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Battery Cell Thermal Control in Electric Vehicles Using Water Cooling Block

Author's Affiliations
***D. Sriram Sanjeev[1], Dr. S. Gnanasekaran[2]**
Department of Mechanical Engineering,
Sri Shakthi Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India
***Corresponding Author: D. Sriram Sanjeev**
Email: sriramsanjeev28@gmail.com

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Abstract

Failure of Auto tensioner was observed at engine Research and development efforts in the field of transportation have recently focused on creating clean, safe, and high-efficiency modes of transportation. It has repeatedly been predicted that electric, hybrid, and fuel-cell vehicles will soon displace conventional automobiles. This research offers an illustration of how a battery-electric vehicle may regulate the flow of coolant over specific battery cells. Each lithium-ion battery cell's heat level is measured by a sensor, which also controls the cooling process. The PID controller (Arduino) and Water Pump both function using a 12V rechargeable battery. Temperature sensors are employed to monitor each Li-ion battery cell independently and provide feedback as an analog signal. The flow of the pump is controlled by the battery's feedback, and the coolant goes via a convey to achieve temperature control. When compared to lead-acid / nickel-metal hydride batteries, lithium-ion batteries offer better energy densities. Moreover, it is far less expensive and doesn't need nickel or cobalt. Also, it is safer since it is more stable. Each battery cell has a water cooling block installed specifically for more effective cooling. When compared to the method of calculating the total battery heat without any controller on any individual cells of the battery, the method of implementing a water cooling block in individual cells will be more effective. The temperature variation in the battery cell was significantly decreased by a water cooling block, which also lowered the thermal effect by around 40%. In the battery cell, a number of cycles and the depth of discharge are recorded, and the findings show that while the coolant temperature rises from roughly 30°C to 50°C, the battery cell's interior temperature drops drastically from 60°C to 20°C of heat.

Introduction

BEV thermal management systems for battery cells generally use air, liquid, or a mix of both types of cooling systems. A variety of variables, including the battery pack's design, affect these systems' efficiency, the environment's temperature, the type of driving conditions, and the specific cooling system being used. The use of battery electric vehicles (BEVs) as a sustainable, clean form of transportation is growing. In contrast to internal combustion engines, BEVs have no emissions and use less energy, making them a desirable alternative for both customers and regulators. However, BEVs also have their own set of challenges, such as managing the battery cells' internal heat. Battery cell heat regulation is critical to the efficient and safe operation of BEVs. Failure to maintain the ideal temperature range for battery cells can result in decreased performance, a shorter lifespan, and even thermal runaway, which can cause fires or explosions. In this paper, we will examine several battery cell temperature management systems used in BEVs as well as the difficulties these tactics face.

The Battery Thermal Management System (BTMS) is in charge of controlling and distributing the heat produced by the electrochemical reactions that take place in the cells, ensuring that the battery operates effectively and safely. Some of the cooling approaches used by battery thermal management systems include thermoelectric cooling and heating systems, liquid cooling systems, direct refrigerant cooling systems, phase change material cooling systems, and air-cooling systems. According to a recent study in Battery Thermal Management Systems, liquid cooling technologies are more effective than conventional cooling systems. According to current research, an effective battery thermal management system is necessary to maximize battery performance and longevity. However, each thermal management system has distinguishing characteristics that differentiate it apart from the others (Olabi et al., 2022). The numerical results show that the cooling system's energy use can be reduced by up to 58%, that it can be monitored within 0.25 °C of the desired value for a variety of operating configurations and situations, and that the maximum inaccuracy of the battery's internal temperature can be monitored within those operating configurations and situations (Xinran Tao et al., 2015). Referring to the Pareto Frontier curve, a balanced management plan may be achieved when the weight coefficient is 0.17, which may reduce battery degrading losses by 62.8% while only giving up 10.22% of the vehicle's operational mileage (Xijin Kuang et al., 2017). Under high-temperature circumstances, lithium-ion batteries are prone to thermal instability, which can result in short circuits, combustion, explosions, and other safety hazards. Low temperatures can lead to the development of lithium dendrites in lithium-ion batteries, which can result in short circuits, an inability to start, and other operational issues (Zhao Li et al., 2021). Choosing the best cooling method for a lithium-ion (Li-ion) pack of batteries for electric drive vehicles (EDVs) and developing an optimal cooling control plan to keep the temperature within an ideal range of 20 °C to 40 °C is crucial for improving safety, prolonging pack life, and lowering costs (Nivedita et al., 2022). The semiconductor-based BTMS maintains the internal temperature differential of the 48 V pack at 1.7°C, while the air-cooled BTMS improves battery temperatures (Rui Yang et al., 2022). Thermal regulation of battery packs is essential for EV and HEV battery packs to function efficiently in a variety of conditions (Pesaran et al., 1999). The best working temperature appears to be between 30 °C and 45 °C, with a maximum difference in temperature of 6 °C between each battery cell. The temperature of the battery cells may be kept within this range with the right battery packaging design. The impacts of external temperature and humidity must be taken into account during design. Numerous design tactics have been documented, such as innovative battery pack architectures, improved coolant material choices, and powerful battery management systems (Robby Dwianto Widyantara et al., 2022). When the suggested MPC-based energy management system was compared to the benchmark system that did not have any control coordination between BTMS and AC, it exhibited a 4.5% decrease in recharging batteries and a 7.5% rise in overall energy consumption (Jie Zhang and Yuanzhi Liu., 2020).

Then we explain how it may cause general and thermal issues, such as thermal runaway, which can blow up batteries, and an imbalanced state of charge (SoC), which impairs battery cell performance. Based on our understanding of thermal behavior, we finally create temperature-control techniques, which we then apply to the development of a battery thermal management system (Eugene Kim et al., 2014). The cooling plate's performance is determined by the channel's shape, including its location, breadth, length, and so on. In this paper, a cooling plate is dynamically modeled, and computational fluid dynamics is used to analyze its properties (Anthony Jarrett and Yong Kim., 2011). The efficiency of power batteries can be greatly increased, user safety can be improved, aging can be slowed down, and service life can be extended with the application of proper cooling technologies (Mengyao Lu et al., 2020). The temperature differential in the radial direction is inversely linked to the diameter of the cell and its rates due to the excellent thermal insulation of the layered substance that operates in a Li-ion cell. Strong forced convection, in comparison to natural convection, will decrease the cell's temperature homogeneity and speed up the pace of thermal aging (Saw et al., 2014). The hydrofluoroether liquid that surrounds the battery cells has a high electric resistance, is non-flammable, is environmentally friendly, and also has a boiling point that is quite near to the temperature at which the battery operates (Hirokazu Hirano et al., 2014). The efficiency of electric cars depends on a precise evaluation of crucial variables, as well as on the battery storage system's appropriate operation and diagnosis (Hossain Lipu et al., 2021). The description of current advances in BTMS with both direct and indirect cooling techniques, which may help lower the weight and price of BTMS needed for cost-effective and renewable electric vehicles (EVs), gives useful information regarding the use of SOC for decreasing the effect of heat on Li-ion batteries (Vima Mali et al., 2021). The most common battery cooling methods are considered to be boiling liquids, liquid metals, and nanofluids due to their increased heat conductivity. Battery performance at high charging and discharging rates would be substantially improved by the development of hybrid cooling employing fins, nanofluids, PCM, and microchannels, and emphasis should be made on a compact, less expensive design (Amrit Kumar Thakur et al., 2021). The need for significant battery technology breakthroughs to enable the widespread usage of electric vehicles (EVs) is becoming more and more obvious. Strong thermal management is necessary to address the substantial issue of temperature sensitivity, which has a detrimental influence on battery performance (Ali Saeed et al., 2021). Even though the fact that lithium-ion batteries are quickly replacing NiMH and nickel-cadmium backup batteries in lightweight cell phones, they are widely employed in motor vehicle applications (Todd Bandhauer et al., 2011).

When the heating element receives 50 V and the TEC module obtains 12 V in a TEC-based liquid cooling system for an individual cell with a copper holder, the battery temperature at the surface drops by approximately 42°C (from 52°C to 10°C) (Lyu et al., 2019). The EV industry has been transformed by lithium-ion batteries, which are currently the preferred choice for EV batteries. These batteries have a very long lifespan because of their excellent features, features include a high density of energy, excessive voltage, minimal self-discharge rate, extended cycle life, and the capability to both charge and discharge at high rates. The lithium-ion cells are connected in series and parallel to the supply energy of the traction motor and other auxiliary systems in electric vehicles (Lip Huat Saw et al., 2016). When SOC is equal to or higher than 80%, the difference between the actual SOC of the battery device and the measured SOC of the BMS system is greater than usual. The errors are, respectively, 2.41% at 25 °C, 3.81% at -10 °C, and 4.43% at 0 °C. At 25 °C, there is a 0.31% discrepancy between the battery system's real SOC and the BMS system's recorded SOC. This difference frequently starts off being smaller before expanding as the temperature rises (Li et al., 2020). High vehicle emissions and the resultant daily increase in air pollution have pushed the automobile industry to look into alternative and more environmentally friendly technology (Manikandan et al., 2022). The battery thermal management system (BTMS) is critical for managing the battery's thermal behavior. Liquid cooling technologies, direct refrigerant cooling mechanisms, phase change material cooling systems, and air cooling systems are examples of BTMS technology. Efficiency, dependability, safety, weight, and size are just a few of the numerous factors that are traded off in the analysis of these systems (Jiling L and Zhen Z., 2014). Lithium-ion batteries are particularly sensitive to thermal runaway occurrences due to several characteristics, including their high density of energy and tendency to self-heat when the solution of electrolyte reaches a specified temperature (between 75° and 135° C). Because of their circumstances of use and charge level, Li-Ion batteries gradually degrade over time (Sourav S. Katoch and Eswaramoorthy M., 2020).

Passive cooling: The simplest and least expensive kind of battery cell heat control. The success of this strategy hinges on the battery pack's ability to naturally dissipate heat by using copper or aluminum to move heat away from the cells. Although it can be helpful in warm climates or low-demand situations, passive cooling has limitations in extreme temperatures or high-demand situations, such as fast charging or high-speed driving.

Active cooling: Active cooling describes cooling solutions that rely on a third-party component to improve heat transmission. The Active cooling methods improve the rate of flow of fluid during convection, significantly raising the rate of heat disposal.

Battery cell thermal control refers to the many strategies and systems used in BEVs to regulate and maintain the temperatures of the battery cells within a tolerable secure limit. Thermal management systems, which may cool or heat the battery cells as needed, must be employed to keep the temperature of the battery packs within the required range. Effective temperature regulation of the cells that make up the battery is required to maximize the performance and lifetime of the battery cells as well as to assure their safety. This study's goal is to provide a comprehensive analysis of battery cell heat regulation in a BEV. The study's goal is to assess current knowledge of battery cell temperature management techniques, including how they affect battery performance and safety. The research initiative also seeks to deliver a case study on the Tesla Model S thermal management system and investigate market trends and best practices in battery cell thermal control. The study also seeks to examine prospective advances in battery cell temperature control technologies and how they could affect the BEV market in the future. Manufacturers are paying more attention to the thermal management of the battery packs in these cars as electric drive vehicles (EVs) gain in popularity. Temperature is one of the most important variables that might have an impact on the functionality and longevity of battery cells. This work's scope includes an analysis of current battery cell thermal control research, as well as a look at the various technologies and methods used to regulate and maintain battery cell temperature in a BEV. The study will also examine different temperature control techniques and how they impact battery safety and effectiveness.

In this study, the major temperature handling of batteries made of lithium-ion in EVs and HEVs. For the first time, the battery water cooling block has been used to keep the batteries from directly coming into touch with the coolant. Reducing the heat produced when an electric car battery is working is the aim of this research project, which employs the liquid cooling approach. This sort of procedure, which incorporates a cooling block, makes the battery safe to use and lowers the risk of explosion in the battery as a result of overheating and overcharging. Where the temperature in the battery gradually starts to drop and reaches the temperature of the atmosphere, the water cooling block can be built in the battery pack's outer part. The PID controller (Arduino Board) will be employed as a feedback module to initiate and terminate the flow of liquid through the cooling block. When compared to other liquid cooling strategies, this technique is more effective. In addition, there is no comparable experimental investigation that has been reported in the literature that pertains to water-cooling block-based battery thermal management systems.

Materials and Methods

Water Cooling Block

A specialized tool used in liquid cooling systems for electronic components like CPUs and GPUs is a water cooling block, commonly referred to as a water block. Its function is to move heat from the component to a liquid coolant, usually water, which circulates through the system and disperses the heat from the component. The water cooling block is designed to fit onto the precise electronic component it is intended to cool as indicated in Figure 1 and is composed of a highly conductive material, such as copper or aluminum. Tiny grooves or fins are commonly cut into the block to increase its surface area and promote better heat transmission from the component to the coolant. The coolant is frequently cooled by a radiator with fans or other cooling techniques and is often pushed through the system with the use of hydraulic pumps and pipes. The fluid that cools the component absorbs the device's heat as it travels through the water block and transfers it away, assisting in maintaining the electronic device's ideal temperatures. It's critical to select a water cooling block that is suitable with the particular component and system configuration you have because there are several varieties of water cooling blocks available with varying designs and materials. To choose a water cooling block that will provide your electronic equipment with the best cooling, you need take into account aspects like size, compatibility, and cooling performance.

Figure 1 Water Cooling Block.

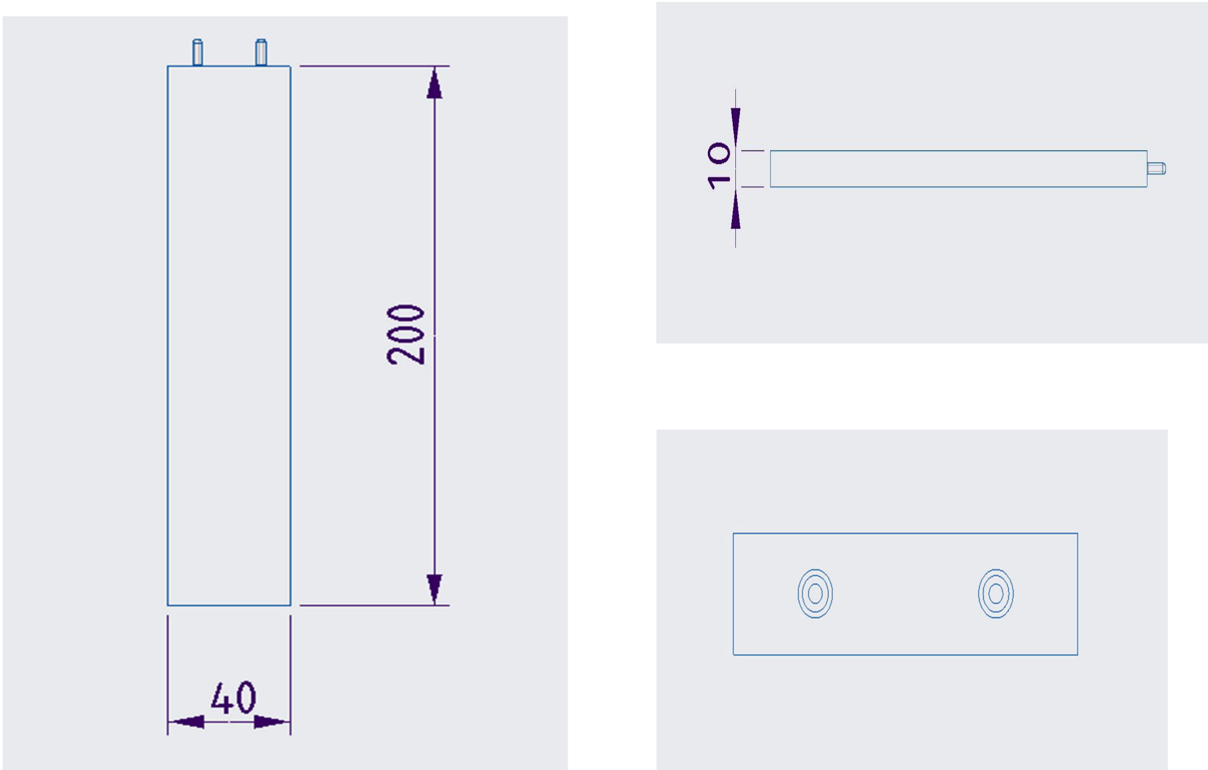

Figure 2 Design of Water Cooling Block.

It is ensured that the feedback to the PID controller (Arduino) and Water Pump is indicative of the thermal conditions at the critical locations by strategically placing the sensors within or near the water cooling block.

Design of Water Cooling Block

Figure 2 displays the dimensions of the water cooling block; all measurements are in millimeters (mm). Creo 9.0 software was used to design the block.

Features of Water Block:

- Completely consistent with the cooling film, and can be used for small productions such as mobile phone and computer heat dissipation, cold transfer, cold water formation, etc.
- Exclusive water-cooling heads, liquid-cooled water plates, and water-cooled exchangers for semiconductor refrigeration fins.
- Appropriate for cooling industrial control cabinets, laser heads, industrial inverter drives, etc.
- High-quality aluminum is a strong, corrosion-resistant material that may be used for heat transfer and cold transmission.
- Made after double-sided polishing surface treatment, exquisite and smooth without burrs.

Specification of Water Block:

Item Type: Water Cooling Block
Material: Aluminum
Purpose: Heat dissipation and Cold transfer
Size: 40 x 200mm

Arduino Board

A microcontroller-based development board called an Arduino is intended for use by hobbyists, artists, designers, and anyone else interested in making interactive electrical devices. The digital input/output pins, analogue input pins, serial communication interfaces, power supply components, and other parts that enable users to connect and operate various electrical devices are often included on Arduino boards. Additionally, they provide several pre-built libraries and functions that facilitate writing and uploading code to the board. Users may create and upload code to the board using the free Arduino Integrated Development Environment (IDE), which connects to the device through USB, may be used to programming Arduino boards, which are open-source.

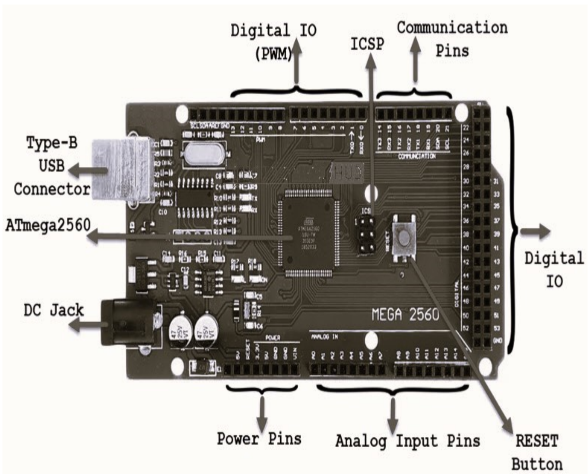

Figure 3 Arduino Board MEGA 2560 R3.

Arduino Board Setup: The temperature sensors, relay module, and cooling or heating equipment are all linked to the arduino board. The code of the Arduino board is set up to take data from the temperature sensor and operate the cooling or heating equipment using a relay or motor driver module.

Frame Stand

This is made of mild steel seen in Figure 4. A functional installation method is used to attach the complete system to the frame structure. The bearing diameters and open bores were bored in one session to ensure proper bearing alignment during assembly. Arc welding, the type of welding used for the production of this frame, is handled by our team members. The upper view of the frame reveals an extra cross element with a 3mm diameter. Mild steel makes up its structure. All of the frame's edges have been thoroughly ground with the use of a grinding machine toto prevent sharp edges.

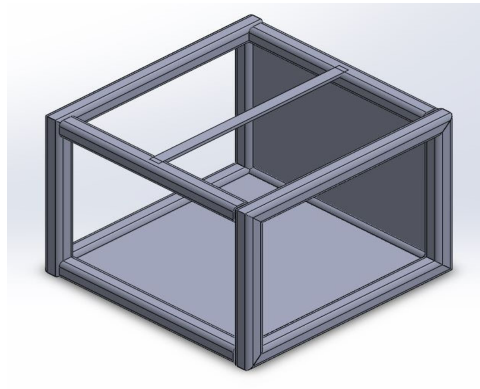

Figure 4 Frame Stand.

Design of Frame Stand

Figure-5 displays the frame stand's dimensions, all the dimensions mentioned below are in (mm), which were designed using Creo 9.0 software.

Type of Battery Used

Throughout my research, a customised lithium-ion battery was one of the most important tools I used. Because of its versatility in meeting the experiment's unique requirements, this specific battery was chosen. Regretfully, the available literature did not specifically mention the manufacturer, model, or technical specifications of the battery. Nonetheless, it is crucial to emphasise that a lithium-ion battery was specifically chosen because of its extensive application in a variety of fields and its capacity to offer a dependable and consistent power source for testing. Because the battery could be customised to meet the specific requirements of the experiment, accurate data collection and optimal performance were ensured. Water cooling blocks are strategically positioned between individual lithium-ion cells, seamlessly integrating with the circulation of a highly efficient Castrol RADICOOL Heavy Duty coolant. This synergistic approach serves as a highly effective means of heat management within the battery system, resulting in a substantial reduction in temperature.

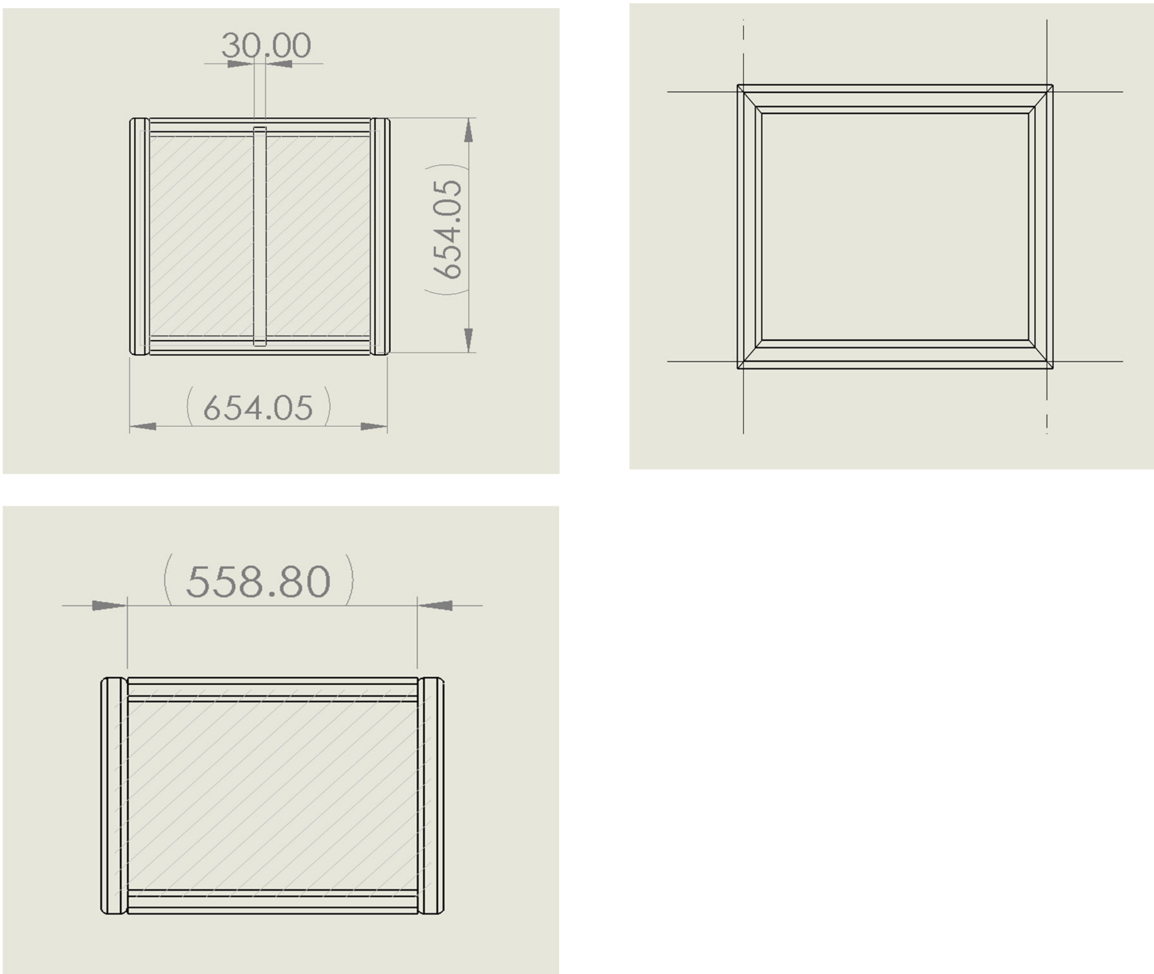

Figure 5 Design of Frame Stand.

Because of their well-known efficiency, these batteries are ideal for a variety of scientific experiments where a steady and long-lasting power source is crucial. Lithium-ion technology is still a popular and useful option in the field of research, even though the exact make and model may change depending on the needs of the experiment.

Water Pump

A 12V water pump is a type of pump that is designed to run on a 12-volt DC power source, the type we used in this work is added as an image below in figure 4.2. These pumps are commonly used in various applications, such as for pumping water from a well or a water tank, for circulating water in a cooling system, or for creating a water fountain or waterfall.

- Flow Rate: 6 Litres Per Min
- Inbuilt Thermal Overload Protector, Long life, self priming
- Input and Output pipe size : 8mm or 8.5mm
- The red wire is positive and green wire is negative.

Temperature Sensor

A temperature sensor is an electronic device that measures the temperature of an object or environment and converts it into an electrical signal that can be read by a computer or other electronic device. There are many types of temperature sensors, including thermocouples, resistance temperature detectors (RTDs), thermistors, and infrared sensors.

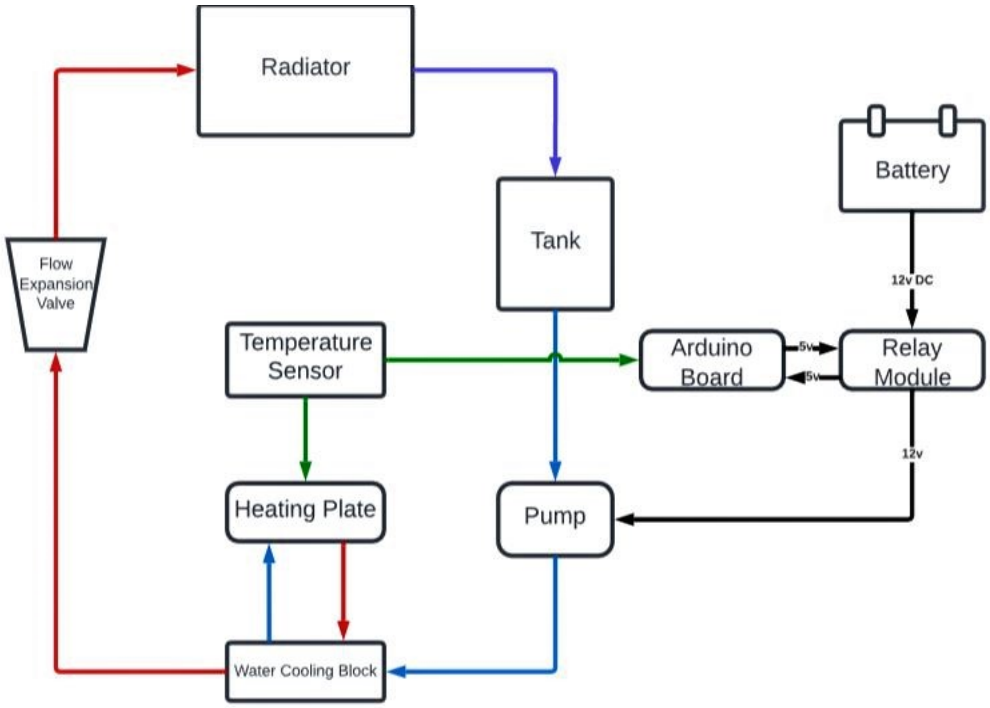

Figure 6 Working Block Diagram.

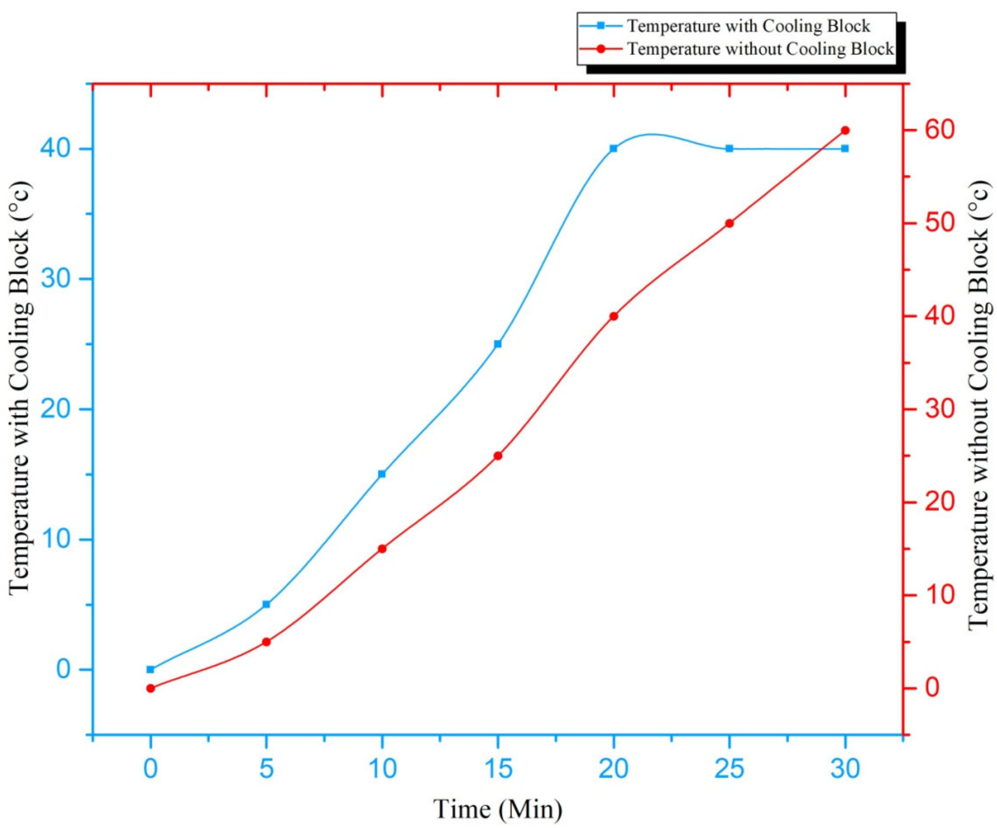

Figure 7 Temperature Variation in Water Cooling Block.

Temperature sensor installation: Temperature sensors are placed inside the battery cell enclosure to monitor the temperature of the battery cells. The number of temperature sensors depends on the size of the battery cell enclosure and the desired level of temperature monitoring.

Result and Discussion

Battery cell heat regulation must be taken into account in both battery electric vehicle (BEV) design and operation. Toto maximize performance, lengthen battery life, and avoid safety risks, the thermal management system of a BEV makes sure that the battery cells function within a specific temperature range. Managing the heat generated while battery cells are being charged and discharged is one of the most difficult tasks. Thermal runaway might occur as a result of the heat produced while charging, which could harm the battery and provide safety risks. On the other hand, high-temperature discharge may have an effect on the functionality and lifetime of a battery. To solve these problems, BEV manufacturers frequently blend passive and active cooling techniques. Using passive cooling techniques like heat sinks and thermal insulation, heat created while charging is expelled and heat loss is avoided during operation. Battery cell temperatures are kept within a certain range using active cooling techniques like liquid or air cooling. Figure 6 illustrates the procedure of the battery cell's temperature control system as well as the actions done during the task completion.

High-performance BEVs commonly use liquid cooling systems because they offer efficient heat transfer and better temperature control than air-cooled devices. A coolant is pumped through the battery pack in liquid cooling systems to soak up the heat generated during the processes of charging the battery and discharging the batteries. After being cooled with a radiator or heat exchanger, the battery pack is then cycled with the coolant.

Temperature Variation in Water Cooling Block

Monitoring and managing the temperature variation in the water cooling block of the battery cell of an electric car is essential. The water cooling block removes heat produced during battery operation, guaranteeing ideal temperatures for effective operation and long battery cell life. Through experimental investigation, it was shown that under normal working conditions, the temperature in the water cooling block stayed within a very small range. The cooling mechanism successfully kept the battery cells' temperature within the intended range, preventing overheating and potential cell damage.

The Figure 7 displays the change in temperature in a water cooling block over time while a battery-powered vehicle is in operation. The y-axis demonstrates temperature in degrees Celsius, and the x-axis denotes time in minutes. The graph depicts how the ambient temperature varies continuously as the car moves up and down.

The battery's heating and cooling cycles when it is in use are to blame for the temperature variations. The heat produced by the battery when current passes through it during usage is absorbed by the water cooling block. The temperature drops as a result of the heat being transferred from the battery to the water. However, when the battery is utilized more, more heat is produced, and the water cooling block's temperature rises once again.

Temperature Difference when Cycle is ON

The difference in temperature in the water cooling block was observed to rise while the battery cycle is ON, which refers to the time when the electric vehicle is in operation and the battery is discharging electricity. The reason for this temperature difference is the heat produced by the battery packs during the discharging process. To maintain the constant operating thermal range, the cooling system continually removes this heat. To avoid overheating, the temperature differential throughout the discharge cycle was closely monitored and managed.

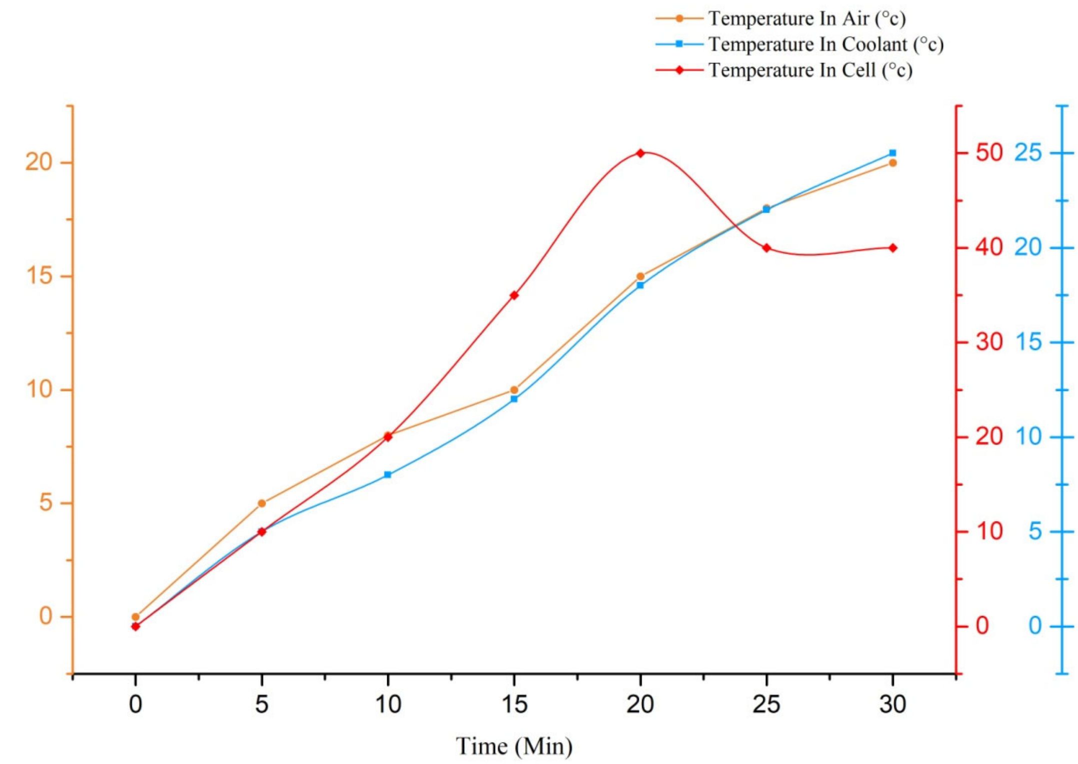

Figure 8 Temperature Difference when Cycle is ON.

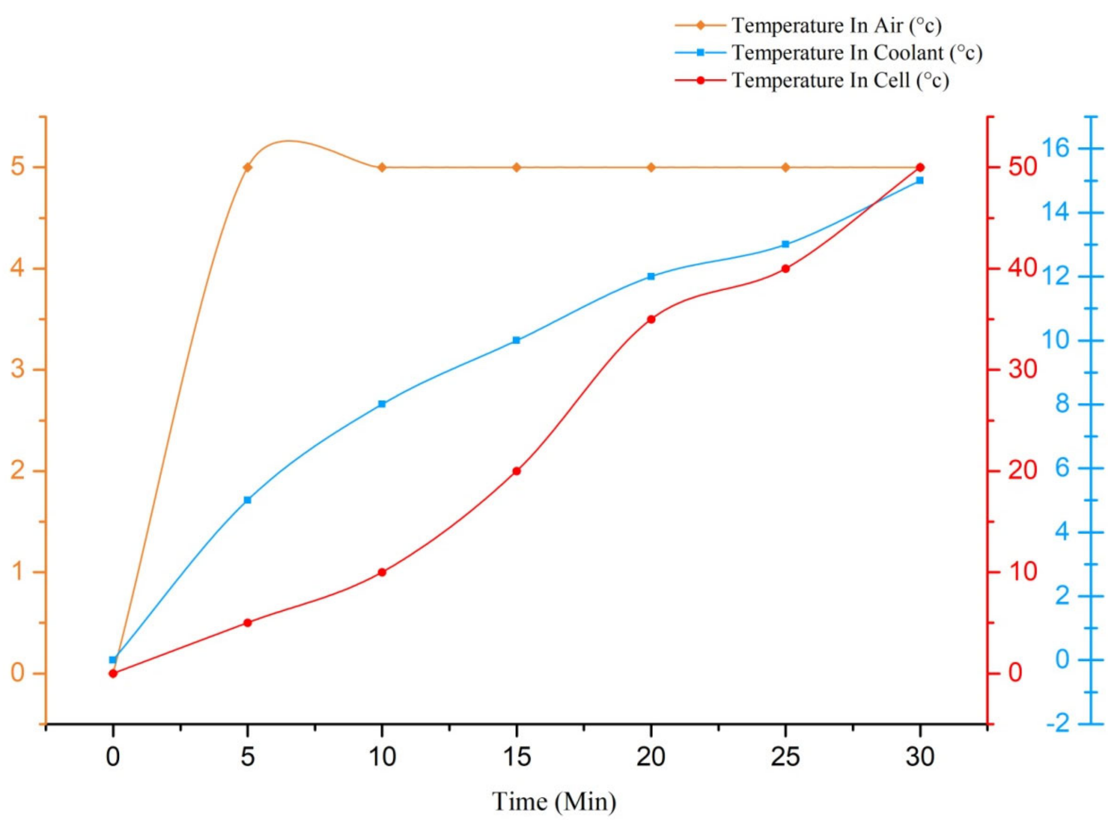

Figure 9 Temperature Difference when Cycle is OFF.

The change in temperature between the battery cell and the cooling water during the cooling cycle is seen in Figure 8. The x-axis depicts the time in minutes, while the y-axis shows the temperature change in degrees Celsius. The temperature discrepancy over time appears to be rather steady on the graph, with rare slight fluctuations.

When the cooling cycle is active, heat from the battery is absorbed and carried away by the water cooling block. As a result, the cooling water's temperature rises while the battery's temperature drops. A steady temperature differential between the two indicates that the cooling system is working effectively and the difference in temperature between the two serves as a gauge of its efficiency.

Temperature Difference when Cycle is OFF

The temperature differential in the water cooling block was seen to diminish during the cycle OFF phase, which is the time when the electric vehicle is not in operation and the battery is not drawing electricity. Heat production decreases much when the battery cells aren't decreased when the battery cells aren't being used for electricity. The cooling system's job at this phase is to keep the battery cells at the proper temperature. At this step, the system's responsibility is to maintain the right temperature to prevent any potential deterioration or damage. To prevent the cells from being overheated, the temperature differential in the water cooling block is kept relatively low as compared to the ON cycle.

The graph in Figure 9 depicts the temperature discrepancy between the battery pack and the cooling water while the cooling cycle is not working. The x-axis exhibits the time in minutes, while the y-axis illustrates the ambient temperature variation in degrees Celsius. When the cooling cycle is switched off, the graph exhibits a dramatic increase in temperature differential, showing that the cooling system is not in use.

When the cooling cycle is off, the battery relies on passive cooling methods such as air flow rather than being actively cooled. As a result, the battery's temperature may rise quickly; creating a significant temperature differential between it and the cooling water is indicated in Figure 9. A large temperature difference might be a symptom that the battery's thermal management is inefficient, which could reduce battery performance and lifespan.

Number of Cycles vs. Depth of Discharge Temperature

When analyzing the efficacy and longevity of battery cells in an electric vehicle, the link between the total number of cycles and the depth of discharging temperature is crucial. The analysis revealed that as the number of cycles grew, so did the level of discharge temperature. Internal resistance and heat accumulation caused by the battery cells' repetitive charging of the battery and discharging from batteries are the major drivers of this temperature rise. Monitoring and adjusting the depth of discharge temperature can assist to mitigate the negative effects of cycling on the battery's overall health. The performance of the battery packs is maintained, & usable life of the battery cells is extended, thanks to the employment of an efficient water cooling block system that lowers the temperature rise that takes place during cycling.

Figure 10 provides the relationship between the number of cycles and the temperature at the depth of drain in a battery-powered vehicle. The y-axis exhibits the range of discharge temperature in degrees Celsius, while the x-axis represents the number of cycles. The temperature at the depth of discharge grows as the total amount of cycles increases. This is because the battery generates heat throughout each cycle of use, potentially leading to a rise in temperature. Additionally, when the battery ages and is used, its internal resistance increases, which might cause even more heat to be produced and higher temperatures.

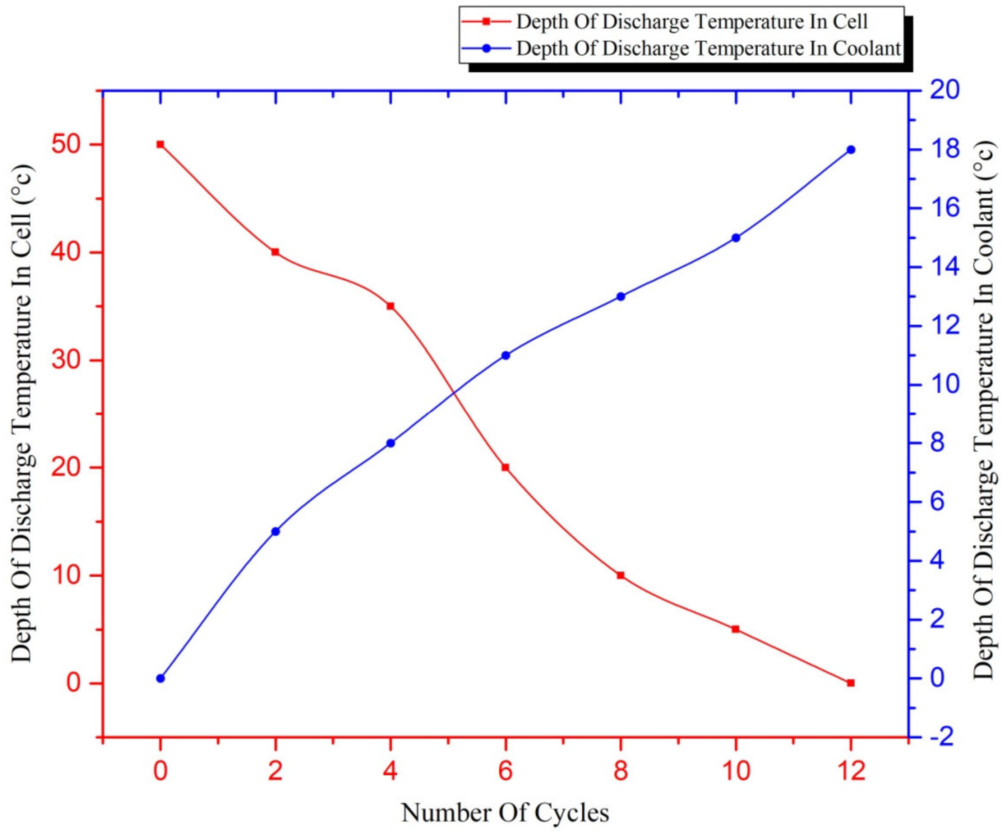

Figure 10 Number of Cycles vs. Depth of Discharge Temperature.

Excessive temperatures can affect battery performance and longevity, hence the amount of discharge temperature is critical for productive battery thermal control. As a result, having a powerful thermal management system is critical for managing the temperature of the battery while in operation, especially as the battery sees more usage cycles. By taking into account the relationship between the total number of cycles and the amount of discharge temperature, the design of a system for thermal control that can properly regulate the battery's temperature may help to assure optimal battery performance and lifespan.

In general, the management of battery cell heat must be examined throughout the development and use of BEVs. The Battery performance may be improved, battery life may be increased, and safety concerns may be decreased with efficient heat management systems. The battery cells are kept within a specific temperature range via a variety of passive, active, and heating technologies used by BEV manufacturers.

Conclusion

The water-cooling block is an efficient method of controlling the temperature of the battery cells in electric vehicles. Because of its high specific heat capacity and thermal conductivity, water is a good cooling medium. These characteristics make it possible for water to effectively absorb and disperse heat, preserving the battery cells' ideal working temperatures. Electric cars may successfully control the battery pack's temperature by using water cooling blocks, ensuring that it works within the intended range. This is essential to preserving the overall efficiency of the vehicle as well as maximizing battery performance and longevity. Blocks made of water evenly cool the battery cells, reducing temperature swings and hotspots. This aids in preventing thermal runaways, a significant safety issue with electric vehicles. The risk of capacity loss, cell deterioration, and safety events can be considerably decreased by properly controlling the battery temperature.

The water cooling block's temperature variation is seen on the graphs. As soon as the system is shut off, the temperature starts to rise gradually. However, when it is turned ON, a specific temperature is maintained. the variations in temperature between the cell, coolant, and air. The air and coolant temperatures are proportional to one another. the normal coolant discharge rate and cell temperature variations during the course of each cycle. It's crucial to remember that water cooling systems need trustworthy engineering and adequate maintenance to avoid leaks and guarantee effective performance. To prevent any potential harm to the battery pack or other vehicle components, adequate sealing and corrosion prevention measures must be in place.

Maintaining optimal performance and avoiding overheating in a variety of applications require efficient heat management. Heat dissipation is greatly aided by mechanisms like convection and conduction, which rely on the movement of fluids, the transfer of materials, and phase changes during state transitions. Furthermore, radiation is an important factor since it involves the electromagnetic waves that transfer heat. Heat transfer is improved through the use of liquid cooling, fans, and heat sinks that are intended to absorb and release heat. The regulation of heat flow is further aided by thermal insulation. This knowledge is especially important for designing robust systems that need to be optimised for effective heat management in the automotive, electronic, and industrial domains.

Overall, employing water cooling blocks to temperature control of electric vehicle battery packs is a viable method that addresses key thermal management challenges. The performance, security, and durability of the battery pack have been increased, allowing electric vehicles to become more extensively utilized and successful in the future.

References

[1] Olabi, A.G., Hussein M. Maghrabie., Ohood Hameed Kadhim Adhari., Enas Taha Sayed., Bashria A.A. Yousef, Tareq Salameh., Mohammed Kamil., Mohammad Ali Abdelkareem., 2022., Battery thermal management systems: Recent progress and challenges., International Journal of Thermal Sciences (2022), 15, 100171.

[2] Xinran Tao., Wagner, J., 2015., A thermal management system for the battery pack of a hybrid electric vehicle: Modeling and control., Proceedings of the Institution of Mechanical Engineers Part D Journal of Automobile Engineering, 230(2), 10.1177/0954407015582323.

[3] Xijin Kuang., Kuining Li., Yi Xie., Cunxue Wu., Pingzhong Wang., Xiaobo Wang.,Chunyun Fu., 2020., Research on control strategy for a battery thermal management system for electric vehicles based on secondary loop cooling., 10. 1109/ACCESS. 2020, 2986814.

[4] Xinghui Zhang., Zhao Li., Lingai Luo., Yilin Fan., Zhengyu Du., 2021., A review on thermal management of lithium-ion batteries for electric vehicles., Energy (2022), 238, 121652.

[5] Nivedita., Jaujaf Shekh., Shriraj Manepatil., Sagar Malusare., Amit Birajdar., 2022., Thermal Management of Lithium-Ion Battery in Electric Vehicle., IRJET, 9, 2395-0072.

[6] Rui Yang., Kuining Li., Yi Xie., Wei Li., Yuping Qian., Yangjun Zhang., Hongxiang Zhang., 2022., Thermal Management of a 48 V Lithium-Ion Battery Pack by Semiconductor Refrigeration., 10.3389/fenrg.2021, 794438.

[7] Pesaran, A.A., Burch, S., Keyser, M., 1999., An Approach for Designing Thermal Management Systems for Electric and Hybrid Vehicle Battery Packs., NREL/CP, 540-25992.

[8] Robby Dwianto Widyantara., Siti Zulaikah., Firman Bagja Juangsa., Bentang Arief Budiman., Muhammad Aziz., 2022., Review on Battery Packing Design Strategies for Superior Thermal Management in Electric Vehicles., Batteries (2022), 8120287.

[9] Yuanzhi Liu., Jie Zhang., 2021., Electric Vehicle Battery Thermal and Cabin Climate Management Based on Model Predictive Control., 10.1115/1.4048816, 143, 031705-1.

[10] Eugene Kim., Kang G. Shin., Jinkyu Lee., 2014., Real-time battery thermal management for electric vehicles., ACM/IEEE (2014), 6843712.

[11] Joshua Smith., Randeep Singh., Michael Hinterberger., Masataka Mochizuki., 2018., Battery thermal management system for electric vehicle using heat pipes., International Journal of Thermal Sciences, 134, https://doi.org/10.1016/j.ijthermalsci.2018.08.022.

[12] Anthony Jarrett., Il Yong Kim., 2011., Design optimization of electric vehicle battery cooling plates for thermal performance., Journal of Power Sources, 196(23), 10359-10368, https://doi.org/10.1016/j.jpowsour.2011.06.090.

[13] Mengyao Lu., Xuelai Zhang., Jun Ji., Xiaofeng Xu., Yongyichuan Zhang., 2019., Research progress on power battery cooling technology for electric vehicles., Journal of Energy Storage, 27, 101155.

[14] Saw, L.H., Ye, Y., Tay, A.A.O., 2014., Electro-thermal analysis and integration issues of lithium-ion battery for electric vehicles., Applied Energy, 131, 97-107, https://doi.org/10.1016/j.apenergy.2014.06.016.

[15] Lip Huat Saw., Yonghuang Ye., Andrew A.O. Tay., 2015., Integration issues of lithium-ion battery into electric vehicles battery pack., Journal of Cleaner Production, 113, 1032-1045, https://doi.org/10.1016/j.jclepro.2015.11.011.

[16] Hirokazu Hirano., Takamitsu Tajima., Takeru Hasegawa., Tsuyoshi Sekiguchi., Minoru Uchino., 2014., Boiling Liquid Battery Cooling for Electric Vehicle., IEEE Conference and Expo Transportation Electrification Asia-Pacific, 10.1109/ITEC-AP.2014.6940931.

[17] Hossain Lipu, M.S., Hannan, M.A., Tahia F. Karim., Aini Hussain., Mohamad Hanif Md Saad., Afida Ayob., Sazal Miah, Md., Indra Mahlia, T.M., 2021., Intelligent algorithms and control strategies for battery management system in electric vehicles: Progress, challenges and future outlook., Journal of Cleaner Production, 292, 126044, https://doi.org/10.1016/j.jclepro.2021.126044.

[18] Vima Mali., Rajat Saxena., Kundan Kumar., Abul Kalam., Brijesh Tripathi., 2021., Review on battery thermal management systems for energy-efficient electric vehicles., Renewable and Sustainable Energy Reviews, 151, 111611, https://doi.org/10.1016/j.rser.2021.111611.

[19] Amrit Kumar Thakur., Rajendran Prabakaran., Elkadeem, M.R., Swellam W. Sharshir., Müslüm Arıcı., Cheng Wang., Wensheng Zhao., Jang-Yeon Hwang., Saidur, R., 2020., A state of art review and future viewpoint on advance cooling techniques for Lithium–ion battery system of electric vehicles., Journal of Energy Storage, 32, 101771, https://doi.org/10.1016/j.est.2020.101771.

[20] Ali Saeed., Nader Karimi., Manosh C. Paul., 2021., Analysis of the unsteady thermal response of a Li-ion battery pack to dynamic loads., Energy, 231, 120947, https://doi.org/10.1016/j.energy.2021.120947.

[21] Lyu, Y., Siddique, A.R.M., Majid, S.H., Biglarbegian, M., Gadsden, S.A., Mahmud, S., 2019., Electric vehicle battery thermal management system with

thermoelectric cooling., Energy Reports, 5, 822-827, https://doi.org/10.1016/j.egyr.2019.06.016.

[22] Dr. Manikandan, M., Madhukar, G., Aparna, V., Gouthami, A., Sriram, N., 2022., Lithium-Ion Battery Thermal Management System Using PID controller., 11,0950-0707.

[23] Todd M. Bandhauer., Srinivas Garimella., Thomas F. Fuller., 2011., A Critical Review of Thermal Issues in Lithium-Ion Batteries., Journal of The Electrochemical Society, 158, 0013-4651.

[24] Sourav Singh Katoch., Eswaramoorthy, M., 2020., A Detailed Review on Electric Vehicles Battery Thermal Management System., Materials Science and Engineering, 912, 042005.

[25] Li, D., Zhimao, M., Mingsheng, C., 2021., Temperature characteristics of SOC estimation for traction battery system., Materials Science and Engineering, 1043, 052035.

[26] Jiling Li., Zhen Zhu., 2014., Battery Thermal Management Systems of Electric Vehicles., Master’s Thesis in Automotive Engineering,42, 1652-8557.