ICEST-2K24 [International Conference on Engineering, Science and Technology]
In Association with
International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN - 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)

Analysis of Battery Pack Used in BTMS by Using ANSYS Software

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ABSTRACT
Efficient thermal management is crucial for the performance, safety, and longevity of lithium-ion battery packs, especially in high-demand applications such as electric vehicles. Traditional cooling methods, including air cooling, often face challenges in maintaining uniform temperature distribution, which can lead to overheating, reduced efficiency, and safety hazards like thermal runaway. This study aims to address these challenges through a detailed Computational Fluid Dynamics (CFD) analysis using ANSYS software, focusing on optimizing air cooling strategies.By developing a comprehensive 3D model of the lithium-ion battery pack and simulating its thermal behavior under various operating conditions, this research evaluates different air cooling configurations to identify the most effective strategies. The findings of this research highlight the critical role of proper cooling strategies in enhancing the thermal performance and safety of lithium-ion battery packs. The results contribute to the development of more efficient and reliable Battery Thermal Management Systems (BTMS), providing valuable guidance for future advancements in battery technology and electric vehicle design

Keywords— ANSYS, Li-ion battery, Design, Meshing, Heat Dissipation

I. INTRODUCTION

The increasing reliance on lithium-ion batteries (LIBs) across various sectors, such as electric vehicles (EVs), portable electronics, and renewable energy storage systems, underscores the importance of efficient thermal management to ensure their performance, longevity, and safety. Among the various methods available, Computational Fluid Dynamics (CFD) analysis has emerged as a powerful tool to study and optimize Battery Thermal Management Systems (BTMS).

This project focuses on performing a CFD analysis of a lithium-ion battery pack using ANSYS software, with air as the chosen cooling medium. Air cooling is a practical and cost-effective method widely used to maintain the temperature of battery packs within safe and efficient operating ranges. By simulating the thermal behavior and heat dissipation characteristics of the battery pack under various conditions, this study aims to enhance the understanding of aircooled BTMS and identify optimal configurations for improved thermal management.

Importance of CFD Analysis in BTMS

CFD analysis is a crucial tool in understanding and optimizing BTMS due to its ability to simulate complex fluid flow and heat transfer phenomena with high accuracy. By leveraging ANSYS software, this project aims to provide detailed insights into the thermal behavior of lithium-ion battery packs and explore innovative air cooling strategies to enhance their performance and safety. By leveraging the capabilities of ANSYS for CFD analysis, this project aims to provide valuable insights into the thermal management of lithium-ion battery packs. The findings will contribute to the development of more efficient and reliable BTMS, ultimately enhancing the performance and safety of energy storage systems.

II. LITERATURE REVIEW

Informed by an exhaustive review of over 10 journal papers and additional scholarly sources, the project's literature review delves into the intricate facets of technology.

In summary, the literature on the analysis of battery thermal management systems using ANSYS software demonstrates the software's pivotal role in understanding, optimizing, and ensuring the safety and performance of batteries in a wide range of applications. This research field continues to evolve as battery technology advances, and ANSYS software remains a valuable tool for engineers and researchers in this domain. We have read the research paper of A.L.Akhawayn university. A study by A.L.Akhawan university (2023) used ANSYS to simulate the performance of battery management system for a PCM based battery. They found the result of the ANSYS simulated system was able to reduce the temperature of the batterypack upto 10 degree C.

A study by Khalil et al. They studied that Thermal management of stationery battery systems. The heat generation mechanism in stationery battery system and their research are provides more efficient and reliability of the battery thermal management system.

A study by Fantin.et.al. (2023) To study by the author used ANSYS to design and optimize an air cooling system for battery pack. The study showed that shows the to reduce the maximum temperature of the battery through the conventional air cooling. They found the result of the use conventional air cooling system we reduce the heat of the battery for it useful to increasing the performance of battery.

We have read the one research paper of Battery Management Systems For Electric Vehicle by researching A. Hariprasad . This present paper focuses on the study of BMS and optimizes the power performance of electric vehicle. Based on the particular situation, different strategies can be applied to upgrade and optimize the performance of BMS in EV’s

III.RESEARCH GAP

There are various methods of cooling for BTMS. In which air cooling, liquid cooling. The majority of the literature explains about the air cooling and direct liquid cooling. Few researches related to comparative experimental study of different types of cooling system. Very less research observed on experimental analysis tube cooling using channel and battery pack. The analytical study for Liquid cooling were carried out by few researchers. The experimental study for coolant used again for cooling is not reported yet. So, there is huge scope for use of coolant for repeatedly. In future it is useful to increasing efficiency improvement of battery pack. An actual design for an electric vehicle or energy storage application needs transient simulations based on the expected driving or load cycle. It is helpful to working on battery cell life improvement.

IV.PROBLEM STATEMENT

To design a battery cell pack using CATIA software and To perform thermal Analysis , simulation and optimization of lithium ion battery cell by using ANSYS software for reducing and analyzing the heat of battery by using CFD analysis for better performance of battery.

V. METHODOLOGY

Part – 1

The methodology for analyzing battery thermal management systems using ANSYS software involves a structured approach that combines simulation, modeling, and analysis. Here's a general outline of the methodology:

1. Prepare 3D-CAD Model of battery cells:

With great attention to detail, the design of the battery pack model incorporating a sophisticated cooling system is meticulously crafted using CAD software. The 3D CAD models are skillfully prepared utilizing the CATIA V5R21 software version, ensuring precision and accuracy in the design process. The battery pack is specifically configured with 96 cells, each carefully spaced with a 1.5 mm gap, dimensions that have been thoughtfully selected based on reliable research papers.

2. Prepare 3D- CAD model of cell stack :

With this information, a CAD model can be developed using software like CATIA V5R21, AutoCAD which allows for the creation of a 3D model considering the specified dimensions, arrangement, and interconnections of the cell stack.

3. Prepare the 3D-CAD Model of cells :

With this information ,a CAD model can be designed using appropriate software, considering the dimensions, layout, and interconnections of the 96 cells. This model can help visualize the physical arrangement and aid in further analysis or design development.

4. Assemble the cells in stacks :

By following these steps, you can assemble the 40 cells into stacks, considering their arrangement, connections, safety, and the overall design of the structure that contains them.

5. Prepare the 3D model of casing and enclosing cell

6. Evaluation of results:

After conducting a meticulous analysis and thoughtful evaluation of the results, the most favorable outcome is determined.

7. Final conclusion:

After a thorough evaluation, the study's conclusion reveals valuable insights and significant findings

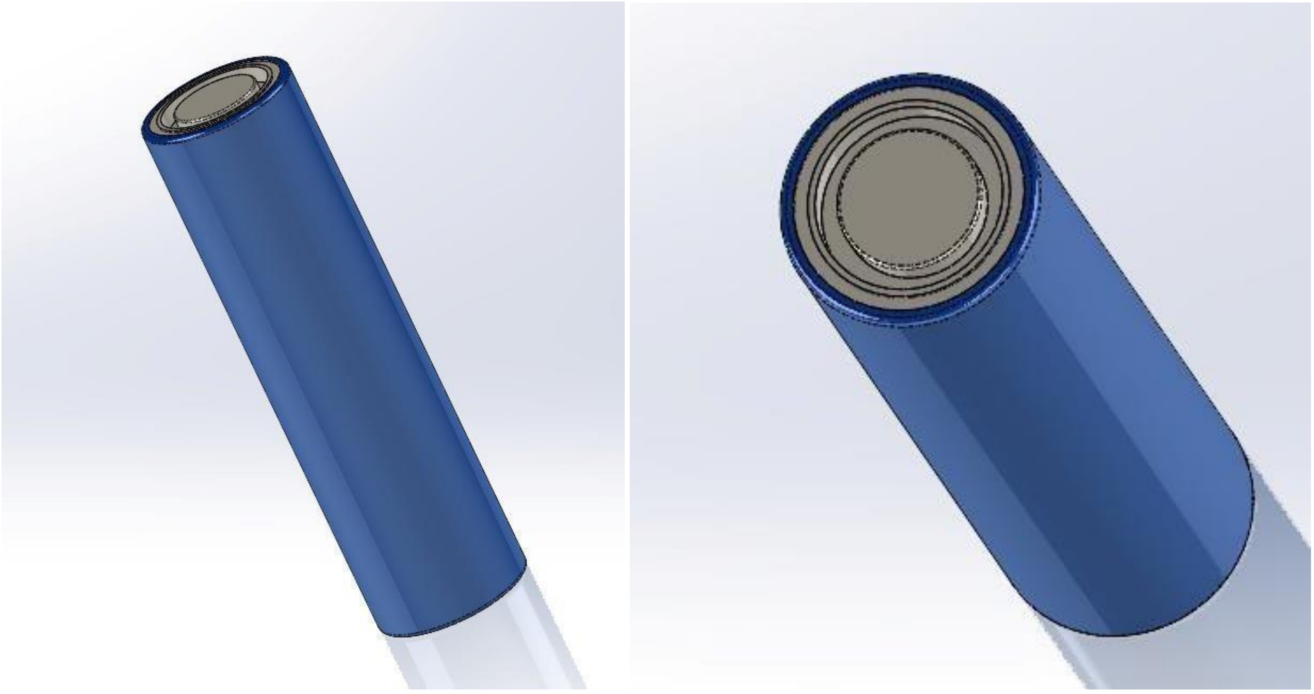


Fig. 1 3D CAD model of a battery cell

Dimensions of the Battery Cell:

Length Of Battery Cell= 100mm

Diameter of Cell = 1.5mm

Width of Cell = 2mm

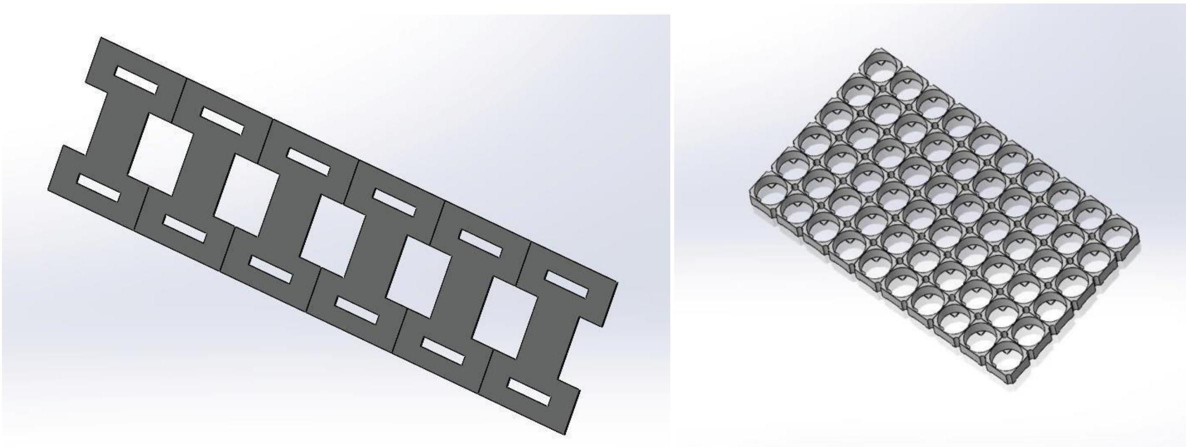


Fig. 3 3D CAD Model of a cell Stack & Upper Stack of Battery cell pack

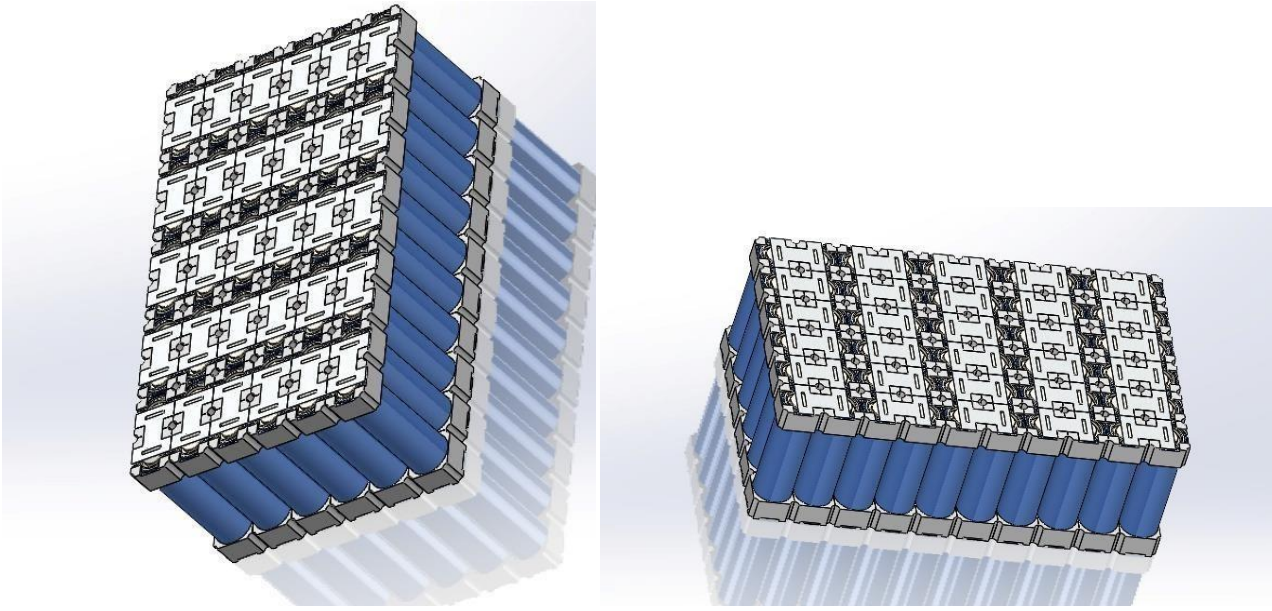


Fig. 4 3D Model of cells

Steps of CFD Analysis of Air Cooling System of Li-ion Battery

Methodology Part – II

Step-by-step methodology for conducting a CFD analysis of a battery air cooling system using Ansys Workbench, with the given condition of an initial air temperature of 22 degrees Celsius:

1 Geometry Creation:

Start by creating a detailed 3D model of the battery cooling system geometry using a CAD software or within Ansys Design Modeler if available.

Ensure the model accurately represents all components including the battery, cooling ducts, inlet, outlet, and any other relevant features.

2 Mesh Generation:

Import the geometry into Ansys Workbench.

Generate a mesh using Ansys Meshing module.

Pay attention to mesh quality, especially near walls and regions of interest.

Refine the mesh as necessary to ensure accurate results, especially in areas of high temperature gradients.

3 Material Properties:

Define material properties for all components involved in the simulation, including the battery, cooling ducts, and surrounding air.

Specify thermal conductivity, density, and specific heat capacity for air and other materials as appropriate.

4 Boundary Conditions:

Define boundary conditions based on the problem statement.

Set the initial air temperature to 22 degrees Celsius.

Specify inlet and outlet boundary conditions for the airflow.

If the battery generates heat, apply appropriate heat generation boundary conditions.

5 Solver Setup:

Choose the appropriate solver within Ansys Workbench, such as Fluent for fluid flow and heat transfer simulations.

Define solution controls including convergence criteria, time step (if transient analysis), and any other relevant settings.

6 Solution:

Run the simulation and monitor the progress.

Ensure that the solution converges within acceptable limits.

If running a transient simulation, monitor the time evolution of the solution.

7 Post-Processing:

Once the simulation is complete, post-process the results to extract relevant information.

Visualize temperature contours, velocity vectors, and other flow characteristics using Ansys CFD-Post or equivalent.

Analyze temperature distributions within the battery and cooling ducts.

Calculate heat transfer rates and other relevant parameters to assess system performance.

8 Analysis and Optimization:

Analyze the results to identify areas for improvement or optimization.

Make design changes as necessary to enhance system performance, such as modifying cooling duct geometry or adjusting airflow rates.

Conduct parametric studies to understand the effects of different design variables on system performance.

9 Validation:

Validate the simulation results against experimental data if available.

Compare simulation predictions with real-world observations to ensure accuracy and reliability.

10 Documentation:

Document the simulation setup, methodology, and results for future reference. • Provide clear explanations of the findings and any recommendations for design improvements.

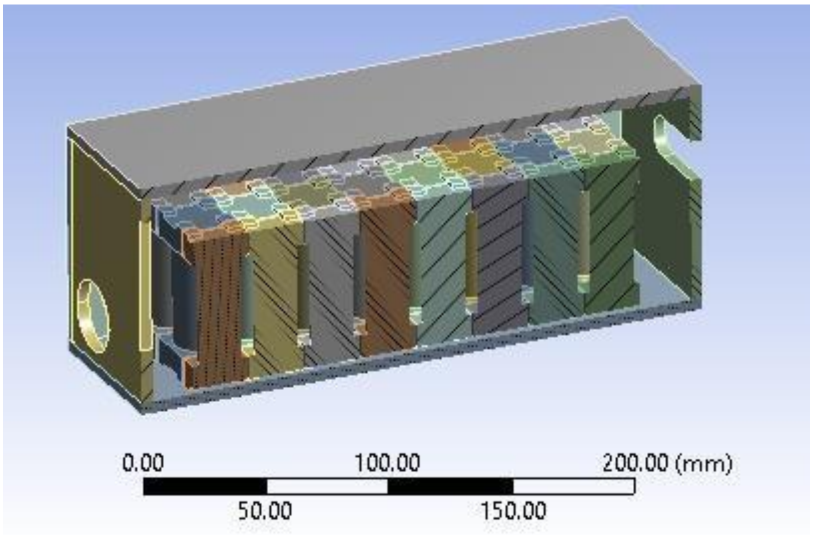


Fig.5 Impetrated geometry in the design Modular with Sectional Cut view

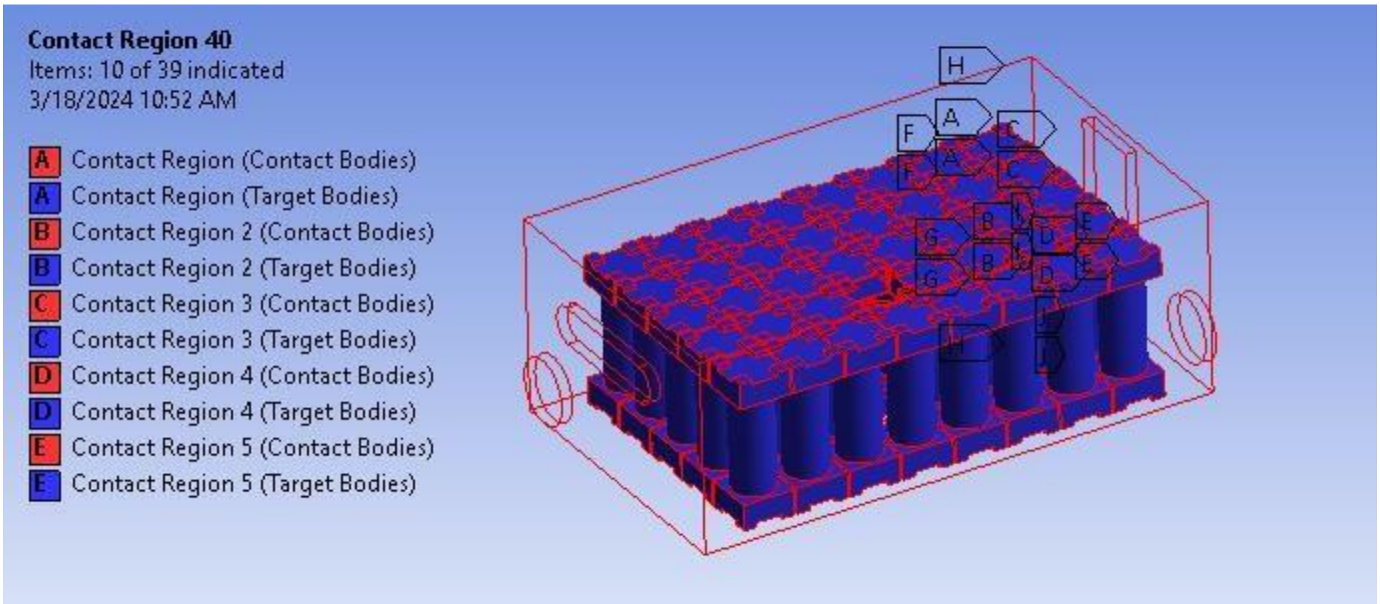


Fig.6 Contact regions of battery case with battery cells

Mesh Generation :

Meshing: - Generate a mesh for the fluid volume. - Pay attention to mesh quality, refinement near critical areas, and ensuring an adequate boundary layer mesh.

Statistics			
Nodes	2160	3090	2160
Elements	905	2085	905

Table Number of Nodes & Elements Generated on the mesh body Mesh

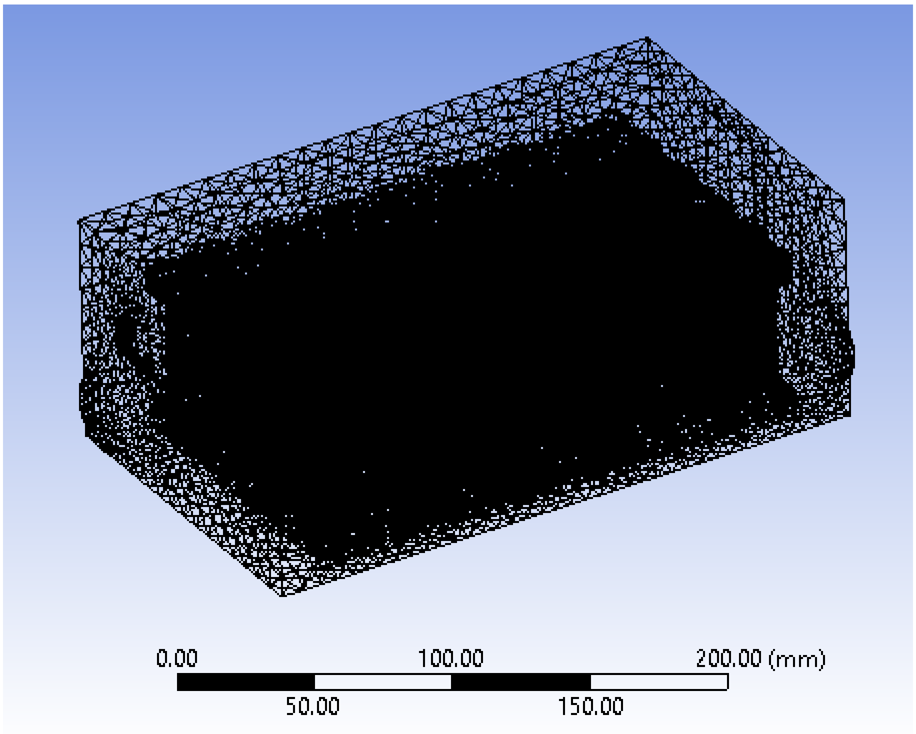


Fig.7 Mesh Generation

- Type of Mesh used 3D Element
- Type of Shape used Tet-Mesh Type
- Size adopted 10 mm

Physics Setup :

Double precision with 1 processing solver

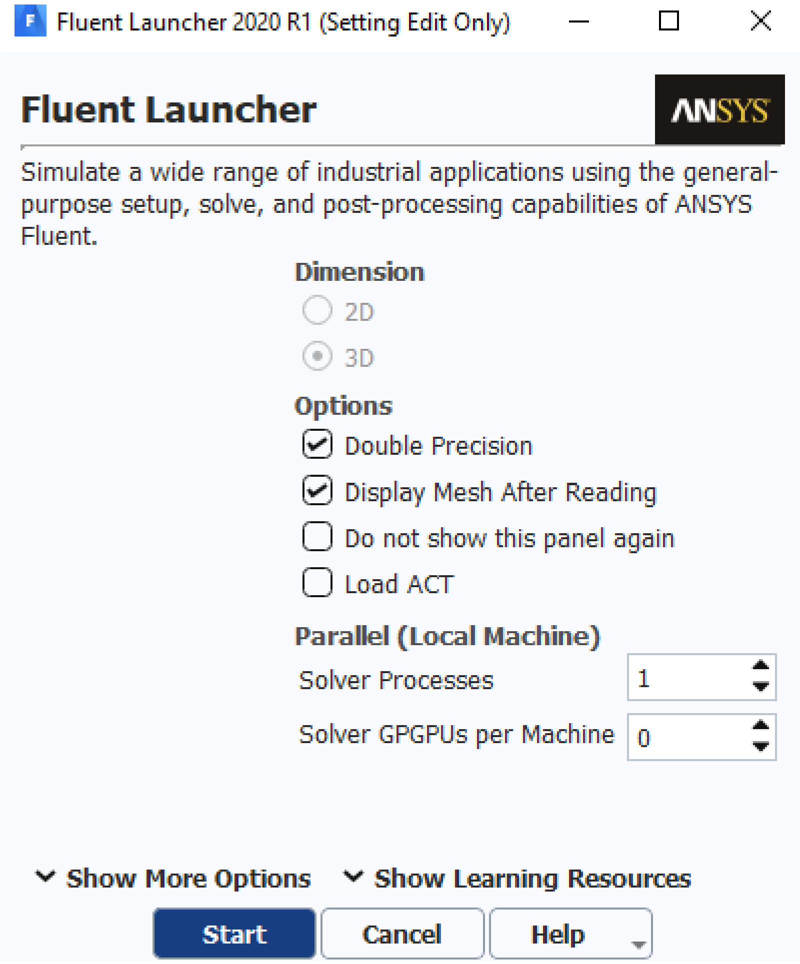


Fig.8 Physics Setup modular

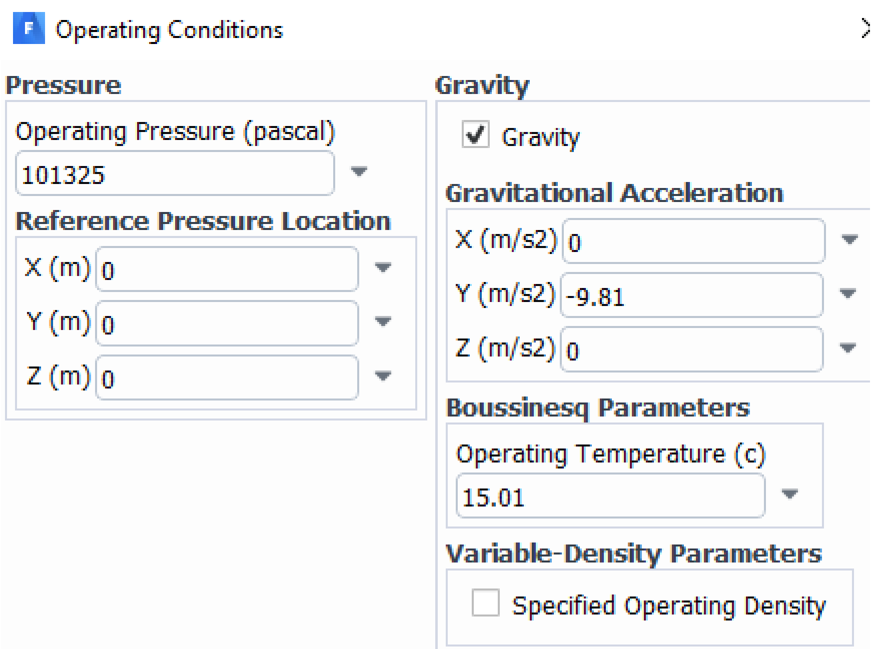


Fig.9 General Operating Conditions

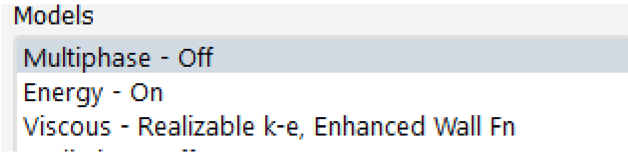


Fig.10 Energy equation turning on

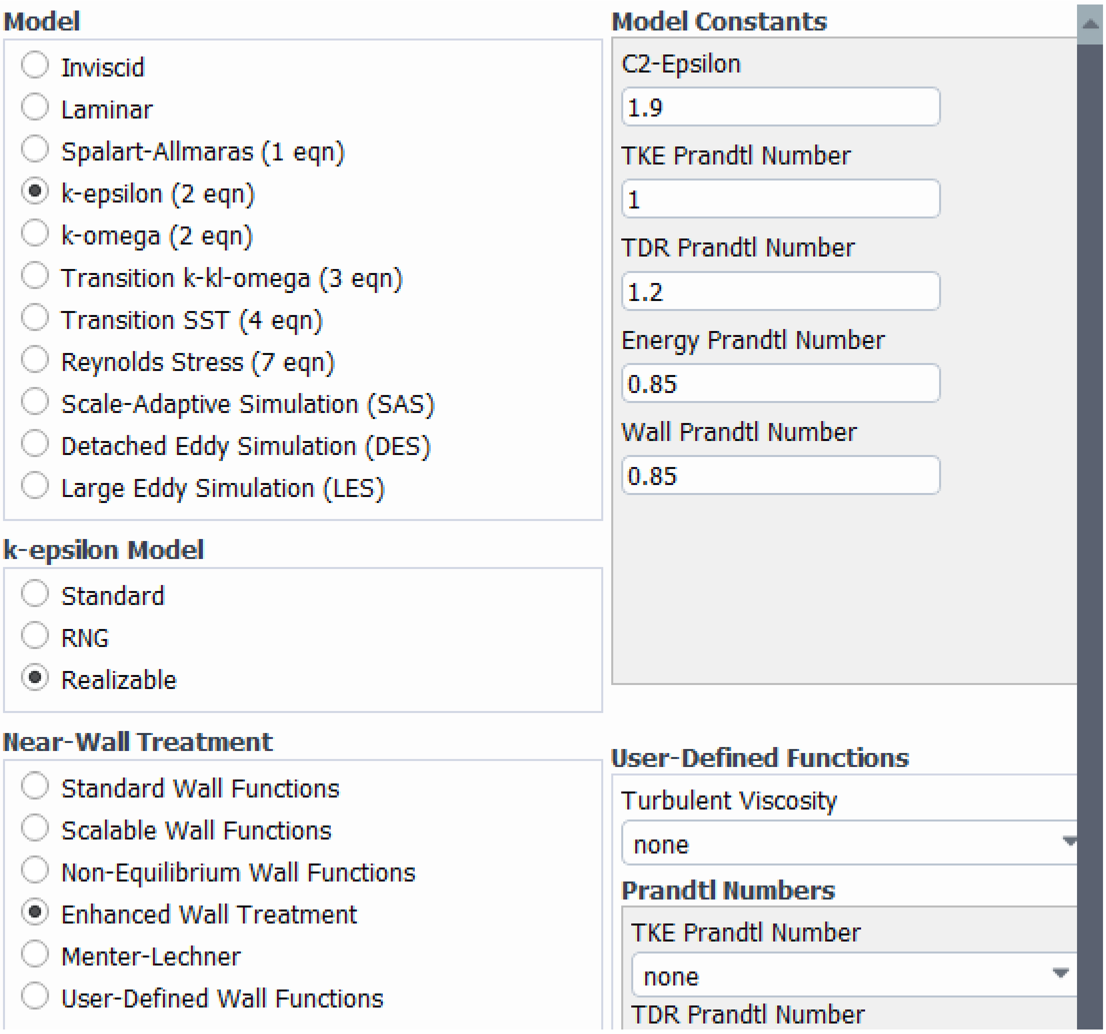
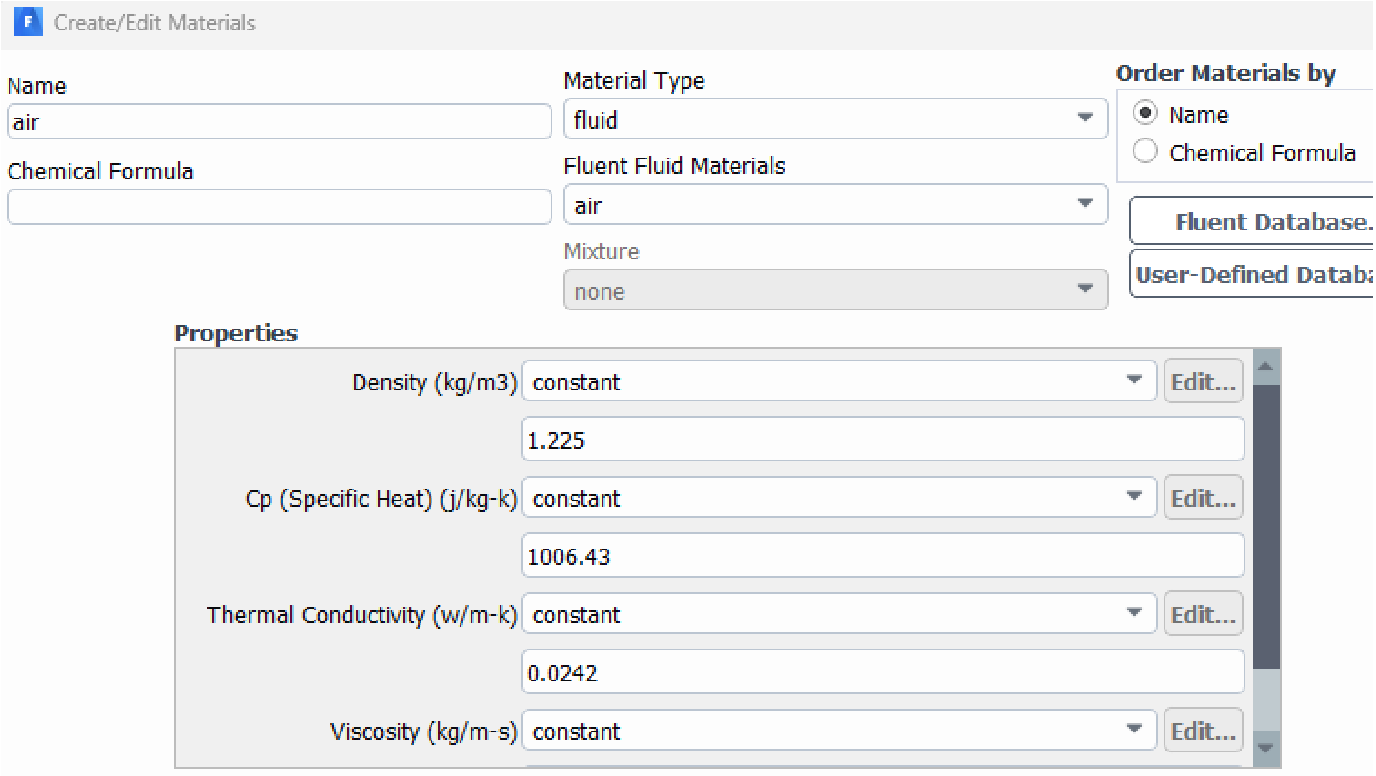


Fig.11 Viscous Flow to K-epsilon Setting

Material Properties

- Define material properties for all components involved in the simulation, including the battery, cooling ducts, and surrounding air.
- Specify thermal conductivity, density, and specific heat capacity for air and other materials as appropriate.



Boundary Conditions:

- Define boundary conditions based on the problem statement.
- Set the initial air temperature to 22 degrees Celsius.
- Specify inlet and outlet boundary conditions for the airflow.
- If the battery generates heat, apply appropriate heat generation boundary conditions.

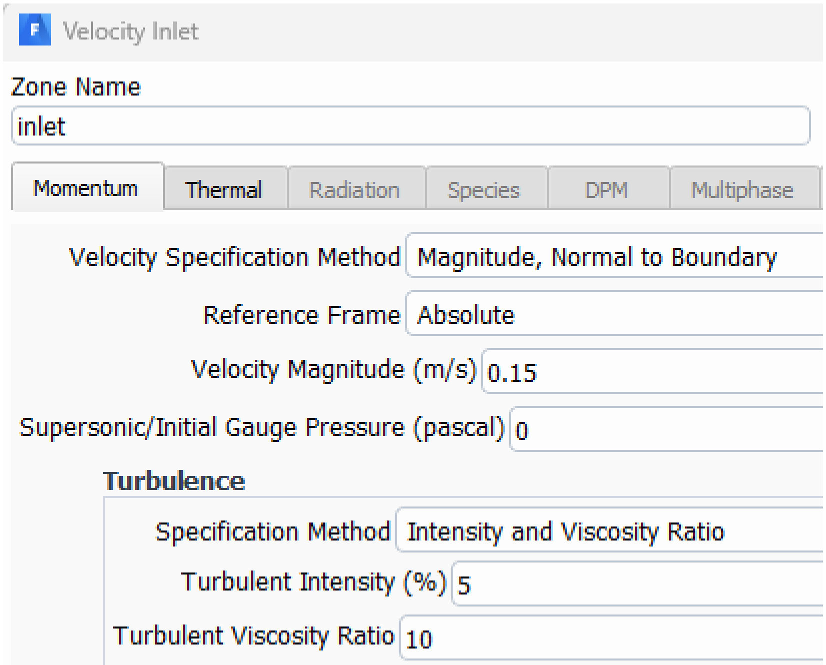


Fig. 12 Boundary Conditions Initial velocity & Air Temperature

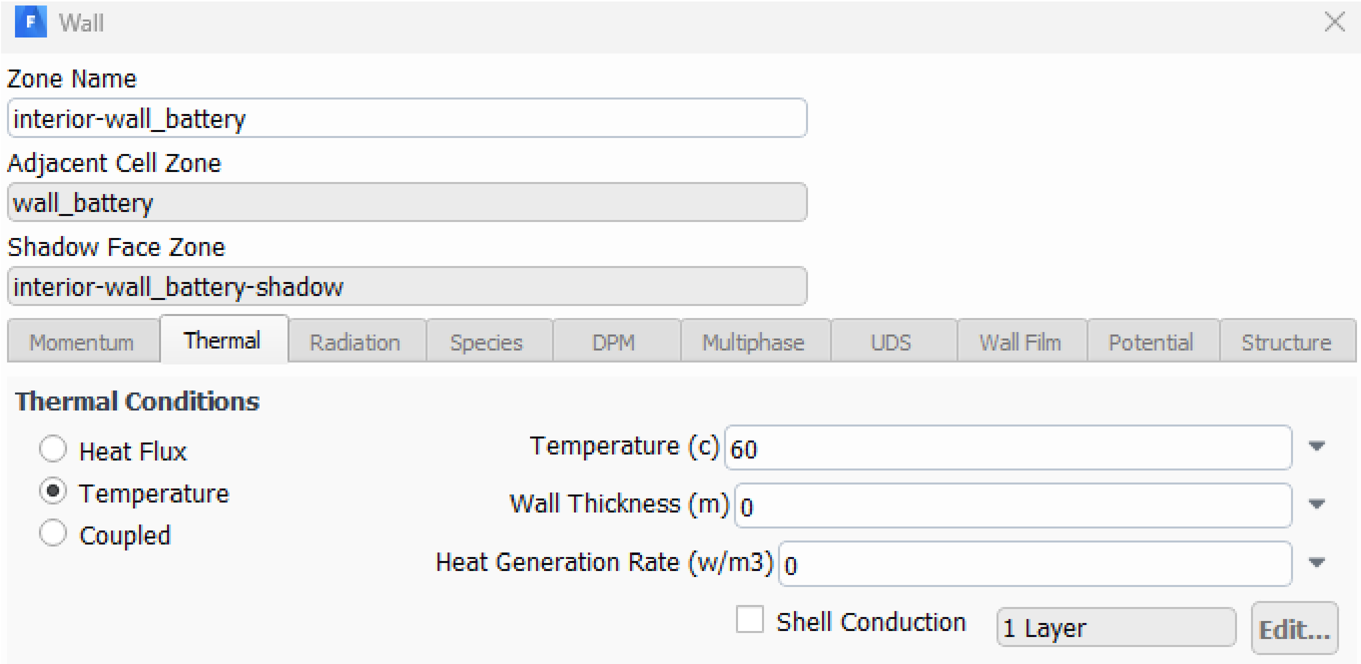
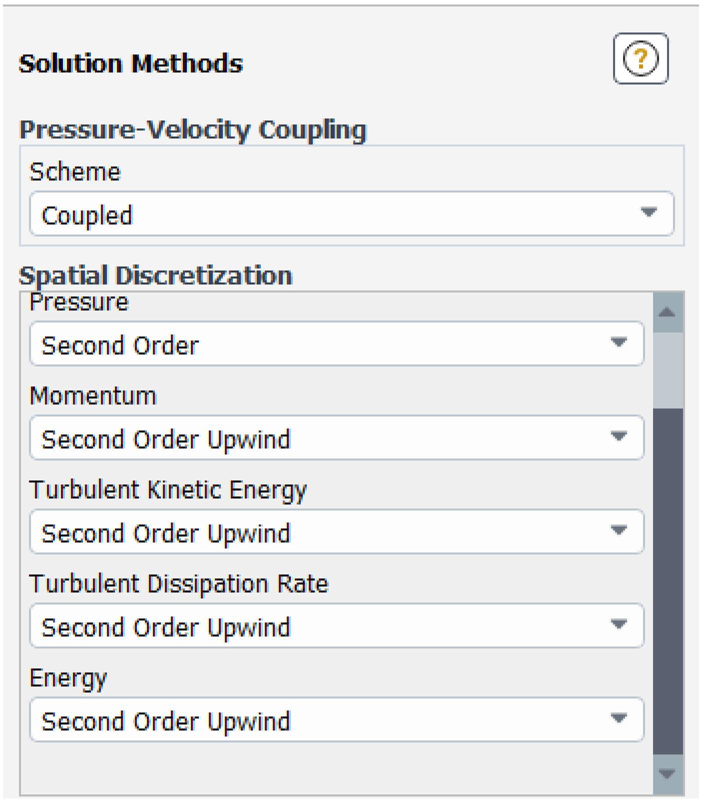


Fig. 13 Battery temperature set for solution

Solver Setup:

- Choose the appropriate solver within Ansys Workbench, such as Fluent for fluid flow and heat transfer simulations.
- Define solution controls including convergence criteria, time step (if transient analysis), and any other relevant settings.



Solution:

- Run the simulation and monitor the progress.
- Ensure that the solution converges within acceptable limits.
- If running a transient simulation, monitor the time evolution of the solution.

Run the Simulation: - Solve the CFD problem using the specified settings. - Monitor the solution for convergence and stability.

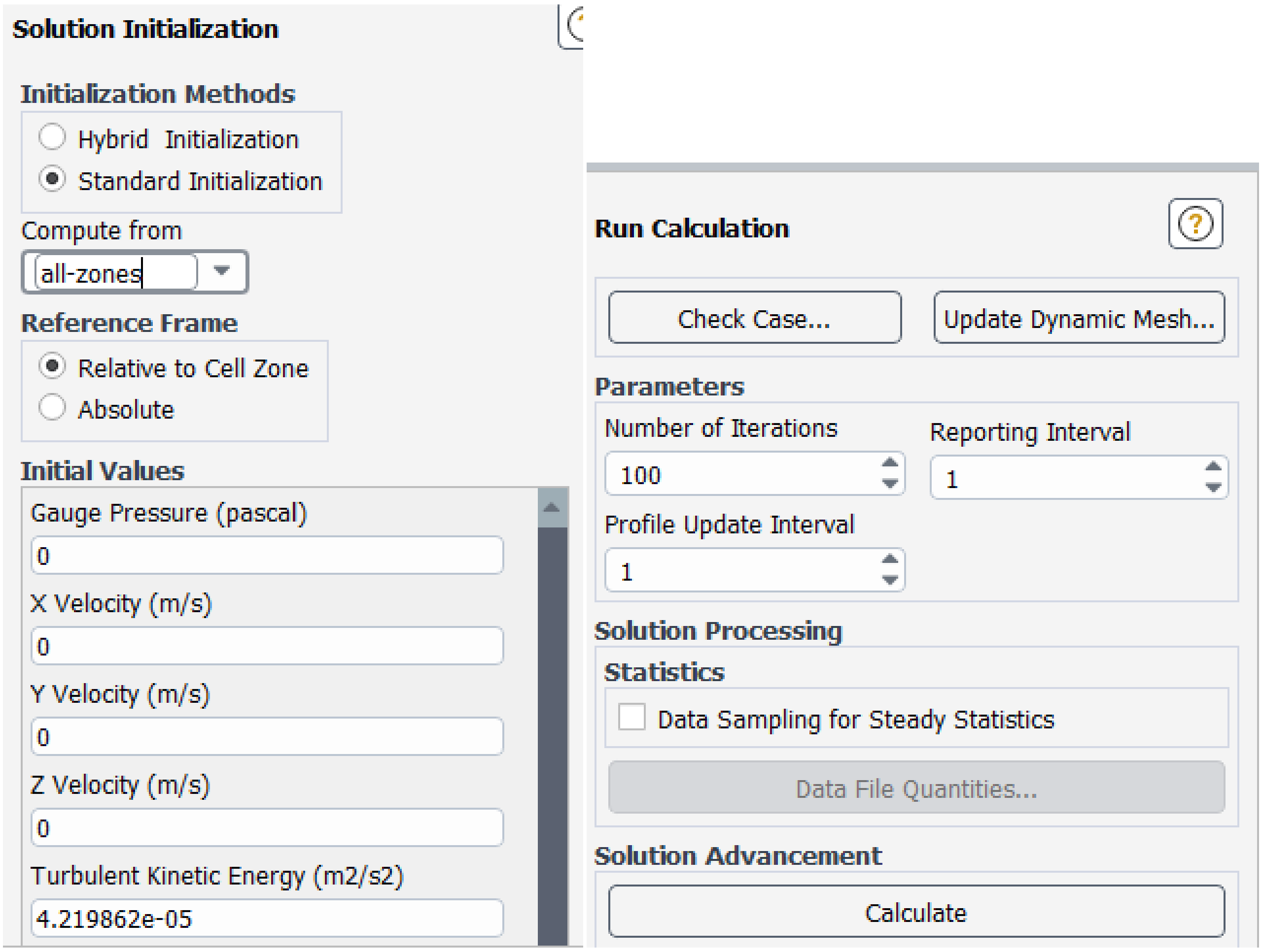


Fig.14 Solution initialization method Standard all Zone & Iteration performed

VI.RESULTS AND DISCUSSION

CFD (Computational Fluid Dynamics) analysis is a powerful tool for simulating and analyzing the performance of various engineering systems, including battery cooling systems. Ansys Workbench, a widely used simulation software package, provides a comprehensive platform for conducting such analyses. In this discussion, we'll delve into the specifics of conducting a CFD analysis of a battery air cooling system using Ansys Workbench, with particular focus on the conditions provided: an initial air temperature of 22 degrees Celsius and an outlet temperature after heat transfer to the lithium battery of 47 degrees Celsius

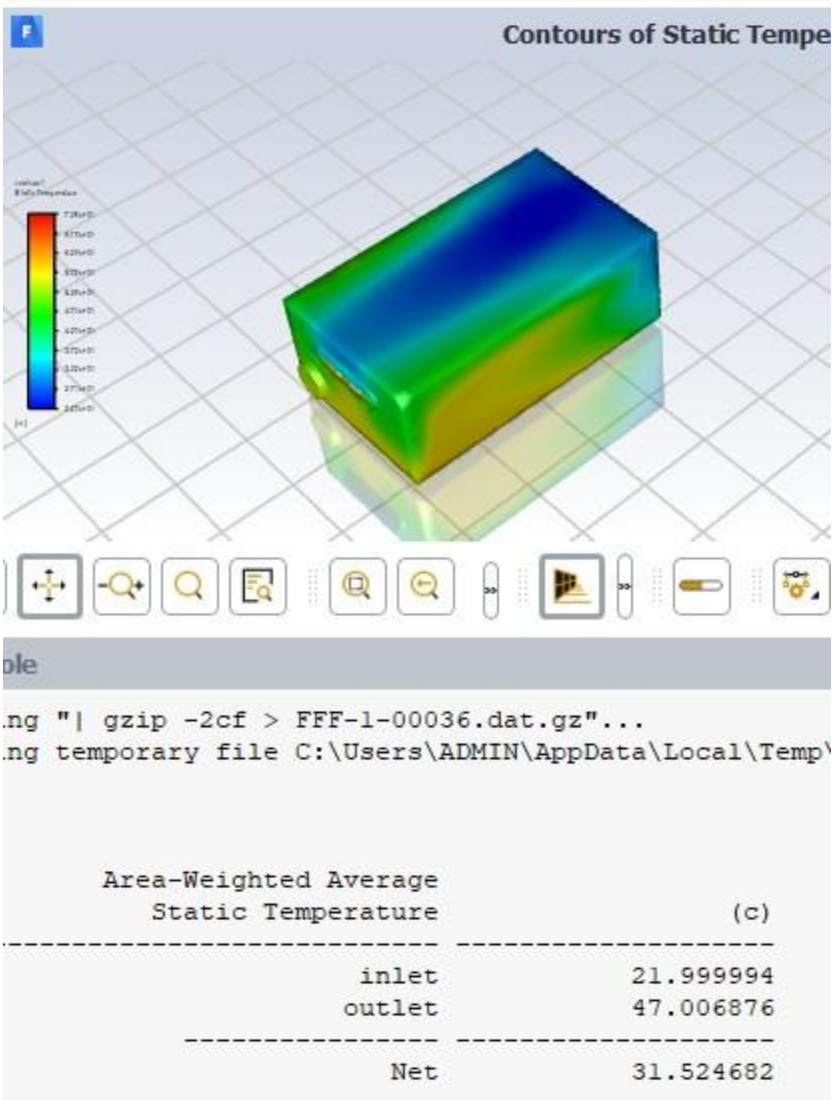


Fig.15 Result plots for temperature of air entering and leaving the case

Once the geometry and boundary conditions are set, the simulation can be run using Ansys Workbench. The software solves the governing equations of fluid flow, heat transfer, and possibly other relevant physical phenomena to predict the airflow patterns, temperature distribution, and other key parameters within the cooling system.

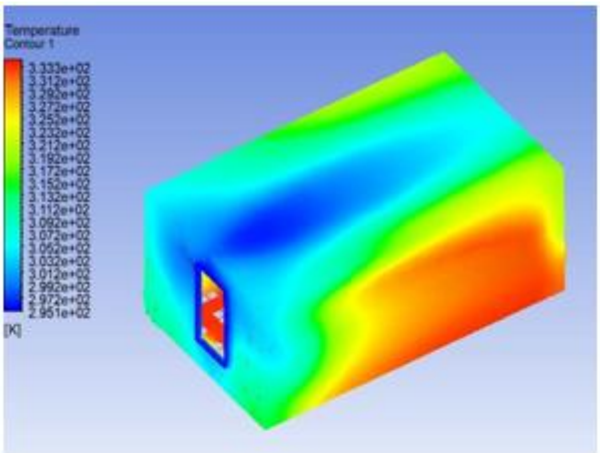


Fig. 16 Temperature Contour for battery as well as air fluid domain

```
                 Area-Weighted Average
                    Velocity Magnitude                      (m/s)
-------------------------------- --------------------
                                 inlet           0.15000001
                                outlet             0.250231
                ---------------- --------------------
                                   Net           0.18817626
```

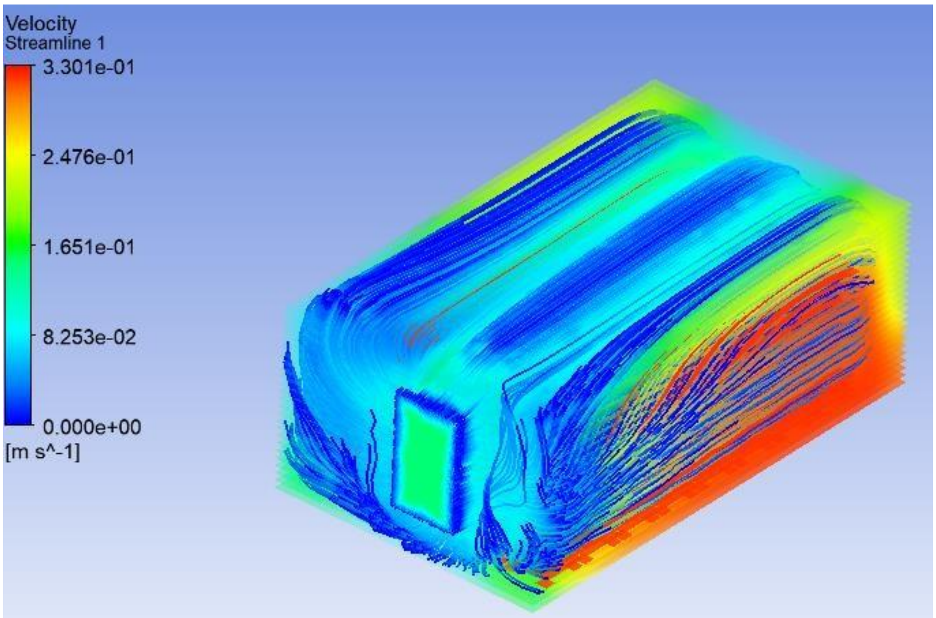


Fig17 Velocity stream line Contour for battery as well as air fluid domain

```
                 Area-Weighted Average
          Wall Func. Heat Tran. Coef.                  (w/m2-k)
-------------------------------- --------------------
                     wall-volume_volume                 25.5786
```

During the simulation, various analyses can be performed to gain insights into the system's behavior. For instance, temperature contours can be visualized to identify regions of high heat transfer and potential hotspots within the battery. Velocity vectors can help understand airflow patterns and ensure adequate cooling throughout the system. Additionally, heat transfer coefficients can be calculated to quantify the effectiveness of the cooling process.

Table of section

Sr No	Material	Temperature in Celsius At Inlet	Temperature in Celsius At Battery	Heat Flux at battery in w/m^2	Velocity in m/sec	Final Temperature at Outlet in Celsius	Heat transfer co-efficient in w/m^2-k
1.	Air – Battery	22	60	80	0.25	40.007	25.54

Table 1. Result plot of section

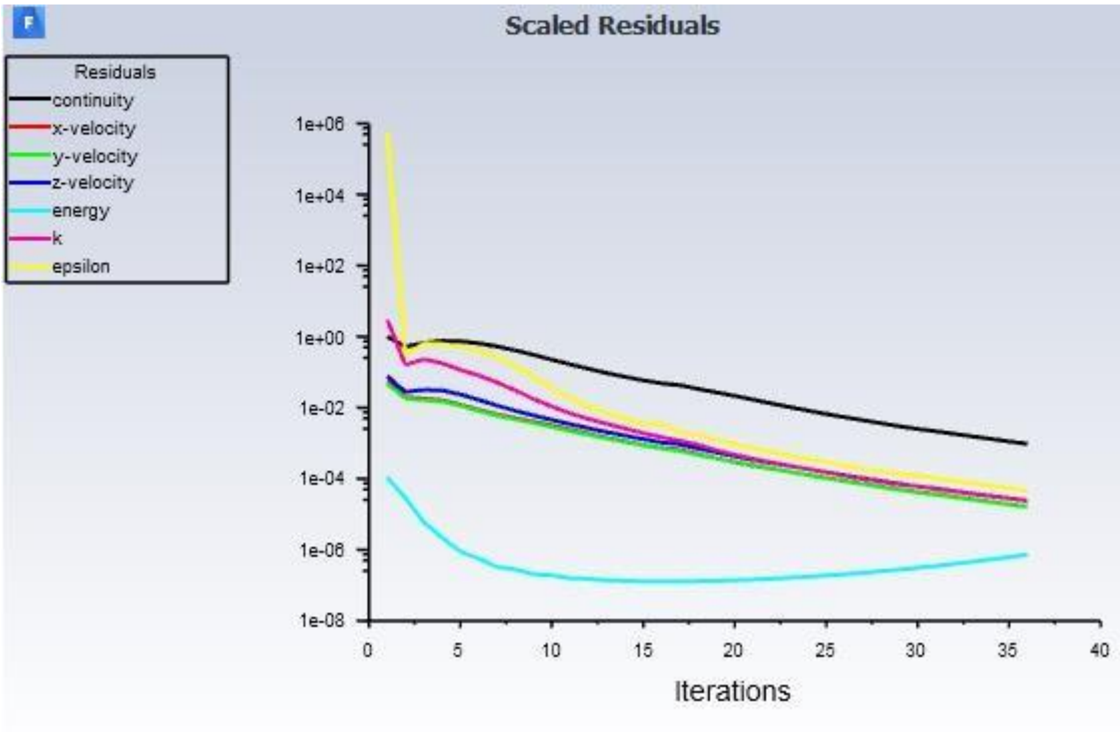


Fig. 18 Residual Plots

VII. CONCLUSION AND FUTURE SCOPE

1) Conclusion

This research successfully demonstrates the significance of efficient thermal management in lithium-ion battery packs, particularly for high-demand applications such as electric vehicles. By employing Computational Fluid Dynamics (CFD) analysis using ANSYS software, we have identified optimal air cooling strategies that ensure uniform temperature distribution, enhance safety, and improve the overall performance of the battery pack. The study's findings underscore the critical role of proper cooling configurations in preventing overheating and thermal runaway, thus contributing to the reliability and longevity of battery systems.

2) Future Scope

- **Advanced Cooling Techniques:** Further research could explore the integration of advanced cooling techniques such as liquid cooling, phase-change materials, or hybrid cooling systems to enhance thermal management.
- **Material Innovation:** Investigating the use of novel materials with superior thermal conductivity and insulation properties could lead to more efficient battery pack designs.
- **System-Level Optimization:** Expanding the study to system-level optimization, considering the interactions between the battery pack, power electronics, and vehicle thermal management systems, can provide comprehensive solutions for thermal challenges.
- **Real-World Validation:** Conducting real-world validation of the simulated results through experimental testing will help in refining the CFD models and ensuring their accuracy and reliability.
- **Transient Analysis:** Implementing transient analysis based on actual driving or load cycles can offer insights into the dynamic thermal behavior of the battery pack under varying operational conditions.

- **Environmental Impact:** Assessing the environmental impact of different thermal management strategies and their sustainability can guide the development of eco-friendly battery systems.

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