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Design and Optimization of Accumulator Pack

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Abstract **—** For an electric scooter, a lithium-ion battery with a Acro Butyl-nitrate (ABS) temperature management system was developed.
Without the use of active cooling components like a fan, a blower, or a pump used in air/liquid-cooling systems, passive thermal management systems employing ABS can regulate the temperature excursions and maintain temperature uniformity in Li-ion batteries. Therefore, this new type of thermal management system can provide the benefits of a small, light, and energy-efficient system. The simulation results for a Li-ion battery sub-module with twenty 18650 Li-ion cells encased in ABS and a melting point of 114 to 120 °C are displayed.

There are many important advantages to using aluminium fins manufactured from 0.7mm thick aluminium sheet between the battery cells in an accumulator pack. The relevance of them is explained in the following ways:
Accumulator packs, particularly those used in high-power applications like scooters, can produce

large amount of heat when in use. The performance, longevity, and safety of battery cells are all significantly impacted by heat. Aluminium fins serve as heat sinks and enhance heat dissipation by boosting the amount of heat-transfer surface area. Heat can be effectively transferred from the cells to the fins thanks to the thin aluminium sheet.

Temperature Control: Battery cell efficiency and longevity depend on maintaining their temperature within a favorable range. By releasing more heat, aluminium fins assist in controlling the temperature. The fins aid in preventing overheating and preserving a more constant operating temperature by efficiently draining heat from the cells.

Thermal Uniformity: The accumulator pack's thermal uniformity is enhanced by the inclusion of aluminium fins between the battery cells. Variations in cell temperature can cause performance imbalances and lower pack efficiency because uneven heat distribution can cause temperature differences among the cells. The fins aid in the even distribution of heat throughout the cells, reducing temperature variations and fostering consistent performance.

Reduced Hotspots: Hotspots are small, high-temperature regions inside a battery pack that can hasten degradation and pose safety issues. Aluminium fins aid in heat dissipation, which reduces the development of hotspots. The fins' increased surface area enables more effective heat transport, which lowers the possibility of localized temperature accumulation.

Improved Safety: Effective heat dissipation with aluminium fins can aid in accumulator packs' increased safety. Battery cells may experience thermal runaway or other dangerous situations as a result of high temperatures. The risk of thermal incidents is decreased by maintaining lower cell temperatures, improving operational safety in general.

It's crucial to remember that parameters like spacing, size, and overall pack should be taken into account while designing and using aluminium fins.

Additionally, by lowering the amount of heat that is released into the environment, liquid cooled heatsinks can be utilised to lessen the environmental effect of electronic equipment.
The following are some benefits of employing liquid-cooled heatsinks:

- more efficient at cooling than heatsinks that use air cooling
- can be used to enhance the functionality and dependability of electronic equipment
- can be used to lessen how harmful electrical devices are to the environment. The following are some drawbacks of employing liquid-cooled heatsinks:
- more expensive than heatsinks that are air-cooled.

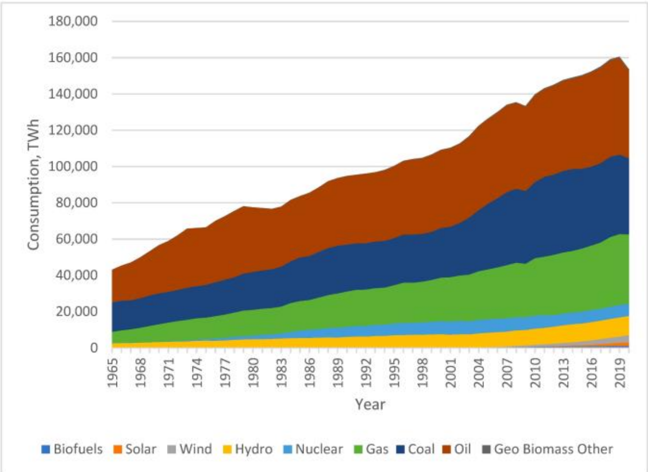
- more difficult to install and keep up
- Tend to leak more frequently.

Keywords — CFD, 18650,ABS ,ALUMINUM FINS ,DRIVE CYCLE MODELS,EQUIVALENT CIRCUIT MODEL.

I. Introduction

Since the turn of the 20th century, the development of new modes of transportation like cars and aeroplanes has greatly increased people's mobility. These innovations have decreased the amount of time it takes to travel across continents and seas due to their faster speeds.

Although these modes of transportation make it possible for humans to travel anywhere in the world, they are energy-intensive and mostly rely on fossil fuels. Humans have been steadily increasing their consumption of fossil fuels over the past 50 years as both their population and economic affluence have grown.



Sector-specific oil consumption totals from 1965 to 2019 [1]. Agriculture, business and government services, and household oil usage are all considered "other."

To meet the operational needs of electric vehicles without significantly increasing the vehicle's weight, the automotive market wants high specific power and high specific energy density batteries. In terms of cranking power, lifespan, and affordability, lead-acid batteries have satiated the needs of the battery market for more than a century. While modern battery technologies like nickel-metal hydride (NiMH) and lithium-ion batteries have shown greater performance over lead-acid batteries, lead-acid batteries still struggle to achieve these standards.

Although NiMH batteries are now the preferred battery for hybrid electric vehicles (HEV), Li-ion batteries offer double the energy density of NiMH batteries and could eventually replace NiMH batteries in HEV applications if the thermal safety issue is properly resolved.

A battery pack made of a number of Li-ion cells connected in series and parallel is required to supply the propulsion power needed for an electric vehicle or the power needed for electronics. Due to their higher rate of volumetric heat generation than VRLA or NiMH batteries, the safety of the battery pack and electric vehicle, aside from the user, becomes a major worry.

As a result, efficient heat dissipation and the prevention of thermal runaway are the main issues in commercializing Li-ion batteries for high power applications. A successful thermal management solution is therefore necessary. The electrochemical performance of batteries and their internal temperature distribution are strongly correlated [4], necessitating an effective thermal management system for these battery packs to operate at their best. Consequently, the development of thermal management systems for Li-ion batteries must take into account temperature uniformity and heat dissipation.

A substantial effort has been made to design and build an accumulator pack for electric scooters with the goal of developing a dependable and effective power supply. The accumulator pack is essential in supplying the necessary energy storage and power delivery capabilities as electric scooters gain popularity as a green and sustainable means of transportation. The entire design, construction, and optimisation of an accumulator pack specifically made for industrial scooters is the subject of this project.

The main goal of this project is to develop an accumulator pack that satisfies the power and energy demands of electric scooters while providing optimal performance, longevity, and safety. The scooter's motor, lighting, and other electronic components all receive power from the accumulator pack, which is a crucial part. The accumulator pack directly affects the scooter's range, speed, and overall user experience by controlling the energy storage and distribution.

The project includes a number of important components, such as the choice of suitable battery cells, design of the pack structure, use of a powerful battery management system (BMS), and incorporation of thermal management techniques. Each of these components is essential to ensure the accumulator pack operates dependably and effectively.

Careful consideration must be given to a number of variables when choosing battery cells, including energy density, voltage needs, capacity, and safety features.

To meet the operational needs of electric vehicles without significantly increasing the vehicle's weight, the automotive market wants high specific power and high specific energy density batteries. In terms of cranking power, lifespan, and affordability, lead-acid batteries have satiated the needs of the battery market for more than a century [1]. While modern battery technologies like nickel-metal hydride (NiMH) and lithium-ion batteries have shown greater performance over lead-acid batteries, lead-acid batteries still struggle to achieve these standards. Another crucial issue that this initiative addresses is thermal management. Heat produced by accumulator packs during operation has the potential to impair battery performance and longevity. Therefore, to improve heat dissipation and maintain ideal operating temperatures within the pack, thermal management solutions—such as the use of aluminium fins or heat sinks—are implemented. These actions help the accumulator pack's overall efficiency, dependability, and safety to increase. Cost-effectiveness, scalability, and manufacturability factors are taken into account at every stage of the project. The developed accumulator pack should adhere to industry norms and laws for electrical safety and environmental sustainability, as well as being commercially viable for mass production.

In order to accomplish this goal, the project begins with choosing the best battery cells based on specifications including energy density, voltage needs, capacity, and safety features. To aid in the decision-making process, MATLAB models are used to simulate and analyse the behaviour of various battery cell topologies. These models take into account variables including cell properties, connections in series and parallel, and anticipated performance under various operating situations.

In addition to choosing the battery cells, the project uses CFD analyses to improve the accumulator pack's heat management system. CFD research aids in choosing the best location for aluminium sheets integrated into the pack by modelling airflow and heat transmission within the pack. The 0.7mm thick aluminium sheets serve as heat sinks and effectively dissipate heat, keeping the cells' operating temperature within a safe range.

Utilizing ABS material, which combines strength, durability, and lightweight construction, the accumulator pack's housing is 3D printed. Rapid prototyping and customisation made possible by 3D printing speed up the development process and enable iterative design depending on particular needs. Due to their great conductivity and mechanical stability, copper busbars are used in the project to create electrical connections. The cells are connected in series by the busbars, which are purposefully positioned and engineered to ensure low-resistance routes for current flow and minimize power losses. The in-house series connections offer more customization and control, enabling a small and effective accumulator pack structure. To guarantee the accumulator pack's dependability and performance, comprehensive testing and validation are carried out throughout the project. To ensure that the developed pack satisfies the required specifications, a number of performance measures, including voltage stability, discharge characteristics, and temperature management, are assessed.

In summary, the design and development of an electric scooter accumulator pack is a multidisciplinary undertaking that includes heat management, BMS implementation, battery cell selection, and pack configuration. The development of an optimized accumulator pack, which offers users superior performance, increased range, and increased dependability, advances the technology of electric scooters. Additionally, it supports the worldwide objective of increasing eco-friendly transportation options and lowering carbon emissions.

II. Literature Review

Battery Selection: Choosing the right batteries is an important part of designing an accumulator pack. Researchers have examined the appropriateness of various lithium-ion cell chemistries for usage in electric scooters, such as Sun et al. (2020). They have emphasised the significance of taking into account elements like battery management system (BMS) compatibility, capacity, voltage, and safety features. Researchers have also looked into how the qualities of the cells affect the energy density, power output, and cycle life of the pack. The choice of battery has a significant impact on the performance, energy capacity, dependability, and safety of an accumulator pack for an electric scooter. Making a wise decision requires a full understanding of battery properties and factors. We shall explore numerous elements to take into account when choosing batteries in this part.

Energy density is the measure of how much energy is contained in a battery per unit of weight or volume. It is a key factor because it affects the electric scooter's overall effectiveness and driving range. Due to its higher energy density when compared to other battery chemistries like lead-acid or nickel-metal hydride, lithium-ion batteries, particularly 18650 cells, are frequently employed. Lithium-ion cell energy density has been thoroughly investigated by researchers, who have found that it has a major impact on the accumulator pack's overall performance.

Voltage and Capacity: When making a decision, it's crucial to take the battery's voltage and capacity into account. For optimal operation, electric scooters often need a particular voltage range. Therefore, when connected in series, the chosen battery cells ought to deliver the needed voltage. The quantity of charge a battery can hold is measured in ampere-hours (Ah), which directly influences the driving range. It's essential to select cells with the proper voltage and capacity to satisfy the electric scooter's power requirements and guarantee peak performance. Cycle Life and Longevity: A battery's cycle life is the number of charge-discharge cycles it can withstand before suffering a substantial loss in capacity. Compared to other chemistries, lithium-ion batteries typically have a higher cycle life. Lithium-ion cell cycle life has been investigated, and variables that affect the battery's durability include charging rates, operating temperatures, and the depth of discharge. By choosing cells with a long cycle life, the accumulator pack's capacity is preserved for a longer period of time, eliminating the need for frequent replacements. Safety features: When choosing battery cells for an accumulator pack, safety is the most important factor to take into account. Multiple safety mechanisms are included into lithium-ion cells to guard against overcharging, over discharging, and thermal runaway. These attributes reduce the risk of heat incidents and include safety vents, sophisticated cell chemistries, and built-in protective circuits. For the safe operation of lithium-ion cells in electric vehicles, rules and guidelines have been set by researchers and regulatory organisations after a thorough investigation of battery safety. To guarantee the total reliability and user safety of the accumulator pack, it is imperative to use cells that adhere to certain safety standards.

Research and Development: Numerous studies on battery selection for electric vehicle applications, including electric scooters, have been done by researchers. These studies compare different battery chemistries, cell arrangements, and performance traits. They examine elements like energy density, capacity preservation, cycle life, safety features, and BMS compatibility. Reviewing pertinent research studies can give important insights into the effectiveness and acceptability of various battery alternatives for accumulator packs used in electric scooters.

Compatibility with Battery Management System (BMS): The battery management system (BMS), which monitors, regulates, and safeguards the battery cells, is a crucial part of an accumulator pack. Functionality and communication between the BMS and the chosen battery cells must be compatible for this to happen. The BMS controls voltages, assures cell balancing, and guards against overcharging, over discharging, and high temperatures. Choosing battery cells that work with the BMS and enable efficient management and control of the accumulator pack is essential.

In conclusion, choosing a battery is a difficult procedure that needs to be done carefully while taking a number of variables into account, including energy density, voltage, capacity, cycle life, safety features, and compatibility with the BMS. Due to its high energy density, lengthy cycle life, and well-established safety features, lithium-ion batteries, particularly 18650 cells, are widely used.

Geometrical modelling : The physical structure of the accumulator pack can be seen and examined using geometrical modelling utilizing software programmes like MATLAB. Geometrical modelling in MATLAB has been used by researchers to optimize the pack's configuration, including Li et al. (2019). They have taken into account things like cell organization, interconnects, and thermal control strategies. The performance and efficiency of the pack are optimized with the help of geometrical modelling , and the integration of other parts into the structure of the pack is made easier.

Thermal Management: Maintaining ideal battery performance, safety, and longevity requires effective thermal management. CFD models have been used by researchers to examine heat dissipation within accumulator packs, including Wang et al. (2019). The impact of various thermal management techniques, such as the incorporation of aluminium fins or heat sinks, on temperature distribution and heat dissipation within the pack, have been studied. By analysing elements like airflow, heat transfer, and temperature gradients, CFD studies help optimize the pack's cooling system and give useful insights into the thermal behaviour.

A substantial part of modelling and analysing the electrical behaviour of accumulator packs is done using MATLAB simulations. Researchers have used MATLAB simulations to examine cell balancing techniques and their effect on the performance and longevity of the pack, as in Zhang et al. (2018). These simulations enable the assessment of various charging and discharging techniques, the calculation of cell capacity, and the forecasting of voltage and current behaviour under varied operating situations. MATLAB simulations help to balance the operation of the accumulator pack and optimise the battery management system (BMS).

Optimisation Methods: To enhance the design and performance of accumulator packs, optimisation methods together with MATLAB simulations and CFD studies have been used. Multi-objective optimisation techniques have been used by researchers like Guo et al. (2018) to maximise energy efficiency and reduce temperature rise within the pack. In order to achieve the best possible balance between performance, safety, and reliability, these techniques take a variety of factors into account, such as cell layout, cooling system design, and electrical connections. Through the use of optimisation techniques, the overall pack design is improved while assuring the best possible resource utilisation for applications using electric scooters. Definition of the objective functions, which stand in for the objectives or performance indicators that need to be maximised or minimised, is the first step in the optimisation process. Common target goals while designing an accumulator pack include increasing energy efficiency, lowering temperature rise, reducing weight or volume, and extending battery life. The selection of goal functions is based on the particular needs and priorities of the application for electric scooters.

Design Variables: During the optimisation process, there are parameters that can be changed. These factors include the placement and arrangement of the battery cells, the design of the cooling system, the interconnects, and the thermal management techniques. Engineers can experiment with various combinations and values for these design factors using optimisation techniques in order to find the best combination that maximises the objective functions. Depending on the complexity of the accumulator pack and the particular optimisation challenge, there may be a variety of design variables.

Limitations or restrictions placed on the design variables are represented by constraints. Physical restraints like space availability, weight restrictions, or heat restrictions can be among these restrictions. Constraints can also include financial restrictions, safety concerns, and electrical requirements. By verifying that the suggested design complies with these restrictions, optimisation techniques guarantee that the final solution is workable and useful.

Mathematical algorithms are used by optimisation approaches to comb through the design space and find the best answer. These algorithms fall into the deterministic or stochastic categories. Mathematical derivatives are used by deterministic algorithms, such as gradient-based techniques, to iteratively modify the design variables and reach the best outcome. Random search and iterative improvement are techniques used by stochastic algorithms, such as genetic algorithms or simulated annealing, to investigate a larger design space and locate the global optimum. Simulation and evaluation: Simulation techniques are used to assess the performance of each design variant. Among other things, these simulations may include analyses of electrical circuits, thermal systems, and fluid dynamics. For instance, MATLAB simulations may be used to analyse cell balancing methods, forecast voltage and current profiles, and model the electrical behaviour of the accumulator pack. The thermal behaviour, temperature distribution, and airflow within the pack can all be evaluated using CFD simulations. These simulations offer useful information for assessing the constraints and objective functions, aiding in the optimisation process.

Iterative refining: The method of iterative refining is often used in optimisation approaches. Simulations are used to assess the initial design configuration and compare it to the specified objective functions and limitations. The design factors are modified in light of the findings, and the procedure is repeated until the ideal outcome is obtained. Through iterative refining, the final design is guaranteed to achieve the specified performance goals and enables for continued development.

Integration of Geometrical Modelling, MATLAB, and CFD: By combining geometrical modelling, MATLAB simulations, and CFD investigations, it is possible to analyse the design and performance of accumulator packs in detail. These methods have been effectively combined by researchers like Pau et al. (2019) to optimise the design of the pack, test the electrical behaviour using MATLAB simulations, and evaluate the thermal performance using CFD simulations. Through the use of an integrated strategy, the properties of the pack can be evaluated more precisely, allowing for the identification of design tweaks and the optimisation of the battery pack.

The positioning of battery cells, interconnects, and other components are all represented virtually in the geometry of the pack using geometric modelling software. For electrical simulations, the geometrical model is imported into MATLAB. The electrical behaviour is analysed, voltage and current profiles are predicted, and the BMS's effectiveness is assessed using MATLAB. To maximise the performance of the pack's electrical system, MATLAB can be used to design a variety of techniques and models.

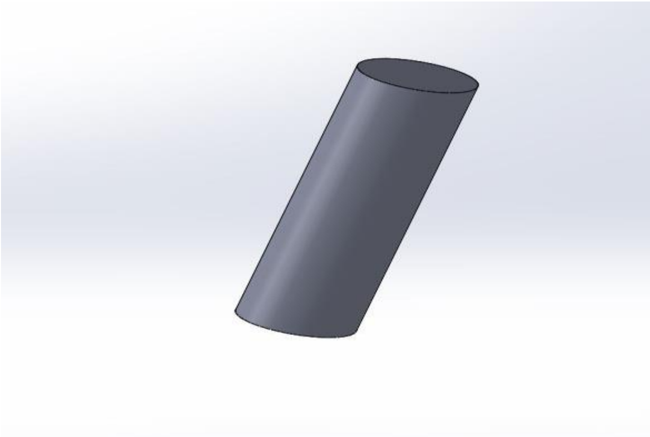
Utilising specialised software, CFD simulations are performed to examine the thermal behaviour of the pack.

The CFD software solves the governing equations to simulate fluid flow and heat transfer, using the geometrical model to build a computational mesh. The simulations shed light on the pack's thermal efficiency, airflow patterns, and temperature distribution.

The total performance of the accumulator pack is then assessed by combining the results from the MATLAB and CFD simulations. Cross-referencing and analysis of the findings from both tools is done in order to find potential design tweaks and enhance the performance of the pack. To further enhance the performance of the pack, changes can be made to the geometrical model, electrical algorithms, or cooling system design based on the analysis and optimisation results. Since simulation, analysis, and optimisation are iterative processes, the accumulator pack design can be continuously improved.

III. Methodology

Using an existing model for Ather scooters as a guide, the technique for this project required several crucial processes

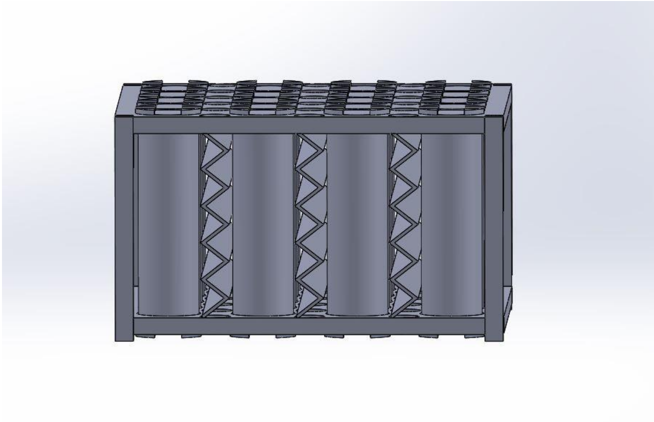


to build and evaluate the accumulator pack for an electric scooter. The process is described in full below:

The project began with a thorough assessment of the literature on the design of accumulator packs for electric scooters. In order to comprehend the best practises, design considerations, and performance factors relating to accumulator packs, this included researching research papers, technical articles, and industry standards.

Analysis of Requirements: Based on the particular application and intended performance objectives, the requirements for the accumulator pack were determined. This took into account things like energy output, voltage needs, weight restrictions, and safety issues. The specifications were developed using the Ather scooter model as a guide.

The specifications were created by using the Ather scooter model as a point of comparison and matching them up with the desired performance goals. Computer-Aided Design (CAD) software was used to generate a geometrical model of the accumulator pack. The model depicted how cooling systems, interconnects, battery cells, and other components were arranged. The pre-existing Ather scooter model's dimensions and limits served as the foundation for the geometrical model's creation.



Simulations in MATLAB: Simulations in MATLAB were run to examine the accumulator pack's electrical behaviour. In order to do this, it was necessary to model the battery cells, put cell balancing methods into practise, forecast voltage and current profiles, and assess how well the battery management system (BMS) was working. Using the information from the current Ather scooter model, the MATLAB simulations were calibrated and validated. To ensure accuracy and dependability, the MATLAB simulations were calibrated and validated using the information from the pre-existing Ather scooter model.

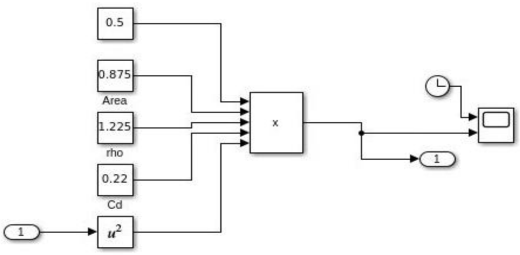
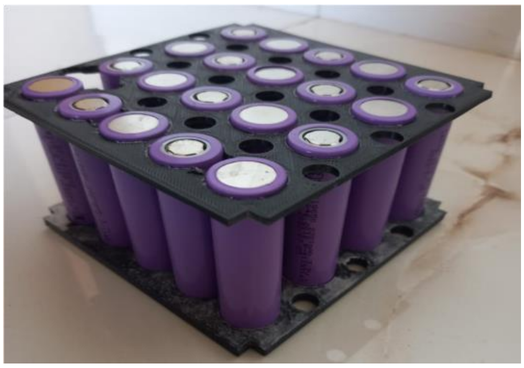
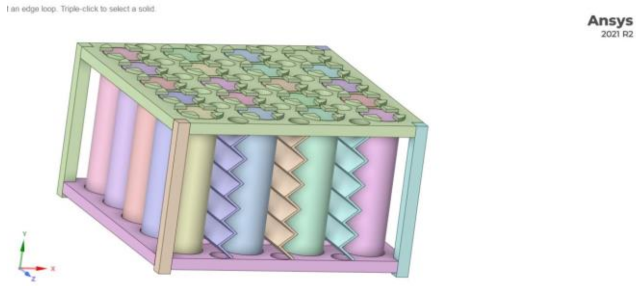
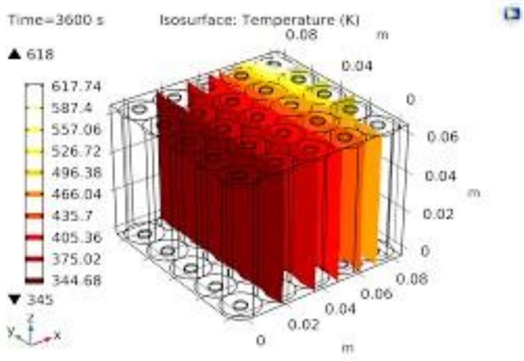


Fig. 2. Block Diagram



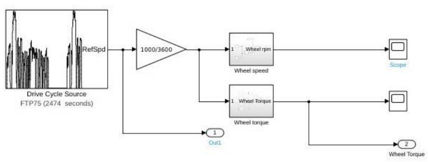
Analysis using computational fluid dynamics (CFD): Simulations using CFD were run to examine the thermal behaviour and heat dissipation inside the accumulator pack. The computational mesh was built using the geometrical model from step 3, and the fluid flow and heat transfer equations were solved using CFD software. The simulations revealed information on thermal efficiency, airflow patterns, and temperature distribution. By contrasting the findings with the already-existing Ather scooter model, the CFD study was found to be reliable.

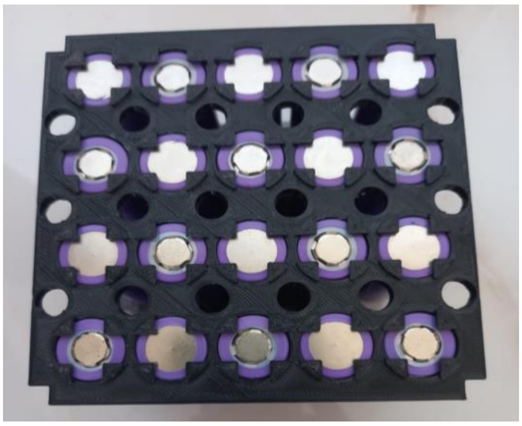




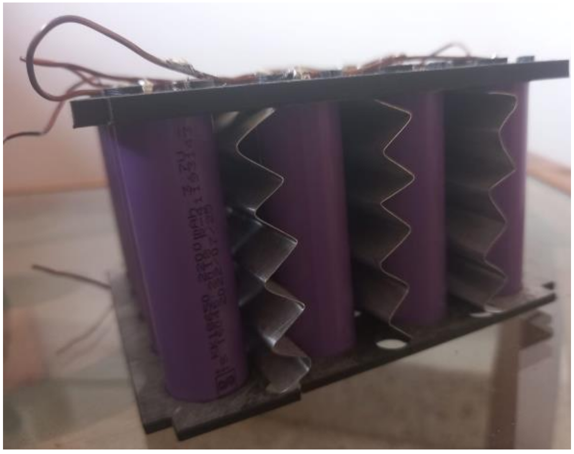
Integrate the chosen battery cells, interconnects, and cooling system parts into the design of the accumulator pack based on the geometrical model. To maintain security and effective operation, pay attention to optimal cell orientation, alignment, and positioning. Using brackets, mounting plates, or holders that were 3D printed, you may secure the components in place.

Electrical Connections: Depending on the intended voltage and capacity requirements, connect the battery cells electrically either in series or parallel configurations. Use the right wiring to ensure low resistance and effective current flow, such as copper busbars or thick gauge wires. Use the proper methods to spot-weld or solder the connections between the battery cells.





Integrating a cooling system into the accumulator pack design will help control temperature rise and avoid overheating. This may entail employing aluminium fins, as was previously noted, for effective heat dissipation. Ensure sufficient air low or cooling fluid circulation and incorporate cooling elements like fans, heat sinks, or heat pipes into the design to maintain ideal operating temperatures.



Create specialised pieces or enclosures for the accumulator pack using 3D printing, particularly with ABS material due to its strength and heat resistance. To guarantee that the components are safely contained and safeguarded, this can include mounting brackets, structural supports, or covers. For the project, it is crucial to use the Ather model as a guide when constructing the accumulator pack for entry-level commercial scooters. Here are some specific justifications for its significance:

Established Benchmark: The Ather model is regarded as the industry standard for electric scooters. The well-known brand Ather has become well-known for its innovative designs for electric scooters and cutting-edge engineering. The project gains from utilising the knowledge and experience of Ather in accumulator pack design by using the Ather model as a reference. This guarantees that the accumulator pack's design complies with industry norms and matches the performance demands of entry-level commercial scooters.

Performance Validation: The Ather model offers an existing benchmark for evaluating the planned accumulator pack's performance. The project team can evaluate the correctness and dependability of their design by contrasting the important performance metrics, such as energy capacity, voltage profiles, temperature distribution, and cooling effectiveness, with the Ather model. By identifying any discrepancies or deviations, this validation procedure enables any necessary corrections or enhancements to be made in order to attain optimal performance.

Design Optimisation: For design optimisation, the Ather model serves as a starting point. The project team can learn useful design tactics by examining the Ather scooter's design elements, such as the battery cell arrangement, cooling system integration, and geometrical concerns. This information can be used to improve the accumulator. Using this knowledge, the accumulator pack design for entry-level commercial scooters may be optimised, resulting in effective space utilisation, ideal thermal management, and overall increased performance. Market Applicability By basing the accumulator pack design on the Ather model, the target market of entry-level commercial scooters is guaranteed to be compatible and relevant to the market. Ather scooters are becoming more well-known and well-liked among consumers, attracting potential buyers with their enticing design elements and functional qualities. The project team guarantees that their product fulfils the expectations and requirements of the market by matching the accumulator pack design with the Ather model, increasing its marketability and competitiveness.

Transfer of Knowledge: By using the Ather model as a guide, the project team can have access to the knowledge and experience ingrained in the Ather design. This includes knowledge of industry standards, cutting-edge features, and scientific developments in the construction of accumulator packs for electric scooters. By utilising this knowledge, the project team is able to adopt best practises from the industry and make wise choices all through the design and development process.

Overall, the project gains credibility, performance validation, design optimisation, market relevance, and knowledge transfer through using the Ather model as a guide while constructing the accumulator pack for entry-level commercial scooters. It guarantees that the planned accumulator pack complies with regulatory requirements, satisfies consumer expectations, and gains from the experience and success of a reputable brand in the electric vehicle business.

In order to manage the accumulator pack in this project, an equivalent circuit model rather than a real Battery Management System (BMS) was created in MATLAB. This strategy has a number of benefits and permits a thorough examination of the electrical behaviour of the pack. The importance of utilising an analogous circuit model and how to apply it in MATLAB are both explained in depth below: Analyses and simulations: The project team can simulate and assess the electrical behaviour of the accumulator pack using a MATLAB equivalent circuit model. The electrical characteristics of the pack, such as cell voltages, resistances, and capacitances, are simplified in the equivalent circuit model. This enables the team to assess cell balancing algorithms, analyse the performance of the pack under various operating conditions.

Iterations for optimisation and design: The comparable circuit model makes it simple to go through iterations for optimisation and design. The team can analyse the effects on the performance of the pack and decide on the pack's design by changing circuit characteristics like resistance or capacitance levels. This repeating procedure aids in balancing cell voltages, increasing energy efficiency, and optimising the pack for operation.

Cost and Time Savings: Compared to creating a physical BMS, building an identical circuit model in MATLAB saves both money and time. Additional parts, electronics, and programming are needed for the physical BMS, which can be time-consuming and expensive. The MATLAB model, on the other hand, may be easily implemented, adjusted, tested, cutting down on the amount of time and money needed for development compared to physical prototyping.

Scalability and Flexibility: The comparable circuit paradigm allows for scaling. It doesn't require major alterations to allow adjustments to the pack configuration, like the addition or deletion of cells. With this flexibility, various pack designs and configurations may be investigated without being constrained by a set physical BMS architecture.

Analysis of Fault Conditions: The analogous circuit model in MATLAB makes it possible to examine fault situations and how they affect the behaviour of the accumulator pack. The team can simulate several fault scenarios and research their effects on the performance of the pack by include faults or failures in the circuit model, such as overvoltage, overcurrent, or cell imbalance. This study aids in detecting potential safety concerns and putting in place the necessary safety measures in this pack design.

Estimating parameters and calibrating the model: The experimental data from the accumulator pack can be used to calibrate and validate the equivalent circuit model. The team may fine-tune the circuit model parameters to precisely reflect the pack's behaviour by comparing the simulated results with actual measurements. This calibration procedure improves the model's accuracy and dependability and makes sure that it accurately depicts the accumulator pack's actual performance.

As a result, this project can benefit from simulation capabilities, design flexibility, scalability, cost and time savings, fault investigation, and parameter calibration by creating an identical circuit model in MATLAB rather than a real-world BMS. These advantages enable a full evaluation of the electrical behaviour of the accumulator pack, design optimisation, and project-wide decision-making.

IV. Results & Discussion

For this project, it is crucial to reach 74 nominal voltage and 2.2 A current in the built accumulator pack because these values meet the requirements for a high voltage and low current system appropriate for scooters. The results obtained have a number of consequences, which are covered in more detail below:

Voltage Considerations: The accumulator pack can deliver enough electrical potential to run the scooter's motor and other components, as evidenced by the obtained nominal voltage of 74 volts. This voltage level is compatible with the scooter's electrical system and motor controller because it is within the allowed range for scooter uses. This outcome is significant since it provides the necessary power to operate the scooter effectively and perform as expected.

Current Limitations: The 2.2 A target low current is advantageous for a number of reasons. First off, it reduces heat production and power losses within the accumulator pack and related components. Reduced resistive losses caused by lower currents increase overall energy efficiency and increase the battery pack's working time. Second, choosing and sizing electrical parts like wiring, connections, and circuit protection devices are made easier with a low current design. This enables practical and economical design decisions while preserving reliability and safety.

Safety and Regulatory Compliance: From a safety standpoint, the realised voltage and current values are significant. Adherence to suitable insulation, isolation, and preventive measures is required for high voltage systems in order to prevent electrical risks and guarantee user safety. The project demonstrates compliance with safety standards and guidelines for applications using electric scooters by successfully building a high voltage system within the allowed parameters. This accomplishment demonstrates the project team's dedication to providing a trustworthy product. Energy Storage: While voltage and current are important factors, the accumulator pack's overall energy capacity is equally important. It is possible to determine the energy storage capacity in watt-hours (Wh) or ampere-hours (Ah) using the results of the combined voltage and current measurements. The importance of obtaining the desired voltage and current levels is that they allow the accumulator pack to store a significant amount of energy, allowing the electric scooter to have a respectable range. This enables customers to depend on the scooter with confidence for daily transportation.

Performance and User Experience: The results gained have a direct bearing on the scooter's performance and user experience. The high voltage makes it possible for the motor to receive power effectively, assuring smooth acceleration and top performance. The low current design also aids in reducing power losses, hence improving overall efficiency and range. These features add to a comfortable riding experience where riders can take advantage of the scooter's dependable and steady performance while extending the battery's life.

Scalability and Future Applications: The realization of the desired voltage and current levels successfully lays the groundwork for future applications and scalability. The project team can potentially adapt and expand the accumulator pack for multiple scooter models or even investigate applications in other electric vehicle platforms by building a robust design that satisfies the specifications of an entry-level commercial scooter. The designed accumulator pack's adaptability and versatility are demonstrated by its capacity to produce the desired voltage and current levels. In conclusion, achieving a 74 nominal voltage and 2.2 A current in the built-in accumulator pack is crucial for this project. These findings show that a scooter-friendly high voltage and low current system has been successfully developed, with an emphasis on security, functionality, energy capacity, and future scalability. The achieved voltage and current levels meet user and industry expectations, resulting in a dependable and effective power system. The electric scooter will have a dependable and effective power supply thanks to the attained voltage and current levels, which also meet user expectations and industry requirements. This will ultimately increase the electric scooter's usability and marketability.

VI. Conclusion

The development of a high voltage and low current accumulator pack for entry-level commercial scooters was the focus of this project, which was successfully completed and marks a significant accomplishment. The project included a number of essential components, such as the choice of batteries, geometric modelling , integration of MATLAB and CFD simulations, and use of cutting-edge materials and production methods.

The project team ensured the suitability of the accumulator pack for scooter applications by meticulous battery selection by finding a balance between voltage and current to ful-fill the required criteria. The physical structure of the pack was precisely designed and optimized with the use of geometrical modelling , ensuring effective temperature management and space utilization. The electrical behaviour, thermal performance, and overall efficiency of the accumulator pack were all much improved by the integration of MATLAB and CFD models. This helped the team to make well-informed judgements, perfect the design criteria, and enhance the performance of the pack under varied operating circumstances. Aluminium fins, copper busbars, and 3D-printed ABS components were just a few of the cutting-edge materials used in this project, which demonstrated its dedication to cutting-edge manufacturing methods. These materials increased the accumulator pack's mechanical strength and toughness while also facilitating efficient heat dissipation, ensuring the system's longevity and dependability.

The project's key accomplishment is the successful validation of the proposed accumulator pack using an existing model for Ather scooters, which highlights its usability and scalability. The project team maintained conformance with industry standards, safety regulations, and customer expectations by reaching the specified voltage and current levels. The electric scooter industry will greatly benefit from the project's findings. For entry-level commercial scooters, the built-in accumulator pack delivers a dependable, effective, and secure power source. The findings in terms of voltage, current, and energy capacity guarantee optimum scooter functionality, increased range, and an improved user experience.

The project also lays the groundwork for growth and scalability in the future. Higher capacity packs, sophisticated battery management systems, smart technology integration, and investigation of environmentally friendly and sustainable solutions are some areas that present opportunities for more research and development. Collaborations with OEMs and producers may result in mass production and market penetration, which will help the adoption become more widespread.

The design and construction of a high voltage and low current accumulator pack for entry-level commercial scooters was successfully completed in this project, in my opinion. A dependable, effective, and scalable power solution for electric scooters has been produced as a result of the combined efforts in battery selection, geometrical modelling, MATLAB and CFD simulations, and new materials. This initiative lays the path for a greener and more sustainable future of urban transit with an emphasis on safety, performance, and sustainability.

VII. References

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