) simulations to analyze airflow and heat dissipation. The methodology includes:

System Design: Development of an air-cooled battery pack with optimized airflow channels

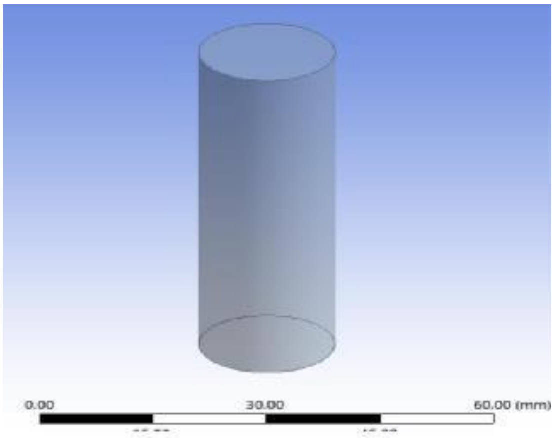

Fig. 1. Design of single cell

Figure 1 shows the design of single cell which has the specifications of IC18650, lithium-ion cell whose radius 18mm and height of 65 mm

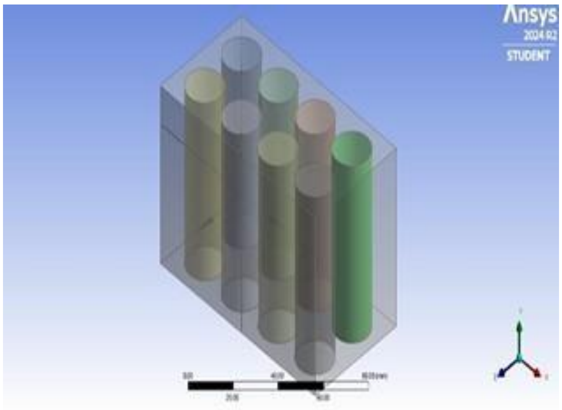

Fig. 2. Design of battery pack

Figure 2 shows an 8-cell lithium-ion battery module arranged in a series configuration. Each cell has a nominal voltage of 3.7V, resulting in a total pack voltage of approximately 29.6V. The battery pack is designed with proper spacing and airflow channels to ensure uniform heat dissipation and prevent thermal hotspots. Figure 2 is an ANSYS model of an eight-cell battery pack. Every round cell sits in clear rectangular box. Four rows of cells are stacked side by side. This configuration uses the available space well and has room for natural convection or phase change materials to cool. It fits into small space, but it's far enough to let the heat dissipation. The size of the pack is 97 mm (X), 65 mm (Y), and 51 mm (Z). 3D-oriented setup of this model will provide a clear view of how it fits into a larger system. This test setup can then be used for thermal simulation analyses, and in fact, these simulations would analyze the distribution of heat, effectiveness of cooling, and temperature profiles to ensure safety and performance stand. Thermal tests might analyze how heat spreads, how well it cools, and Temperature levels should be kept maintaining safety and good working condition.

CFD Analysis: Simulation of airflow distribution and heat dissipation under various conditions. The battery pack is analyzed in **ANSYS Fluent** at different discharge rates (1C, 2C, and 3C) and airflow velocities (1 m/s, 2 m/s, and 3 m/s). This project uses 3 Types of Duct design **J,U,Z** type

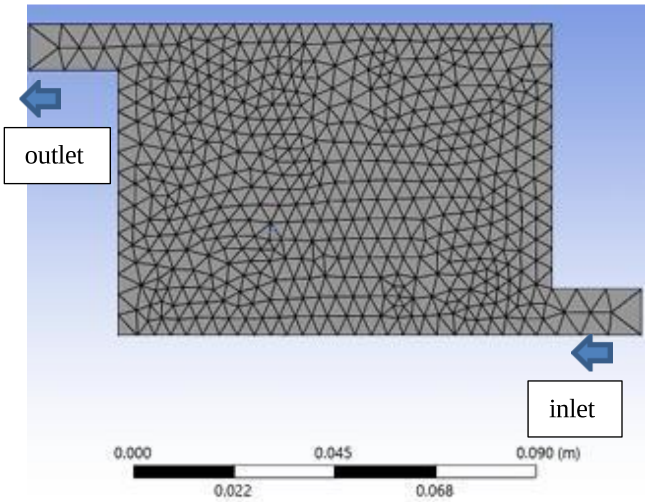

Fig. 3. Design and mesh of Z Type duct

Figure 3 shows the mesh diagram of the **Z** shape duct where the inlet and outlet is shown. The air is bought from the cars cabin with temperature around 20-22°C where it passes inside the inlet and absorb the temperature inside the battery pack and comes out through outlet leading to maintain the battery temperature within its optimal range.

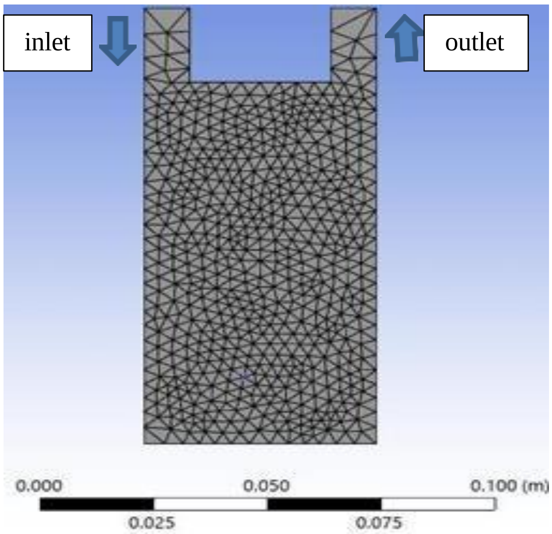

Fig. 4. Design and mesh of U Type duct

Figure 4 shows the mesh diagram of the **U** shape duct where the inlet and outlet is shown. The air is bought from the cars cabin with temperature around 20-22°C where it passes inside the inlet and absorb the temperature inside the battery pack and comes out through outlet leading to maintain the battery temperature within its optimal range

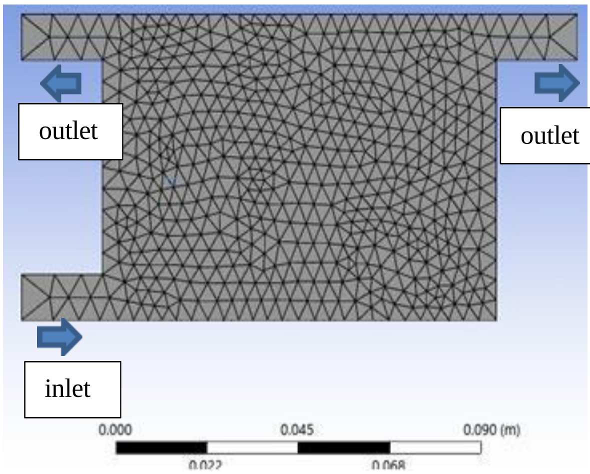

Fig. 5. Design and mesh of J Type duct

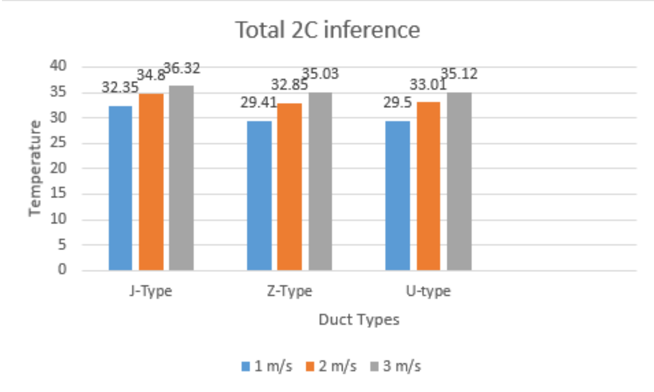

Fig. 7. Overall Graphical Representation of 2C discharge condition for different duct types with varying velocity

Figure 5 shows the mesh diagram of the **J** shape duct where the inlet and outlet is shown. The air is bought from the cars cabin with temperature around 20-22°C where it passes inside the inlet and absorb the temperature inside the battery pack and comes out through outlet leading to maintain the battery temperature within its optimal range.

All the above simulation setup is simulated in **ANSYS Fluent** and analyzed and the better system for cooling the battery is said in the conclusion.

III SIMULATION/RESULTS OF THE PROPOSED SYSTEM

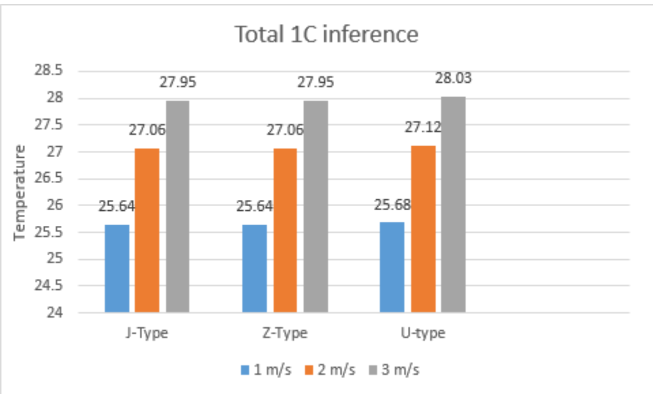

Fig. 6. Overall Graphical Representation of 1C discharge condition for different duct types with varying velocity

From the above figure its observed that for all the Three Types of Duct and all varying velocity. The temperature showing under 1 m/s velocity is low compared to all other velocities.

From the above figure its observed that for all the Three Types of Duct and all varying velocity. The temperature showing under 1 m/s velocity is low compared to all other velocities.

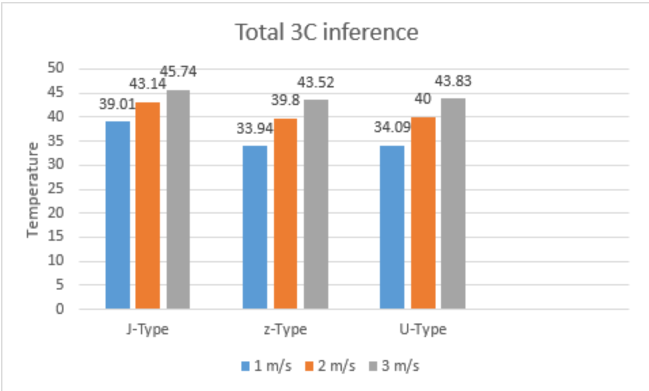

Fig. 8. Overall Graphical Representation of 3C discharge condition for different duct types with varying velocity

From the above figure its observed that for all the Three Types of Duct all varying velocity. The temperature showing under 1 m/s velocity is low compared to all other velocities.

IV CONCLUSION

In this project the different types of ducts is used for analyzing the air cooled thermal battery management system. Its observed that for different C rating the analysis is done for different velocities

From the above result and discussion its observed that for 1C discharge condition both Z-type and J-type duct show the lowest temperature as **25.64 C** at air velocity of 1 m/s

From the above result and discussion its observed that for 2C discharge condition both Z-type duct show the lowest temperature as **29.41 C** at air velocity of 1 m/s

From the above result and discussion its observed that for 3C discharge condition both Z-type duct show the lowest temperature as **33.94 C** at air velocity of 1 m/s

Hence Finally the project shows that for a lithium ion cell or lithium ion battery pack with 1C discharge condition J and Z typed duct is the best solution to maintain the battery optimal temperature within its range

For the 2C discharge condition Z type duct will be the best solution for the battery to maintain its temperature within optimal range

For the 3C discharge condition Z type duct will be the best solution for the battery to maintain its temperature within its optimal range.

V REFERENCE

[1] X. Zhang, Y. Li, and J. Wang, "Thermal management of lithium-ion batteries using air cooling," *Journal of Energy Storage*, vol. 25, pp. 100885, 2020.

[2] M. Chen and P. Wang, "Optimization of battery cooling systems in electric vehicles," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 5, pp. 4820-4831, 2021.

[3] A. Gupta, R. Kumar, and S. Singh, "A review on battery thermal management techniques for electric vehicles," *Renewable and Sustainable Energy Reviews*, vol. 135, pp. 110126, 2021.

[4] L. Wang, H. Huang, and J. Xu, "Numerical study on forced air cooling for cylindrical lithium-ion battery packs," *Applied Thermal Engineering*, vol. 182, pp. 116154, 2020.

[5] R. Sharma, B. Verma, and N. Patel, "Impact of airflow velocity on thermal performance of EV battery packs," *International Journal of Heat and Mass Transfer*, vol. 164, pp. 120506, 2021.

[6] Y. Feng, Z. Liu, and C. Zhou, "Experimental investigation of air cooling strategies for lithium-ion battery thermal management," *Energy Reports*, vol. 8, pp. 1456-1465, 2022.