International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252

Design and analysis of external air cooling for the battery of an electric scooter to control the explosions

U Jawahar Surendra M.Tech (Ph.D), D Jaya Chandra, K Mahesh, D Chandra Nivas, R VijayaRamaraju, A Rahul Kumar, B Shiva Krishna, V Sreedhar Naik.
Sri Krishnadevaraya university college of Engineering and Technology,Anantapur, 515003
Corresponding Author:U Jawahar Surendra sir M-Tech [Ph.D.]

Date of Submission: 05-04-2023 Date of Acceptance: 15-04-2023

ABSTRACT: The use of electric vehicles (scooters) in the world could face several problems related the high temperature, mostly when charging at high power and discharging continuously by running a vehicle. This paper proposes a new external cooling solution for cooling EV battery packs at a higher temperature condition, especially for those without an effective cooling system embedded. A 3-D thermal model has been developed in order to investigate and analyze the temperature distribution over the battery pack, when the air is passed across the battery pack, the ANSYS FLUENT software has been used to solve the model development for thermal analysis and fluid flow analysis. Furthermore, different external cooling solutions have been proposed by using the engineering process design to study their impact on the internal temperature of the battery pack.

KEYWORDS: Lithium-ion battery pack, cooling fan, Housing box, Rubber corks, thermal analysis, fluid flow analysis, Environmental concern, Safety

I. INTRODUCTION

Conventional vehicles use fossil fuel and pollution due to combustion is a serious concern for the environment. The scope of electric vehicles (EVs) has been essential due to the adverse impact of fossil fuels on the environment. An electric vehicle does not use any fossil fuels for power generation and has zero emissions. Many initiatives have been taken to reduce air pollution using non-conventional energy sources.

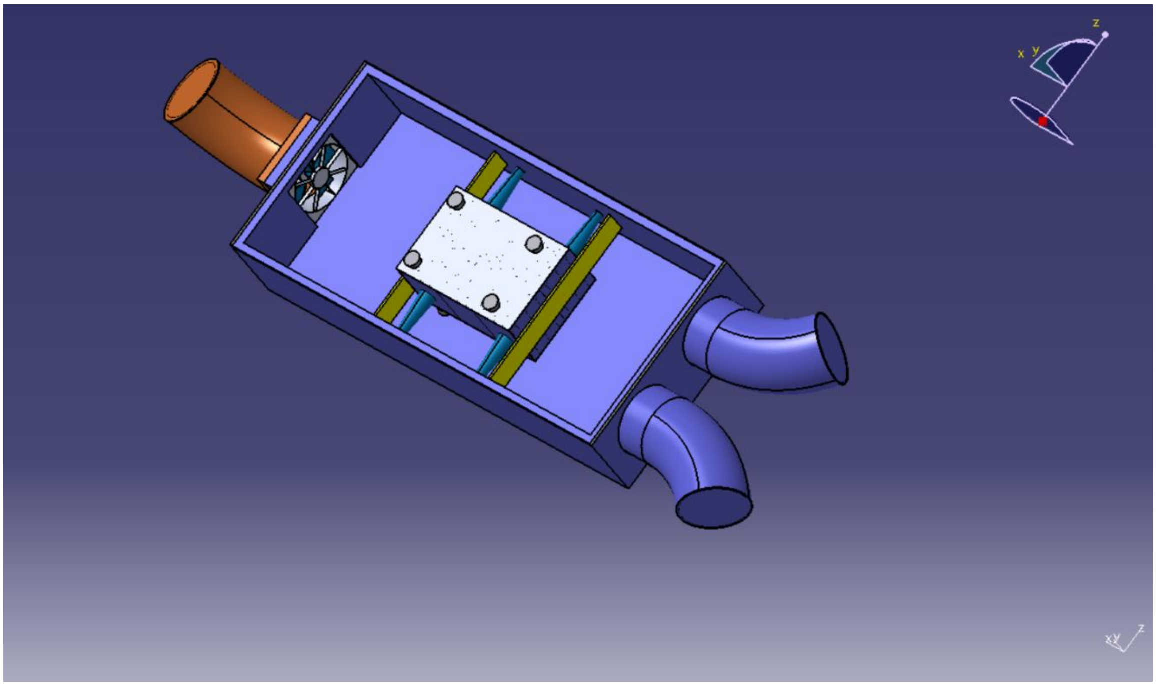
Non-renewable energy resources are increasingly exhausted and environmental pollution is continuously aggravated. It is an irreversible trend to use clean energy to replace traditional resources such as oil and coal. The Lithium-ion battery has become the core technology in many new energy fields by virtue of its characteristics of high energy density, low maintenance cost, and no memory effect. Although the development of the lithium-ion battery market is already mature, there are still some safety issues. Once the battery is in a state of short circuit, overheating, overcharge, over-discharge and other abuses, the heat inside the battery will accumulate rapidly, resulting in safety accidents such as deflagration and explosion. Therefore, it is particularly important to introduce a battery thermal management system (BTMS).

Researchers have proposed a variety of management technologies for the thermal runaway behaviour of lithium batteries, including air cooling, liquid cooling, and phase change material cooling. Among the above thermal management methods, liquid cooling has a higher specific heat capacity and good cooling effect, which is easier to achieve uniform distribution of battery temperature. The main disadvantages of liquid cooling are the large total weight of the system, high cost, and poor reliability. PCM cooling has the advantages of low energy consumption, simple system accessories, and low cost. But it can't meet the requirement of continuous heat dissipation due to the long curing time of PCM.In view of low cost and simple industrial design, the air-cooling system is the most widely used lithium battery cooling system which is commonly used in electric vehicles, especially scooters. It is generally divided into active and passive cooling methods. Passive systems get air directly from the atmosphere, while active systems get pre-regulated air from devices such as fans.

Air-cooling BTMS is widely used due to its relatively simple structure, small space occupation, low cost and easy maintenance. However, due to the small specific heat capacity of air, air-cooling BTMS has some defects, such as the high temperature of the battery module and poor temperature uniformity. Therefore, it is an important research topic to design air-cooling BTMS with higher cooling efficiency and better temperature uniformity.Both natural convection (passive) and forced convection (active) can be used as air cooling methods, but the heat transfer capacity of natural convection is much smaller than that of forced convection. Due to the drastic change in air velocity induced by fans, the heat transfer capacity of forced convection is greatly strengthened. At present, the parameter improvement of active air-cooling BTMS mainly focuses on three aspects: flow parameters, operating parameters and design parameters. The indicators used to evaluate the performance of BTMS include the maximum temperature in the battery module, temperature uniformity in the battery module and system pressure drop [9]. The higher the system pressure drops, the higher the parasitic power required to operate the cooling system; therefore, more energy will be consumed.

This paper designed an external air-cooling system for the battery module in the scooter, established the heat generation and air-cooling heat dissipation model of lithium iron phosphate power battery and simulated its temperature field distribution and also the flow of air across the battery using ANSYS CFD. For this kind of air-cooled BTMS, air can easily enter the flow channel from the inlet, and hot air can easily be discharged from the air outlet. It is expected to enhance the local heat dissipation effect of the system. Furthermore, this design structure changes the shape of the flow pass, reduces the volume of the flow passage, increases the flow rate of air per unit time, speeds up the heat exchange rate between the air and the battery pack, and is beneficial to improve the heat dissipation effect. This study proposes a foundation design of the air-cooling system with the design structure to improve the safety of electric scooters, which has certain engineering value for the further development of BTMS. The goal is to increase the lifespan and performance of the battery module by maintaining a suitable temperature range during operation.

II. DESIGN OF AN EXTERNAL AIR COOLING FOR THE BATTERY



The battery module with forced air cooling consisted of an internal battery pack and external shell, and the module was improved from the optimal model. The inner battery pack consists of 54 pieces of 18,650 lithium-ion batteries arranged in a rectangular array. The specific dimensions were: cell-to-shell top spacing (30 mm), cell-to-shell bottom spacing (30 mm), and cell-to-shell sidewall

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252

spacing (15 mm). The battery pack is placed in the rubber corks which are used to support the battery and provide space between the battery cell and the housing shell. By using the solid work software to create a 3-D model design, which is suitable for easy heat dissipation, where the internal heat generation is from the battery pack. To provide cooling to the battery pack atmospheric air is used to remove the heat.

Solid Works is a solid modeling computer-aided design and computer-aided engineering application software, by using software to generate models for the external cooling of battery of an electric scooter.

1. Battery pack specifications:

The first step in designing a cooling system for an electric scooter battery is to determine the battery pack specifications. In this project, the battery pack consists of 54 single cylindrical li-ion batteries 18650 cells, with a maximum voltage of 12V and a maximum temperature limit of 40°C.

2. Cooling System Design:

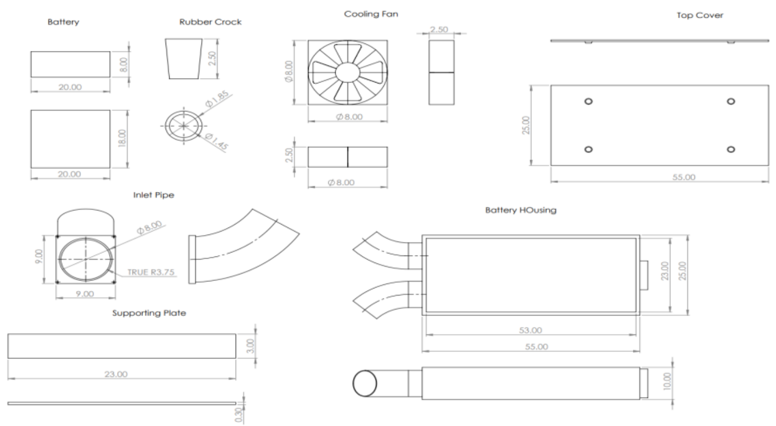
The cooling system consists of an external air cooling mechanism that facilitates the flow of air over the battery pack. The air intake and exhaust fans are placed strategically to ensure adequate airflow. The cooling system also includes a heat sink, which is in direct contact with the battery pack to aid in heat transfer.

3. Fan Selection:

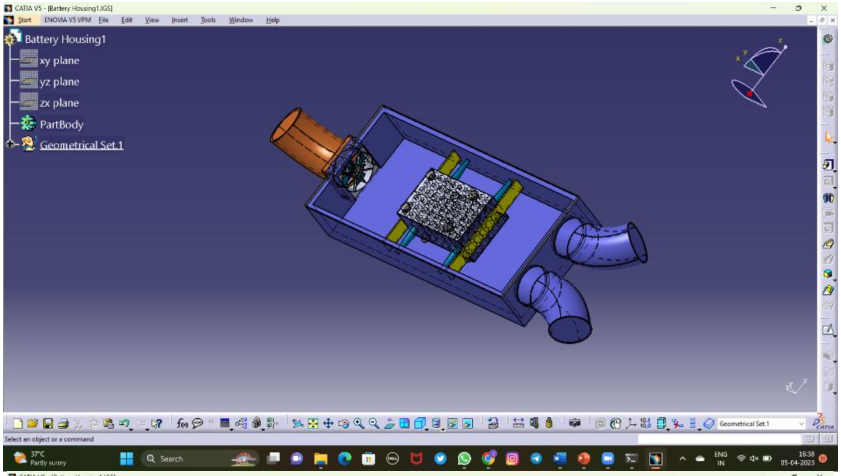
To ensure adequate cooling, the appropriate fan type and capacity are required. In this project, a DC axial fan with a high static pressure rating is chosen. The fan should have a rating of at least 2 CFM and a max. of 60 CFM at 0.1 inches WC to ensure that the required airflow rate is achieved.

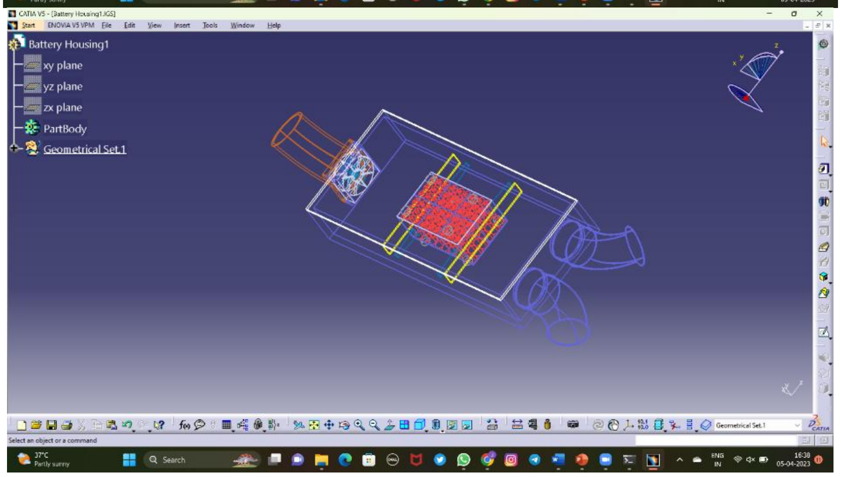
4. Heat Sink Design:

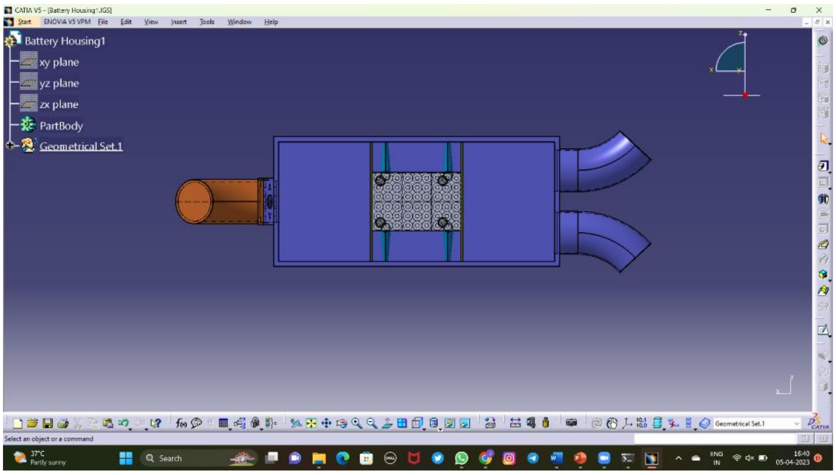
The heat sink design is crucial to the overall effectiveness of the cooling system. A well-designed heat sink facilitates the transfer of heat from the battery pack to the cooling medium (air). The heat sink should have a large surface area and be in direct contact with the battery pack to ensure efficient heat transfer.



International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252

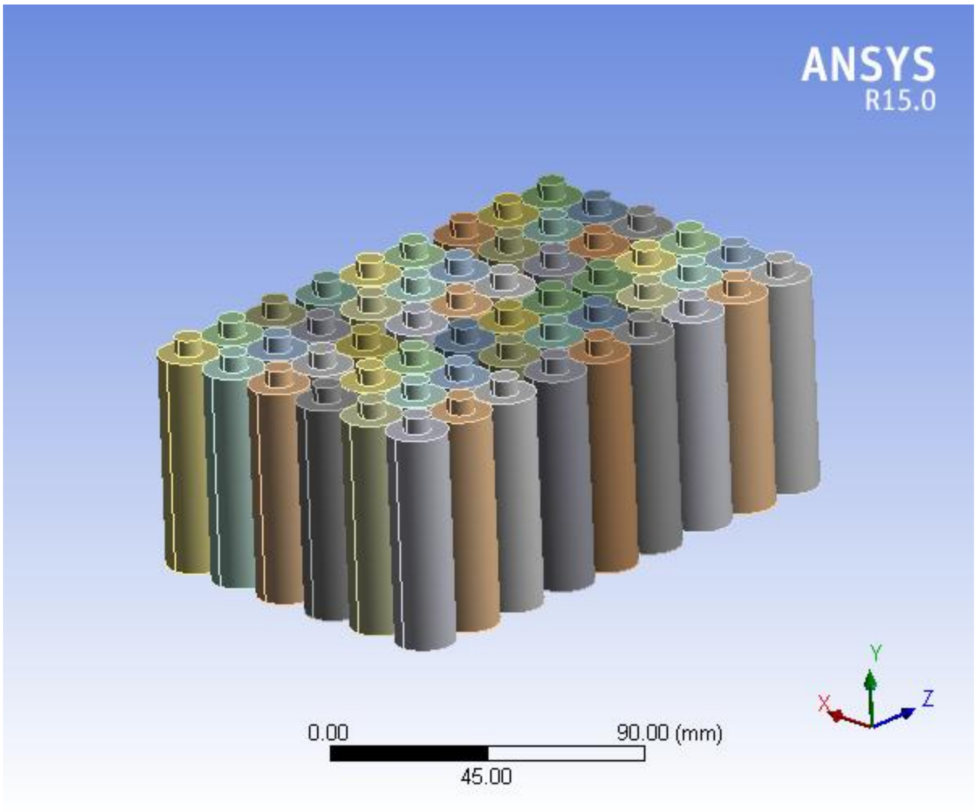






III. THERMAL ANALYSIS OF THE BATTERY PACK.

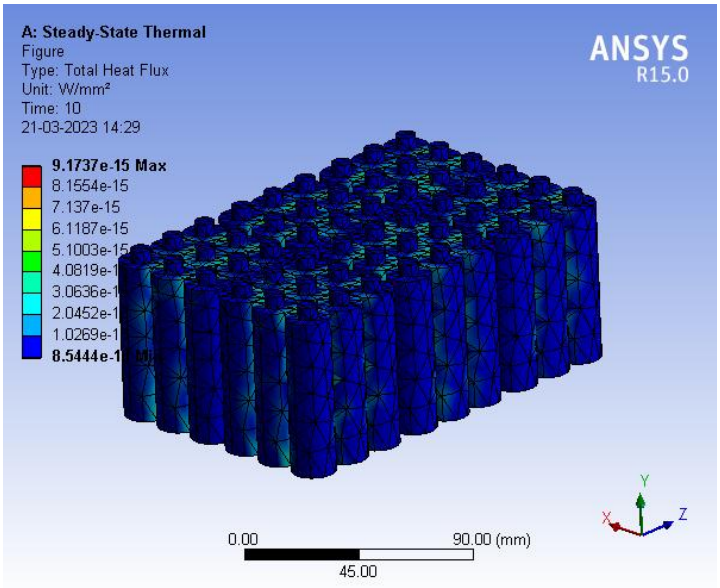
In the thermal analysis of battery packs, the generated heat from battery cells is an important source of heat. So far, there are two means to obtain this physical parameter. The first one is based on the thermal-electro-chemical battery model, which enables our attention to be paid to the underlying mechanism of heat generation; however, this model requires a large number of electro-chemical parameters and these unknowns are difficult to determine. The second one is the simplified Bernardi's heat generation model which is wildly used because of it's physical-based properties and few parameters are required. In Bernadi's heat generation model, the entropy coefficient is an important parameter as it is related to reversible heat. This important parameter, however, is difficult to test and determine and sometimes neglected or assumed to be a constant. Apparently, these simplified treatments will lead to the bias of the generated heat between the calculation and the test, and thus it is necessary to measure and calculate the real values of the entropy coefficient. To obtain this parameter, small-capacity cells of 18650 were selected and medium-size capacity cells were selected by Zhang et al, but unfortunately, large-capacity cells are rarely used to conduct research as from the literature. Considering a large-capacity cell has less heat releasing rate due to the small ratio of surface to volume, we use a large-capacity cell of 153 Ah to investigate the entropy coefficient for thermal management analysis of a battery pack in this research.



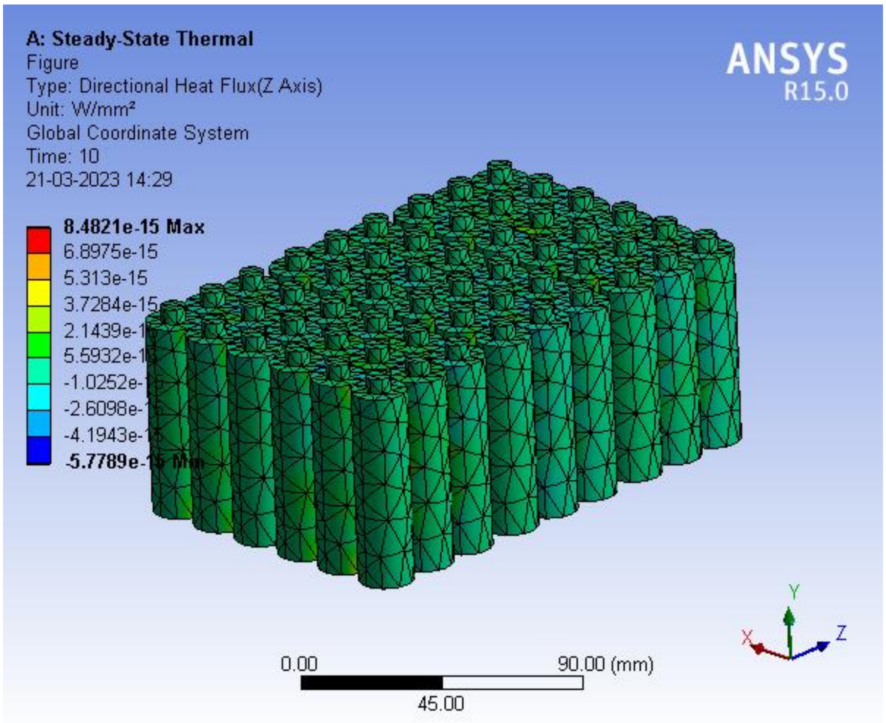
The thermal analysis is performed in the workbench ansys software, which is to be determined how much heat flux will be generated in the total and also directional heat flux and also temperatures of maximum.

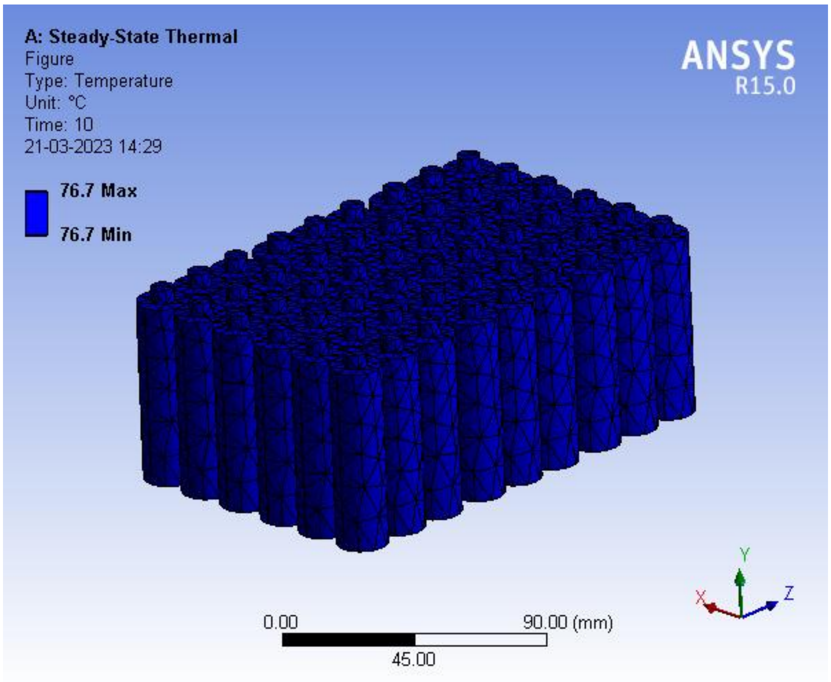
1.Total Heat Flux

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252



2.Directional Heat Flux





Object Name	Temperature	Total Heat Flux	Directional Heat Flux
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			Z Axis
Coordinate System			Global Coordinate System
Results			
Minimum	76.7 °C	8.5444e-018 W/mm²	-5.7789e-015 W/mm²
Maximum	76.7 °C	9.1737e-015 W/mm²	8.4821e-015 W/mm²
Minimum Occurs On	Solid		
Maximum Occurs On	Solid		
Minimum Value Over Time			
Minimum	76.7 °C	8.5444e-018 W/mm²	-5.7789e-015 W/mm²
Maximum	76.7 °C	8.5444e-018 W/mm²	-5.7789e-015 W/mm²
Maximum Value Over Time			
Minimum	76.7 °C	9.1737e-015 W/mm²	8.4821e-015 W/mm²
Maximum	76.7 °C	9.1737e-015 W/mm²	8.4821e-015 W/mm²
Information			

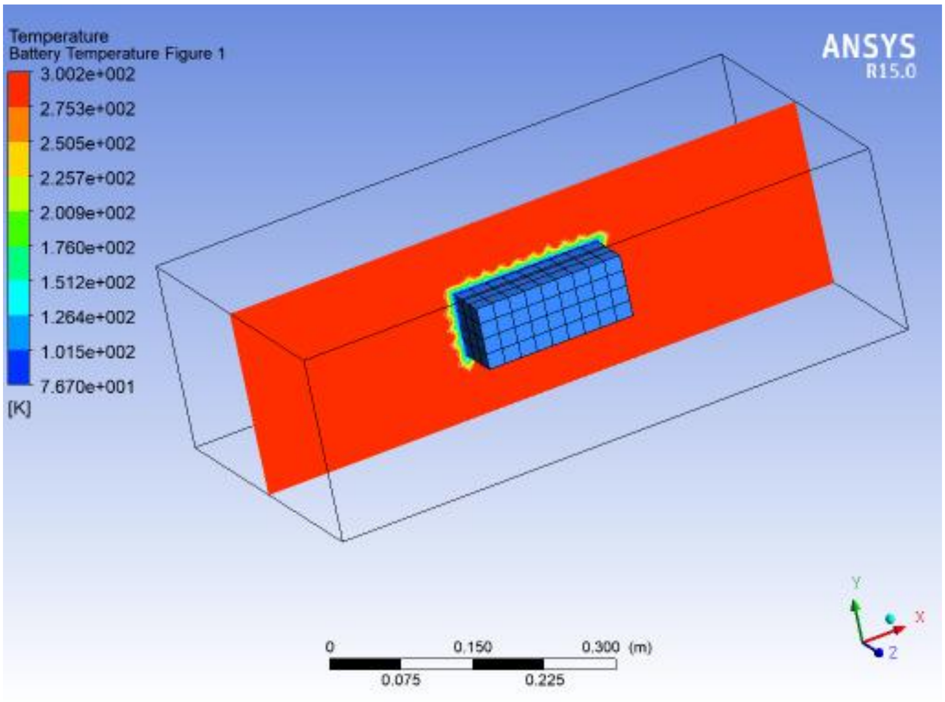
Time	10. s	
Load Step	1	
Substep	1	
Iteration Number	1	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

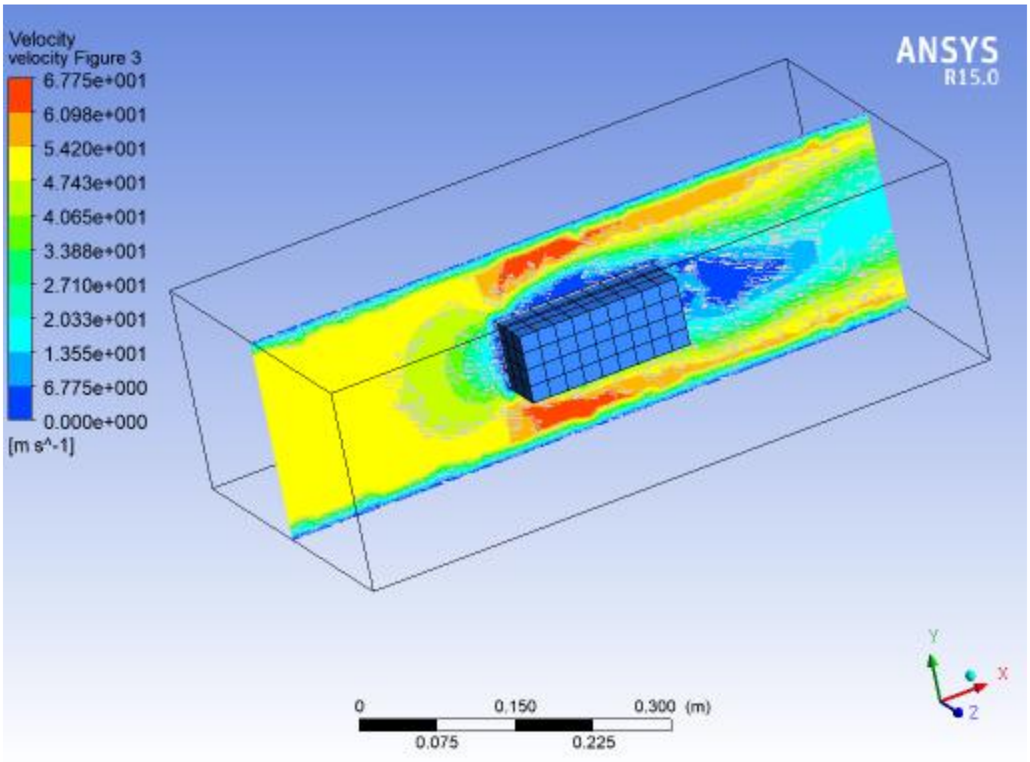
IV. FLUID FLOW ANALYSIS OF THE DESIGN OF COOLING SYSTEM.

ANSYS Fluent 2020 R1 was used for coolant flow simulation purposes. During the discharging cycle, heat transfer between the lower-temperature coolant fluid mixture and the higher-temperature cells in the battery pack takes place. To simulate the temperature distribution during coolant(air) fluid flow for the three different tier systems of battery packs, certain boundary conditions as these were preset with the initial temperature of the cells set at 60 °C, as a steady-state condition provides an assumption that the cells have reached their peak heating temperatures during discharging/charging cycles.

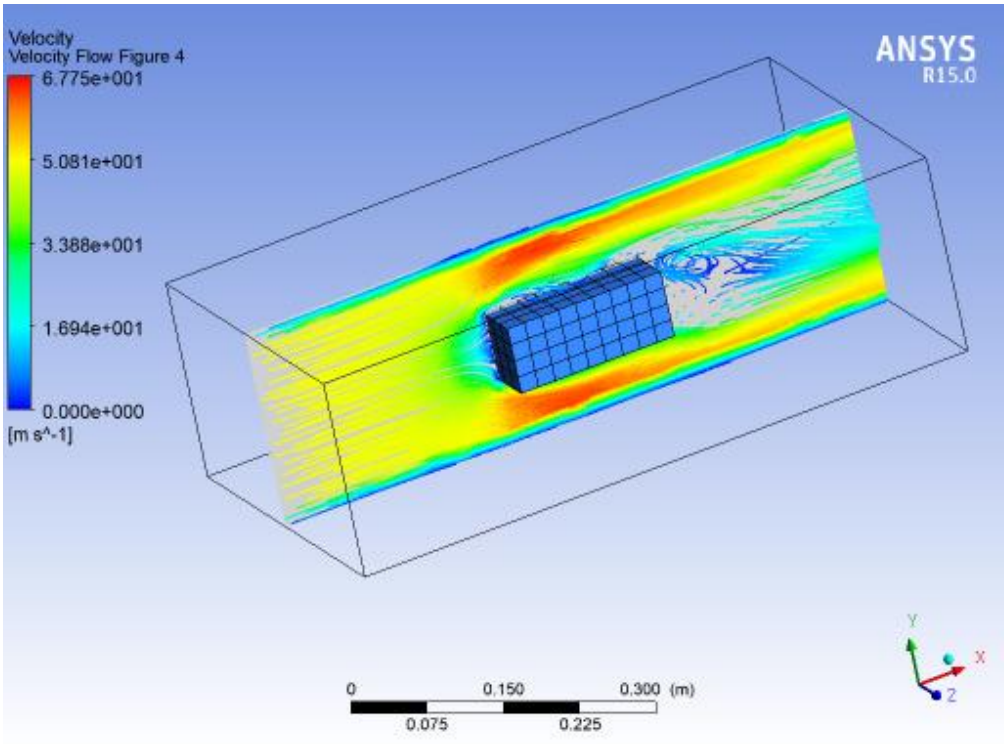
Based on ambient conditions, the inlet coolant fluid temperature was set to a modest 35 °C. Additionally, a heat generation rate of 5318 W/m^3 within the pack was considered. Considering an ideal working temperature range of 35 °C to 45 °C for batteries in EVs temperatures within the battery pack were evaluated after 15 s (to achieve steady-state conditions) of coolant flow within the pack.

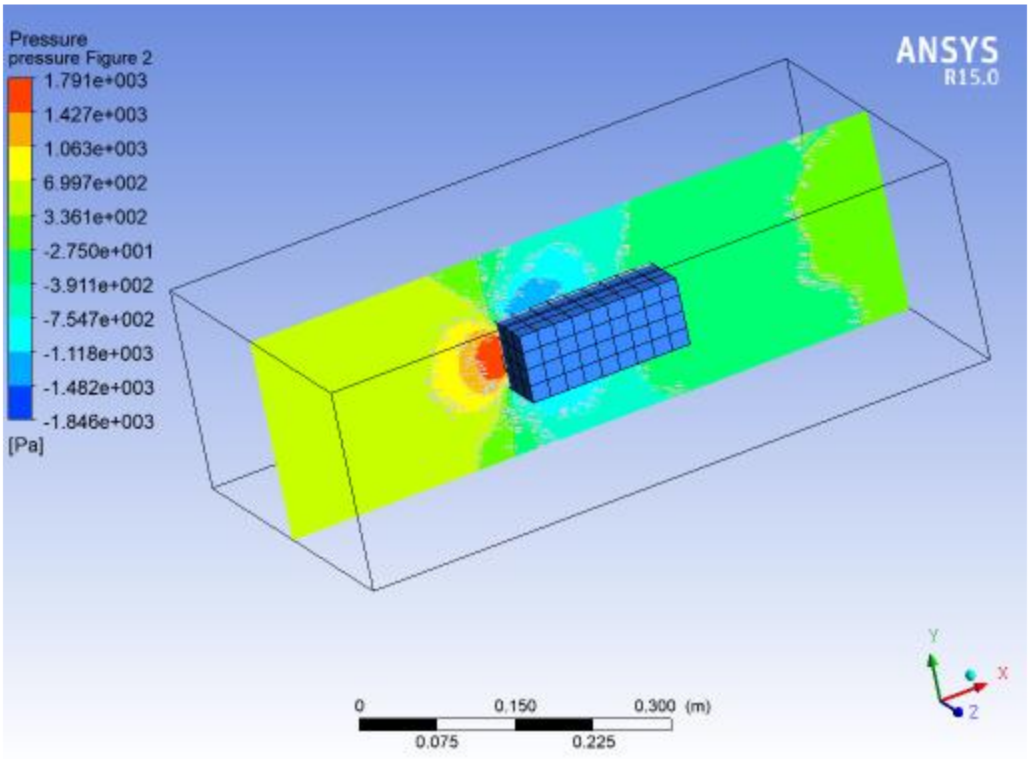
- CFD ANALYSIS:


Temperature
Battery Temperature Figure 1
3.002e+002
2.753e+002
2.505e+002
2.257e+002
2.009e+002
1.760e+002
1.512e+002
1.264e+002
1.015e+002
7.670e+001
[K]
ANSYS
R15.0
0
0.150
0.300 (m)
0.075
0.225

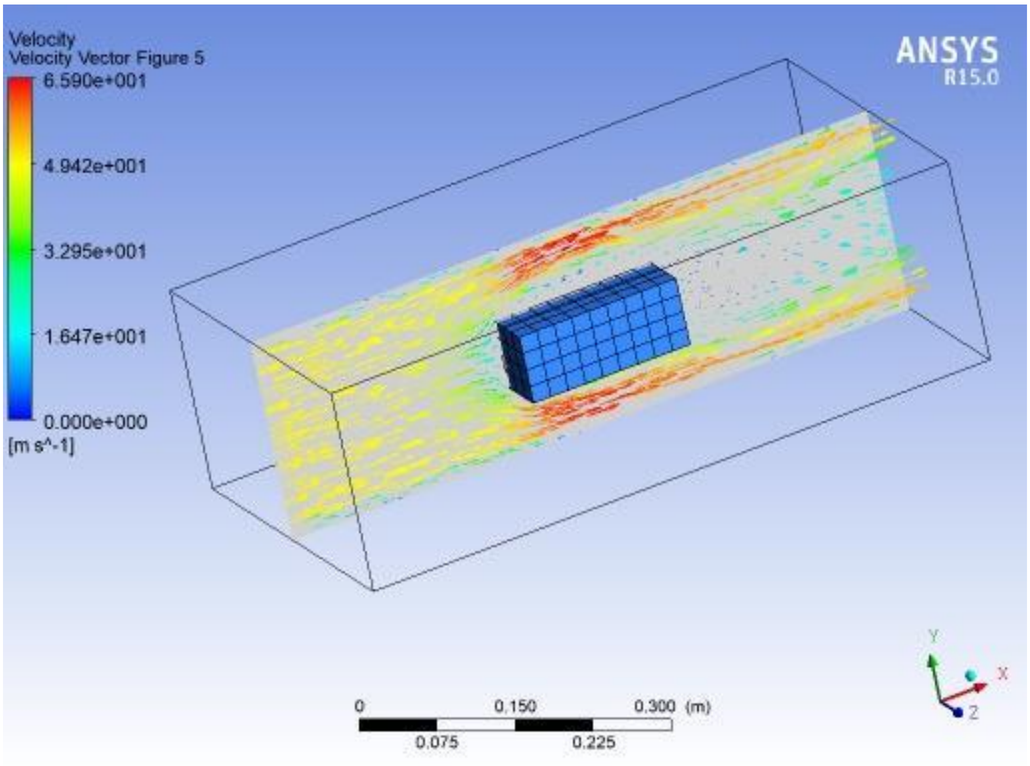

Velocity
velocity Figure 3
6.775e+001
6.098e+001
5.420e+001
4.743e+001
4.065e+001
3.388e+001
2.710e+001
2.033e+001
1.355e+001
6.775e+000
0.000e+000
[m s^-1]
ANSYS
R15.0
0
0.150
0.300 (m)
0.075
0.225

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252





International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 4 April 2023, pp: 600-610 www.ijaem.net ISSN: 2395-5252



V. RESULTS & DISCUSSION

All equations are simultaneously solved numerically in ANSYS FLUENT by using the Finite Element Method. However, the unstructured mesh was generated by using the ANSYS Meshing software, with refining zones at the cooling channel zones. The temperature is solved by using the SIMPLE Solver Algorithm. For each time step, the convergence is reached where the relative tolerance is below 10−3 for all variables. The simulation of the different cooling system designs is performed by using the same conditions, and physical and cooling parameters. The impact of the air cooling designs on the battery pack behaviour is investigated by considering the heat removed by the and the heat dissipated through the ambient air with the convective coefficient of 100 W/m2K.

From the above thermal analysis tables and CFD diagram are shown the maximum temperatures and minimum temperatures to maintain the battery pack and operating conditions. It's indicates also heat generation and heat dissipation. The external air cooling system can be successfully installed in the electric scooters to control the explosions due to overheating at charging and discharging

VI. CONCLUSION

A 3D-thermal model is developed for Li-ion battery pack for EVs (scooters), which is able to investigate and to analyze the temperature distribution of the battery at discharging conditions. The ANSYS FLUENT software has been used to solve the model development. The simulation result show that the battery surface temperature is nearly uniform, except in the middle where the maximum temperature is located (48 ◦C). This value is higher than the recommended operation value in the charging state which means that an external cooling system is required to reduce it. Moreover, externalair cooling configurations have been investigated in order to obtain the efficient cooling architecture, which allows to decrease the temperature and to obtain a more uniform temperature distribution over the surfaceof the battery pack. It has been found that the cooling atmospheric air with (design 2) successfully controls the maximum temperature and reduces the temperature gradient due to the high surface contact between the cooling channel and plates. Furthermore, the optimization of the operating conditions for this solution has been calculated for a flow rate of 1.5 kg/s at inlet temperature or the ambient temperature of 25 ◦C. These values represent an optimum for lowering the maximum temperature increase. Finally, the required pump power needed is about 1 Kw for efficient cooling of the investigated pack battery. Future work will focus on the optimization of the cold plate. And its operating conditions.

REFFERENCES:

1. **Thermal analysis of modified Z-shaped air-cooled battery thermal management system for electric vehicles**
Xueyang Shen [a], Tianao Cai [a], Chunmin He [a], Yi Yang [a], Miao Chen [b]
2. F. He et al.
Combined experimental and numerical study of thermal management of battery module consisting of multiple Li-ion cells
Int. J. Heat Mass Transf.
(2014)
3. L.H. Saw et al.
Computational fluid dynamic and thermal analysis of Lithium-ion battery pack with air cooling
Appl. Energy
(2016)
4. Z. Rao et al.
A review of power battery thermal energy management
Renew. Sust. Energ. Rev.
(2011)
5. A.A. Pesaran
Battery thermal models for hybrid vehicle simulations
J. Power Sources
(2002)
6. R. Sabbah et al.
Active (air-cooled) vs. passive (phase change material) thermal management of high power lithium-ion packs: limitation of temperature rise and uniformity of temperature distribution
J. Power Sources
(2008)
7. F. Zhang et al.
Optimization design for improving thermal performance of T-type air-cooled lithium-ion battery pack
J. Energy Storage
(2021)
8. J. Xie et al.
Structural optimization of lithium-ion battery pack with forced air cooling system
Appl. Therm. Eng.
(2017)
9. N. Yang et al.
Assessment of the forced air-cooling performance for cylindrical lithium-ion battery packs: a comparative analysis between aligned and staggered cell arrangements
Appl. Therm. Eng.
(2015)
10. Y.S. Choi et al.Prediction of thermal behaviors of an air-cooled lithium-ion battery system for hybrid electric vehicles
J. Power Sources
(2014)
11. Computational Fluid Dynamics (CFD) analysis of Graphene Nanoplatelets for the cooling of a multiple tier Li-ion battery pack
panelPrashant Jindal [a], Pranjal Sharma [a], Manit Kundu [a], Shubham Singh [a], Deepak Kumar Shukla [a], Vikram Jit Pawar [a], Yang Wei [b], Philip Breedon [c]
12. Explosion-proof lithium-ion battery pack – In-depth investigation and experimental study on the design criteria
panelLingyu Meng [a e], K.W. See [b], Guofa Wang [a e], Yunpeng Wang [b], Yong Zhang [c], Caiyun Zang [d], Bin Xie [b]
13. Prediction of thermal behaviors of an air-cooled lithium-ion battery system for hybrid electric vehicles
Yong Seok Choi, Dal Mo Kang
14. A Review on lithium-ion battery thermal management system techniques: A control-oriented analysis
2023, Applied Thermal Engineering
Show abstract
15. Modelling and optimisation of a battery thermal management system with nano encapsulated phase change material slurry for 18650 Li-ion batteries
2023, Thermal Science and Engineering Progress
Show abstract
16. Multi-objective optimization of U-type air-cooled thermal management system for enhanced cooling behavior of lithium-ion battery pack
2022, Journal of Energy Storage
Show abstract
17. Numerical evaluation of the effect of air inlet and outlet cross-sections of a lithium-ion battery pack in an air-cooled thermal management system
2022, Journal of Power Sources
Show abstract

18. Battery thermal management systems: Recent progress and challenges
2022, International Journal of Thermofluids
19. K. Chen et al.
Cooling efficiency improvement of air-cooled battery thermal management system through designing the flow pattern
Energy
(2019)