

ELECTRIC BIKE WITH AIR COOLING SYSTEM

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechanical Engineering

By

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A++” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of A.HARRISON KEVIN RAJ (Reg.No. 40150013) and C.E.AKASH PANDIAN (Reg.NO. 40150705) who carried out the project entitled "**ELECTRIC BIKE WITH AIR COOLING SYSTEM**" under our supervision from December 2023 to April 2024.

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Submitted for Viva voce Examination held on 06/04/2024

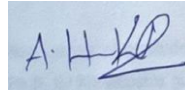
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DECLARATION

We, A.HARRISON KEVIN RAJ (Reg.No.40150013) and C.E.AKASH PANDIAN (Reg.NO.40150705) hereby declare that the Project Report entitled “**ELECTRIC BIKE WITH AIR COOLING SYSTEM**” done by under the guidance of **Dr.S.P.VENKATESAN,M.E.,Ph.D.** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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06/4/2024

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ABSTRACT

In our rapidly evolving modern world, the detrimental impacts of fossil fuel exploitation and its environmental repercussions, particularly concerning pollution, have emphasized the imminent need to transition away from traditional fuel-powered vehicles. As society endeavours to find sustainable solutions for the transportation sector, the utilization of renewable and eco-friendly resources emerges as an increasingly imperative choice.

Our ground breaking initiative involves the intricate assembly of an electric bike meticulously crafted from reclaimed and repurposed vehicle parts, thereby harnessing the potential of renewable energy sources. Echoing the words of Winston Churchill, who astutely observed that "Nothing is perfect in the human world," it's evident that electric vehicles, while promising, come with their own set of advantages and drawbacks.

Among the notable challenges faced by electric vehicles, a considerable concern revolves around the issue of battery overheating, which has garnered significant attention within the realm of sustainable transportation innovation. In response to this critical concern, we have embarked on a comprehensive endeavour focused on designing and implementing a cutting-edge cooling system dedicated to maintaining the optimal operating temperature of batteries within electric vehicles.

This ambitious project revolves around the development of a robust forced convection air cooling system, integrated with a sophisticated mechanism designed to meticulously monitor and regulate the cooling system's performance. Through painstaking attention to detail, an intricate model has been meticulously crafted to facilitate a comprehensive exploration and analysis of the aforementioned project, thereby heralding a new era in sustainable and efficient urban mobility solutions.

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CHAPTER 1

INTRODUCTION

The traditional reliance of conventional vehicles on fossil fuels has been a longstanding issue, contributing significantly to environmental concerns such as pollution and its enduring consequences. However, the emergence of electric vehicles has marked a crucial turning point in addressing these challenges. Unlike their conventional counterparts, electric vehicles operate entirely without the need for fossil fuels, presenting a sustainable alternative with zero emissions. This pivotal shift not only reduces environmental impact but also underscores the importance of transitioning towards more eco-friendly transportation options.

A regenerative electric bike equipped with an air cooling system represents a significant advancement in sustainable transportation technology, addressing the pressing environmental concerns associated with conventional vehicles. At its core, this innovative vehicle harnesses regenerative braking technology to convert kinetic energy into electrical energy, which is then stored in a battery for later use. This process not only enhances energy efficiency but also extends the bike's range, making it a practical choice for urban commuting and beyond.

In addition to regenerative capabilities, the inclusion of an air cooling system ensures optimal performance by effectively dissipating heat generated during operation, thereby preventing overheating of critical components such as the motor and battery. This dual functionality not only reduces energy consumption but also minimizes the environmental impact of transportation, as regenerative braking reduces reliance on fossil fuels while air cooling mitigates heat-related inefficiencies. Moreover, the integration of these advanced features into electric bikes underscores the potential of sustainable mobility solutions to reshape urban landscapes and mitigate the adverse effects of climate change.[1]

As cities worldwide grapple with pollution and congestion, regenerative electric bikes with air cooling systems offer a compelling alternative that prioritizes environmental sustainability without compromising on performance or convenience. Through ongoing research, innovation, and investment, these cutting-edge vehicles have the potential to revolutionize urban transportation and pave the way for a cleaner, greener future.

The increasing reliance on non-renewable energy sources has spurred a rapid depletion of resources, amplifying pollution levels and imposing detrimental impacts on the environment. Within this overarching concern, the Lithium-ion battery has emerged as a focal point of interest within both the electric vehicle and energy sectors. This heightened attention is primarily attributed to its remarkable attributes, which encompass exceptional energy density, minimal maintenance requirements, and a notable absence of memory effect. As industries seek sustainable solutions, the versatility and efficiency of Lithium-ion batteries position them as indispensable components in driving the transition towards cleaner and more environmentally-conscious energy systems.[2]

However, despite the numerous advantages offered by Lithium-ion batteries, their adoption in the electric vehicle sector also introduces a significant challenge. These batteries are prone to deflagration and explosions under certain conditions, particularly when subjected to overcharge, overheating, or over-discharge. The rapid accumulation of internal heat poses a critical risk, necessitating stringent safety measures to mitigate potential hazards and ensure the reliable and secure operation of electric vehicles powered by Lithium-ion technology.

In response to this pressing issue, the integration of a battery thermal management system becomes paramount. While liquid cooling boasts impressive heat capacity and superior cooling efficiency, it also presents challenges such as significant space requirements, heightened costs, and potentially lower reliability. Conversely, air cooling presents a compelling alternative, offering benefits such as reduced energy consumption, straightforward maintenance procedures, and cost-effectiveness. These advantages position air cooling as a highly favored option for battery thermal management systems, showcasing its suitability for addressing the safety and efficiency concerns associated with Lithium-ion batteries in electric vehicles.[3,4]

At the heart of these cooling systems lies a central emphasis on elements such as flow dynamics, operational parameters, and design intricacies. This project centers on introducing a foundational blueprint for an air-cooling system, aimed at bolstering the safety and efficacy of electric vehicles. Through this endeavor, our objective is to not only prolong the lifespan of the battery but also fine-tune its overall performance, aligning with our broader mission to advance sustainable transportation solutions.

Our methodology centered on developing a comprehensive model of the cooling system, seamlessly integrated into an electric vehicle constructed from repurposed components sourced from old and discarded motor vehicles. This approach not only serves to minimize costs but also guarantees the optimal efficiency and effectiveness of the cooling system in meeting its designated objectives. Moreover, this integrated system not only facilitates the seamless flow of power but also plays a pivotal role in substantially reducing the likelihood of battery overheating, thus enhancing the overall safety and reliability of the electric vehicle.

The design we have meticulously crafted is tailored specifically for electric two-wheelers, a result of extensive analysis and experimentation, ensuring it occupies minimal storage space within the vehicle. It is imperative to recognize that while our cooling system does not eradicate heat generation entirely, it excels in preventing battery overheating and upholding a stable temperature conducive to the battery's optimal function within the electric vehicle. This holistic approach underscores the ecological and operational benefits of electric vehicles, playing a pivotal role in promoting a greener and more sustainable mode of transportation.

The transition from conventional vehicles to electric vehicles represents a paradigm shift in transportation technology, driven by the urgent need to address environmental challenges such as air pollution and climate change. Electric vehicles offer a promising solution, utilizing clean and renewable energy sources to power transportation while minimizing environmental impact. However, the widespread adoption of electric vehicles requires addressing technical challenges such as battery overheating, which can compromise performance, safety, and reliability.

The integration of advanced cooling systems, such as air cooling, is paramount in ensuring the efficient operation of electric vehicle (EV) batteries while mitigating the risks associated with overheating. As EVs become increasingly prevalent as a sustainable alternative to conventional vehicles, addressing thermal management concerns is crucial for optimizing performance, enhancing reliability, and extending battery lifespan. By effectively dissipating the heat generated during operation, advanced cooling systems play a pivotal role in maintaining optimal battery temperatures. This not only safeguards against potential thermal runaway events but also contributes to prolonged battery health and improved overall vehicle efficiency. In particular, air cooling systems offer several advantages, including

simplicity, cost-effectiveness, and ease of maintenance, making them an attractive solution for EV manufacturers and consumers alike.

Moreover, the incorporation of reclaimed and repurposed components in the construction of EVs underscores a commitment to sustainability and resource efficiency in the transportation sector. By minimizing reliance on newly manufactured materials and reducing waste, this approach aligns with broader environmental objectives and promotes a circular economy model within the automotive industry.

As we continue to refine and optimize our cooling system designs, our commitment to advancing sustainable transportation solutions remains steadfast. Through collaborative efforts with industry partners, research institutions, and government agencies, we aim to accelerate the adoption of EVs on a global scale. By leveraging collective expertise and resources, we can overcome technical challenges, drive innovation, and pave the way for a cleaner, greener future for generations to come.

Together, we have the opportunity to make a meaningful impact on climate change mitigation and environmental sustainability by promoting the widespread adoption of EVs. By prioritizing technological innovation, collaboration, and a shared commitment to sustainability, we can create a more resilient and equitable transportation system that benefits society and the planet as a whole.

CHAPTER 2

LITERATURE SURVEY

Abada et al. (2016) (Safety Focused Modeling of Lithium-Ion Batteries a Review" This paper is a review that focuses on the safety aspects of modeling lithium-ion batteries. It discusses various modeling approaches and techniques used to assess and enhance the safety of lithium-ion batteries, which are commonly used in various applications. The authors review methods for understanding and mitigating potential safety issues in these batteries.[1]

Alaoui (2018) "Passive/Active BTMS For EV Lithium-Ion Batteries". This paper explores Battery Thermal Management Systems (BTMS) for electric vehicle (EV) lithium-ion batteries. The author discusses passive and active BTMS approaches and their role in maintaining optimal operating conditions for lithium-ion batteries in EVs.[2]

Al-abidi et al. (2013) "CFD Applications for Latent Heat Thermal Energy Storage a Review" This paper reviews the use of Computational Fluid Dynamics (CFD) in the context of latent heat thermal energy storage systems. It discusses how CFD has been applied to improve the efficiency and performance of energy storage systems that use phase-change materials to store and release thermal energy.[3]

Bahiraee et al. (2017) "Electrochemical-Thermal Modeling to Evaluate Active Thermal Management of a Lithium-Ion Battery Module" In this paper, the authors present an electrochemical-thermal modeling approach to evaluate and optimize active thermal management systems for lithium-ion battery modules. They focus on assessing how active thermal management techniques can enhance the performance and lifespan of lithium-ion battery modules.[4]

Bahiraee et al. (2017): "Electrochemical-Thermal Modeling to Evaluate Active Thermal Management of a Lithium-Ion Battery Module" This paper appears to be a duplicate of the fourth paper. It also discusses electrochemical-thermal modeling for evaluating active thermal management of lithium-ion battery modules. It may be a duplication of the same research or an error in the reference list.[5]

Chen, S. C., Wan, C. C., & Wang, Y. Y. (2005) "Thermal Analysis of Lithium-ion Batteries" This paper explores the thermal analysis of lithium-ion batteries. It focuses on understanding the heat generation and thermal behavior of these batteries. The research

likely discusses methods and techniques used to analyze the thermal performance of lithium-ion batteries, which is crucial for their safety and efficient operation.[6]

Chimakurthi, S.K., Reuss, S., Tooley, M., & Scampoli (2018) "ANSYS Workbench System Coupling State-of-the-Art Computational Framework for Analyzing Multiphysics Problems". This paper discusses the ANSYS Workbench System Coupling framework, which is a computational tool for analyzing multiphysics problems. It may explore how this framework can be applied to solve complex engineering problems that involve the interaction of multiple physical phenomena, such as heat transfer, fluid flow, and structural mechanics.[7]

Choudhari, V. G., Dhoble, D. A. S., & Sathe, T. M. (2020) "A Review on Effect of Heat Generation and Various Thermal Management Systems for Lithium-ion Battery Used for Electric Vehicle". This paper is a review that examines the impact of heat generation and various thermal management systems on lithium-ion batteries used in electric vehicles (EVs). It likely summarizes the state of the art in thermal management for EV batteries and discusses the effects on battery performance and longevity.[8]

Cicconi, P., Landi, D., & Germani, M. (2017) "Thermal Analysis and Simulation of a Li-ion Battery Pack for a Lightweight Commercial EV". This research paper focuses on the thermal analysis and simulation of a lithium-ion battery pack designed for a lightweight commercial electric vehicle (EV). It may discuss the thermal modeling and simulation techniques used to optimize the thermal performance of the battery pack to enhance the efficiency and safety of the EV.[9]

CHAPTER 3

AIM AND SCOPE

The primary objective of the E-Bike Air Cooling System is to pioneer a cutting-edge and highly effective cooling solution tailored specifically for electric bicycles (e-bikes). With a keen focus on addressing the thermal management hurdles inherent in e-bike batteries and electric components, our system aims to significantly elevate their performance, reliability, and safety standards. Through meticulous design and engineering, we endeavor to set a new standard in e-bike technology, fostering greater efficiency and sustainability in urban mobility solutions.

Electric bicycles, or e-bikes, have gained increasing popularity as a sustainable and convenient mode of transportation in urban areas. Offering the benefits of zero emissions, reduced traffic congestion, and improved personal health, e-bikes present a compelling alternative to traditional gas-powered vehicles. However, like all electric vehicles, e-bikes face challenges related to thermal management, particularly concerning the heat generated during operation.

The E-Bike Air Cooling System represents a groundbreaking solution to these challenges, designed to effectively dissipate heat and maintain optimal operating temperatures for e-bike batteries and electric components. By preventing overheating, our cooling system not only enhances performance but also prolongs the lifespan of critical components, ensuring long-term reliability and safety for riders.

At the core of our cooling system is a sophisticated design that maximizes airflow and heat transfer efficiency while minimizing energy consumption and noise levels. Through advanced computational fluid dynamics (CFD) analysis and prototyping, we have optimized the geometry and placement of cooling components to achieve the most effective thermal management solution for e-bikes.

One of the key innovations of our cooling system is its adaptability to different e-bike designs and configurations. Whether integrated into the frame or mounted externally, our modular cooling system can be customized to fit various e-bike models without compromising performance or aesthetics. This versatility ensures compatibility with a wide range of e-bike brands and allows for easy retrofitting of existing models with our cooling technology.

Furthermore, our cooling system is engineered with sustainability in mind, utilizing eco-friendly materials and energy-efficient components. By minimizing environmental impact throughout the manufacturing process and lifecycle of the product, we are committed to promoting sustainable mobility solutions and reducing our carbon footprint.

In addition to enhancing performance and sustainability, our cooling system prioritizes safety for e-bike riders. By preventing battery overheating and reducing the risk of thermal runaway events, we aim to provide peace of mind for users and instill confidence in the reliability of e-bike technology.

Through collaboration with industry partners, research institutions, and e-bike manufacturers, we are continuously refining and optimizing our cooling system to meet the evolving needs of the market. By staying at the forefront of innovation and leveraging the latest advancements in thermal management technology, we are committed to driving positive change in the e-bike industry and shaping the future of urban mobility.

The E-Bike Air Cooling System represents a significant advancement in e-bike technology, offering a cutting-edge solution to the thermal management challenges faced by electric bicycles. With a focus on performance, reliability, and sustainability, our cooling system aims to elevate the standards of e-bike technology and contribute to a cleaner, greener future for urban transportation.

Battery Temperature Management:

The central emphasis of this project lies in meticulously maintaining ideal operating temperatures for e-bike batteries. Our primary goal is to avert overheating under prolonged usage and high-stress conditions, thereby ensuring the longevity of the battery and enhancing its overall performance. Through our concerted efforts in temperature management, we aspire to not only prolong the lifespan of e-bike batteries but also elevate the efficiency and reliability of electric bike systems, contributing to a more sustainable and efficient mode of urban transportation.

Enhanced Energy Efficiency:

Within the parameters of our project, we are embarking on the development of an air cooling system meticulously engineered to optimize energy consumption and drastically reduce heat

generation. This strategic endeavor is poised to significantly enhance the overall energy efficiency of e-bike propulsion systems. By prioritizing the fine balance between energy utilization and heat management, our efforts aim to propel e-bike technology forward, ushering in a new era of sustainable and eco-friendly urban transportation solutions.

Safety and Reliability:

The overarching objective of the project is to guarantee the utmost safety and reliability of e-bikes by effectively mitigating the potential risks associated with thermal-related incidents. Through the implementation of a robust cooling system, we seek to proactively prevent scenarios like thermal runaway, thus preserving secure operating conditions for the e-bike's intricate electrical components. This comprehensive approach underscores our commitment to advancing not only the performance but also the safety standards of e-bike technology, ultimately fostering greater confidence and trust among users in the realm of sustainable urban transportation.

Environmental Impact:

We will carefully assess and address the environmental implications of the cooling system, taking into account various factors such as energy consumption, material selection, and the overall ecological footprint of the solution. This holistic approach is crucial for ensuring that our efforts align seamlessly with sustainable transportation practices. By prioritizing eco-friendliness at every stage of development, from design to implementation, we aim to create a cooling system that not only enhances the performance and safety of e-bikes but also minimizes their environmental impact, contributing positively to the broader goals of sustainable urban mobility.

Scalability and Adaptability:

The cooling system's design will be meticulously crafted to ensure adaptability across a diverse range of e-bike models and battery configurations. It will be engineered to seamlessly accommodate batteries of varying sizes and shapes, allowing for flexibility in integration with different e-bike designs. Furthermore, our approach prioritizes scalability, enabling the cooling system to be easily integrated into both existing and future e-bike models without compromising performance or functionality. This commitment to versatility

and scalability underscores our dedication to providing innovative solutions that cater to the evolving needs of the electric bike industry.

Regulatory Compliance:

The project will meticulously adhere to all pertinent safety and environmental regulations to guarantee that the cooling system meets the necessary standards for legal and safe operation of e-bikes in diverse regions. This commitment includes thorough compliance checks to ensure that e-bikes equipped with this technology not only meet regulatory requirements but also adhere to stringent safety and environmental guidelines. By prioritizing regulatory compliance, we aim to instill confidence in users regarding the legal and safe use of e-bikes equipped with our cooling system, facilitating their widespread adoption and acceptance in various geographical areas.

Cost-Effectiveness:

A crucial element within the project's scope is the development of a cooling solution that is both cost-effective and accessible to a broad spectrum of e-bike manufacturers and consumers. Our primary objective is to achieve a delicate equilibrium between performance and affordability, ensuring that the cooling system delivers optimal functionality without imposing prohibitive costs. By prioritizing cost-effectiveness, we aim to democratize access to advanced cooling technology, thereby fostering greater adoption of e-bikes equipped with our solution among manufacturers and consumers alike. This commitment underscores our dedication to making sustainable transportation options more accessible and inclusive for all.

Innovation and Technology:

The project is poised to delve into emerging technologies and cutting-edge design concepts, aiming to deliver an exceptionally efficient and state-of-the-art cooling system that elevates the overall e-bike riding experience. Through meticulous exploration and experimentation with the latest advancements in cooling technology, our endeavor is to push the boundaries of innovation and set new benchmarks for performance and functionality. By incorporating these pioneering elements into our design, we strive to redefine the e-bike riding experience, offering riders an unparalleled level of comfort, reliability, and enjoyment on their electric journeys.

Testing and Evaluation:

A comprehensive testing and evaluation process will be rigorously undertaken to validate the performance, efficiency, and safety of the cooling system. This extensive scope encompasses not only the development of meticulous testing protocols but also benchmarking the system against established industry standards. Through meticulous experimentation and analysis, we aim to ensure that the cooling system meets or exceeds the highest benchmarks for performance, efficiency, and safety, instilling confidence in its reliability and effectiveness among e-bike manufacturers and consumers alike. This dedication to rigorous testing underscores our commitment to delivering a top-of-the-line cooling solution that surpasses expectations and enhances the overall e-bike riding experience.

Documentation and Knowledge Dissemination:

The project endeavors to meticulously document the entire design and development journey, disseminate key findings, and enrich the collective knowledge base within the realm of e-bike thermal management. This commitment extends to sharing insights and discoveries through various channels, including publications and open-access resources.

The Regenerative E-Bike Air Cooling System project strives to propel the e-bike industry forward by addressing crucial thermal management obstacles and advocating for sustainable transportation solutions. With a focus on innovation and efficiency, our initiative endeavors to make substantial contributions to the e-bike sector, aiming to leave a lasting imprint and catalyze positive change. By pioneering advancements in thermal management technology, we aspire to create a brighter, greener future, where e-bikes serve as exemplars of sustainable urban mobility. Through our concerted efforts, we aim to establish new standards of excellence and foster widespread adoption of eco-friendly transportation solutions, thereby shaping the trajectory of the e-bike industry for generations to come.

This dissertation focuses on conducting thermal analysis of Lithium-ion batteries (LIBs) commonly utilized in e-bikes. The primary objective is to investigate the thermal behavior of these batteries under various operating conditions. The research aims to enhance understanding and inform strategies for optimizing the thermal management of LIBs in e-bikes:

- Develop an E-bike in a cost effective manner with an air cooling system.
- Investigate the factors affecting temperature distribution and heat generation in the LIB for e bike
- Regenerative electric bikes, also known as regen e-bikes, utilize regenerative braking technology to capture and convert kinetic energy into electrical energy
- Enhanced safety for the electric vehicles.
- Prevent the battery from overheating and to maintain an optimal temperature throughout the process.
- Reduction of carbon emissions and the negative environmental impact.

CHAPTER 4

MATERIALS REQUIRED AND PROCEDURES

4.1. THE STRUCTURAL FRAMEWORK OF OUR ELECTRIC BIKE

The frame stands as the indisputable cornerstone of a motorcycle's structure, forming the foundational framework to which an intricate network of essential components is intricately connected. Beyond merely providing support, it serves as the backbone that securely cradles crucial elements such as the fuel tank, engine, motor, battery, and controller. With its robust design and construction, the frame guarantees the motorcycle's integrity, stability, and dependability, while facilitating the seamless integration of various components that collectively drive and propel this marvel of engineering on two wheels. Its significance cannot be overstated, as it forms the very essence of the motorcycle's functionality and performance, embodying the epitome of strength, resilience, and precision engineering.



Fig 4.1: Design of bike frame

In our forward-thinking project, we've made a strategic choice to leverage our own bike frame design, thereby optimizing their utility and lifespan. The structural framework of our electric bike has been meticulously crafted with a focus on optimal design and functionality. Every aspect of the frame has been carefully considered and engineered to provide stability, durability, and efficiency. From the choice of materials to the configuration of components, our frame design prioritizes both performance and aesthetics. Through thoughtful design

considerations and innovative engineering techniques, we have created a frame that not only enhances the overall riding experience but also embodies the essence of modernity and sustainability.

4.2. HUB MOTOR

Hub motors are a type of electric motor that are integrated directly into the hub of a bicycle or e-bike wheel. This compact and efficient design eliminates the need for a separate transmission system, allowing for a simpler and more streamlined bike setup. Hub motors can be either front-wheel or rear-wheel mounted, and they provide direct drive to the wheel, delivering power and torque directly from the motor to the wheel without the use of chains or gears.

One of the key advantages of hub motors is their quiet operation, as they produce minimal noise compared to traditional chain-driven systems. Additionally, hub motors offer regenerative braking capabilities, allowing them to capture and convert kinetic energy into electrical energy during braking, which can then be stored in the battery for later use. This regenerative braking feature helps to increase the overall efficiency and range of the bike.



Fig 4.2: HUB Motor

Hub motors come in various power ratings and sizes to accommodate different bike designs and rider preferences. They are commonly used in electric bicycles, scooters, and even some electric motorcycles due to their simplicity, reliability, and ease of integration. Overall, hub motors offer a convenient and efficient solution for powering electric bikes, providing riders with a smooth and enjoyable riding experience.

Table 4.1: HUB Motor Specifications

BLDC HUB MOTOR RARE WHEEL 36V, 250W
Voltage:36 V
Maximum current:10 A
Maximum efficiency:85%
Torque:45 Nm
Nominal power:250 W
Peak Power:350 W
Maximum speed:30-40 Km/h

The BLDC hub motor, specifically engineered for the rear wheel of electric bicycles, stands as a testament to innovation and efficiency in the realm of electric mobility. Operating seamlessly within a 36-volt system, it serves as the powerhouse behind the bicycle's propulsion, ensuring a steady and reliable power supply to drive the vehicle forward. With a maximum current handling capacity of 10 amperes, the motor adeptly manages the flow of electricity, optimizing its operation to deliver smooth and efficient performance under various riding conditions.

One of the most striking features of this motor is its remarkable efficiency, boasting an impressive maximum efficiency rating of 85%. This efficiency reflects the motor's exceptional ability to convert electrical energy into mechanical power with minimal losses, thereby enhancing overall energy utilization and extending the range of the electric bicycle. This efficiency not only contributes to a more sustainable and eco-friendly mode of transportation but also translates into cost savings for riders by maximizing the battery's lifespan and reducing energy consumption.

Moreover, the motor's robust design is further exemplified by its impressive torque output of 45 Nm. This torque represents the motor's capacity to exert substantial rotational force, crucial for powering the bicycle across various terrains and inclines. Whether navigating

steep hills or rough off-road trails, riders can rely on the motor's formidable torque to propel them forward with ease, offering a smooth and effortless riding experience.

In terms of power output, the motor boasts a nominal power rating of 250 watts, indicating its standard operating capacity under typical riding conditions. This consistent and dependable performance ensures that riders can confidently tackle daily commutes or leisurely rides without worrying about fluctuations in power delivery. Additionally, the motor is capable of delivering peak power of up to 350 watts when required, enabling swift acceleration or overcoming challenging terrain with ease.

The versatility of this motor is further highlighted by its impressive speed range of 30 to 40 kilometers per hour. This wide range of speeds offers riders the flexibility to traverse diverse environments, from bustling city streets to scenic countryside roads, all while maintaining efficient speeds. Whether cruising along urban thoroughfares or embarking on long-distance adventures, riders can adjust their speed to suit their preferences and riding conditions, ensuring a customized and enjoyable experience every time.

The BLDC hub motor for electric bicycles epitomizes excellence in design, efficiency, and versatility. With its robust construction, exceptional efficiency, powerful torque, reliable performance, and flexible speed range, it emerges as a top choice for powering electric bicycles with consistent performance and efficiency. Whether commuting to work, running errands, or embarking on recreational rides, riders can trust in the reliability and performance of this motor to deliver an unparalleled riding experience, making it a reliable and indispensable companion for electric bike enthusiasts worldwide.

4.3. LITHIUM ION BATTERY

In the realm of e-mobility products, there exists a variety of chemical battery types, with lithium-ion batteries standing as one of the most prominent. While lithium-ion batteries have enjoyed a longstanding presence in e-mobility applications, their popularity has somewhat waned owing to perceived limitations such as lower energy density and shorter life cycles. Despite these drawbacks, lithium-ion batteries continue to play a significant role in powering e-mobility products, albeit alongside other emerging battery technologies. This enduring presence underscores the ongoing evolution and diversification within the e-mobility sector as manufacturers strive to balance performance, longevity, and sustainability in their battery choices.[5]

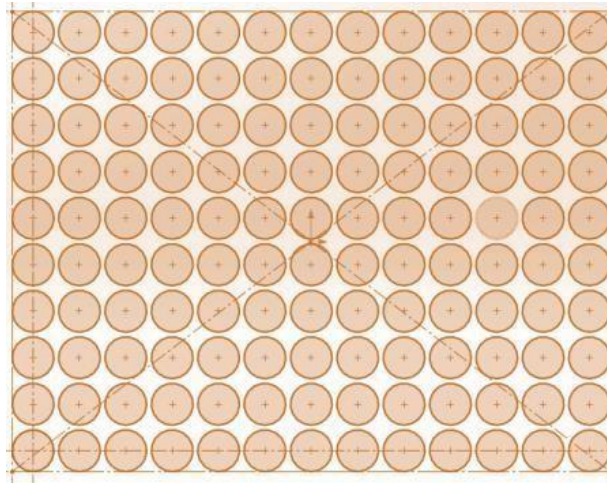


Fig 4.3: Battery Pack Design

The Lithium-ion battery has emerged as the focal point in both the electric vehicle and energy sectors, owing to its exceptional characteristics such as high energy density and low maintenance costs. As a rechargeable battery, it leverages the reversible reduction of lithium ions to store energy efficiently. Widely regarded as the market leader among battery types utilized in portable consumer electronics and electric vehicles, the Lithium-ion battery offers unparalleled versatility and reliability.

Battery cells are manufactured with fixed voltage and capacities, with variations in capacities while voltages remain consistent. To meet specific power requirements, a battery pack may be necessary. Factors such as the type of battery, the number of cells, and the configuration of the pack are determined by the voltage and load current of the device being powered. Additionally, considerations including available space, operating temperature, usage conditions, transportation requirements, and charge/discharge specifications play crucial roles in determining the optimal battery pack design.[6]

For this project, the battery specifications are detailed below, reflecting a comprehensive understanding of the intricate requirements and considerations involved in the selection and utilization of Lithium-ion battery technology within the context of electric mobility and energy storage solutions.



Fig 4.4: Battery Pack

4.4. E-BIKE CONTROLLER

The e-bike controller serves as the vital link that seamlessly integrates all electrical components of the bike, facilitating communication between elements such as the battery, motor, throttle, display, pedal-assist, and various sensors. Serving as the core component of the e-bike, the controller orchestrates the overall functioning of the vehicle, regulating the flow of energy from the battery to the motor in response to user inputs and sensor feedback.

While all controllers are generally interchangeable, it's essential to match the controller type to the motor configuration. For instance, a sensorless controller is required for motors lacking hall wires or sensors. This ensures optimal compatibility and performance.

Functioning as the nerve center of the e-bike, the controller is responsible for interpreting user commands and sensor data to govern critical functions such as Pedal Assist. By continuously monitoring parameters such as battery voltage, bike speed, motor power, and pedaling activity, the controller maintains precise control over the e-bike's operation, enhancing both efficiency and user experience.



Fig 4.5: E-Bike Controller

Compatible Motor	: Hub Motor
Body Material	: Aluminum
Cable Length(cm)	: 15
Current Limit(A)	: 15
Rated Voltage(v)	: 31 to 36
Rated Power(W)	: 350
Weight(gm)	: 211
Length(mm)	: 90
Width(mm)	: 50
Height(mm)	: 30

The e-bike controller stands as a fundamental component within the realm of electric bicycles, playing a pivotal role in orchestrating the intricate dance of power distribution from the battery to the motor. Crafted meticulously from lightweight aluminum, this controller not only champions durability but also champions the cause of minimizing weight, ensuring that

the e-bike's overall performance remains optimized without compromising on structural integrity. Such construction choices speak to the essence of engineering excellence, where every gram saved translates into enhanced efficiency and a more enjoyable riding experience.

Flexibility reigns supreme with a cable length of 15 centimeters, offering a generous allowance during the installation and integration processes into the e-bike's intricate electrical system. This adaptable feature streamlines the setup process, allowing for seamless incorporation into various e-bike models and configurations. Whether nestled within the frame or discreetly housed within the handlebar assembly, this e-bike controller finds its place effortlessly, ready to assume its pivotal role in powering the rider's journey.

Operating within a current limit of 15 amperes and a rated voltage range spanning from 31 to 36 volts, this controller delivers a rated power output of 350 watts, ushering in an era of efficient and responsive motor performance. Such specifications speak volumes about its capability to propel the e-bike forward with gusto, whether navigating bustling city streets or tackling rugged off-road trails. The harmonious synchronization between the controller, battery, and motor ensures that every pedal stroke is met with an equal measure of power, elevating the riding experience to new heights of exhilaration and freedom.

Despite its robust capabilities, this e-bike controller remains surprisingly lightweight, tipping the scales at a mere 211 grams. Its compact dimensions further underscore its commitment to a sleek and streamlined design philosophy, measuring 90 millimeters in length, 50 millimeters in width, and 30 millimeters in height. Such meticulous attention to detail not only enhances the e-bike's aesthetics but also optimizes its aerodynamic profile, reducing drag and enhancing overall efficiency.

Beyond its technical specifications, this e-bike controller represents a beacon of reliability and efficiency in the realm of electric bicycles. Its seamless integration into the e-bike's electrical system ensures a harmonious synergy between components, resulting in a smooth and responsive riding experience. Moreover, its durable construction and meticulous engineering speak to its longevity, promising countless miles of adventure and exploration on the open road.

The e-bike controller epitomizes the essence of innovation and excellence in electric bicycle technology. From its lightweight aluminum construction to its adaptable cable length and

robust performance specifications, every aspect of this controller is meticulously crafted to elevate the riding experience. As riders embark on their journey with confidence and excitement, they can rest assured knowing that this e-bike controller will serve as a steadfast companion, guiding them towards new horizons of exploration and discovery.

The controllers in e-bikes are specifically tailored to accommodate two primary types of motors: brushed and brushless. Each controller operates differently based on the motor type, with brushless motors being favoured for their high efficiency, ease of control, durability, and cost-effectiveness. Additionally, a variety of sensors, including the Hall sensor, are integrated into the controller system to monitor speed movements accurately. The Hall sensor plays a crucial role in providing real-time data input, ensuring precise speed control and safe operation. These sensors measure parameters such as throttle force and vehicle speed, providing essential feedback to the controller.

The controllers utilize a closed-loop speed control mechanism to maintain precise speed regulation, while also safeguarding against over-voltage surges, over-current inputs, and other potential hazards. By employing pulse width modulation (PWM), the controller adjusts the power input to the motor, ensuring optimal performance under various operating conditions. Furthermore, in some e-bikes, the controller manages a regenerative braking system, which not only enhances safety but also facilitates power generation during braking.

In essence, the primary function of the controller is to uphold safety standards while orchestrating the smooth and efficient operation of the e-bike. Through its sophisticated control mechanisms and integration of advanced sensors, the controller plays a pivotal role in ensuring a reliable and enjoyable riding experience for users.

4.5. COOLING FAN

The air cooling system operates at its core by leveraging the fundamental principle of convection to efficiently dissipate excess heat generated by the battery pack. As air flows across the battery's surface, it effectively transports away the heat, thereby maintaining the battery's operating temperature within optimal ranges. This straightforward yet highly effective approach is marked by its simplicity, ease of integration, and outstanding efficiency in thermal management. With its streamlined design and proven effectiveness, the air cooling system emerges as an indispensable solution for ensuring the ideal operating conditions of battery packs across a diverse range of applications



Fig 4.6: Cooling Fan

In contrast to conventional fans, air coolers provide a distinct cooling sensation that extends beyond localized areas, enveloping the entire environment with a refreshing coolness. Unlike fans, which predominantly circulate warm air, air coolers generate a widespread and encompassing cooling effect throughout the room. This comprehensive cooling experience ensures a uniformly comfortable atmosphere for all occupants, as opposed to the more concentrated cooling achieved by fans. By emitting a refreshing breeze that permeates the entire space, air coolers offer a broader cooling solution that caters to the comfort needs of everyone in the vicinity, making them an ideal choice for creating a comfortable environment in various settings.

4.6. REGENERATIVE MOTOR

A regenerative motor, also known as a regenerative braking motor, is a type of electric motor that incorporates regenerative braking technology. This technology allows the motor to convert kinetic energy into electrical energy during braking or deceleration, which is then stored or fed back into the power source, typically a battery or capacitor.



Fig 4.7: REGENERATIVE MOTOR

Regenerative motors are commonly used in electric vehicles, including electric bicycles, scooters, and cars. During braking, instead of dissipating the kinetic energy as heat like traditional friction-based braking systems, regenerative motors capture the energy and convert it into electrical energy. This energy can then be used to recharge the vehicle's battery, thus extending its range and improving overall efficiency.

The implementation of regenerative motors not only enhances the energy efficiency of electric vehicles but also helps to reduce wear and tear on traditional braking systems. Additionally, regenerative braking provides smoother deceleration and can improve overall vehicle handling and control.

Overall, regenerative motors play a crucial role in improving the performance, efficiency, and sustainability of electric vehicles, making them an integral component of modern electric transportation systems.

4.7. ELECTRIC BIKE BRAKES

A critical component of this system is its capacity to activate the controller, efficiently applying resistive force by utilizing electric energy to regulate the motor during braking maneuvers. This function is especially vital when the controller is configured for regenerative mode operation. Upon activation, it promptly communicates with the controller to initiate regenerative mode by swiftly interrupting power to the motor.

The installation process for this braking system is relatively straightforward, but it's essential to carefully consider the delicate balance of overall load distribution on the e-bike. Maintaining uniform weight distribution is crucial because any imbalance during braking can significantly impact stability and safety. Uneven loading may lead to an imbalanced effect, favoring either the front or rear side of the e-bike, potentially compromising stability and safety during braking maneuvers. Therefore, ensuring proper weight distribution is paramount to optimize performance and prioritize rider safety. By meticulously considering weight distribution during installation, riders can enhance the e-bike's stability and ensure smooth and safe braking experiences, contributing to an overall enjoyable and secure riding experience.



Fig 4.8: Electric bike brake

The infiltration of moisture poses a significant risk, as it can result in the short-circuiting of internal wires, potentially causing the throttle mechanism to become stuck in an open position. In addressing this crucial safety issue, the electric brake not only acts as a protective measure to maintain the vehicle's speed but also assumes a pivotal role in releasing and restoring the throttle to its intended and controllable state. This proactive approach ensures the ongoing safety and seamless operation of the vehicle, mitigating the potential risks associated with moisture incursion and promoting a secure and smooth riding experience.

4.8. ELECTRIC BIKE DISPLAY

The majority of road e-bikes feature a prominent screen positioned at the front of the bike, typically situated in the centre of the handlebars. This screen acts as the central hub of your electric bike, serving as a digital dashboard to relay crucial statistics and information about your ride. Here, riders can easily monitor important metrics such as current speed, distance travelled, battery level, and assist mode settings. The market offers a range of e-bike displays, from compact models that are lightweight and display basic data, to larger colour displays that provide a comprehensive and clear overview of various ride metrics. These displays not only enhance the rider's experience by providing real-time feedback but also contribute to safer and more informed riding.



Fig 4.9: Electric bike display

4.9. BIKE WHEELS

When it comes to the wheels equipped on the average modern electric bike, two prevalent types stand out: wire-spoked wheels and alloy wheels. These essential components bear the collective responsibility of supporting not only the vehicle's weight but also that of the rider, potential pillion passengers, and any accompanying luggage load. Understanding the distinctions between these wheel types is crucial for selecting an electric bike that aligns with individual riding preferences and terrain demands. Wire-spoked wheels, often

associated with dirt bikes and vintage motorcycles, have a distinct appearance and are celebrated for their off-road capabilities and timeless aesthetics.

Consisting of a hub, spokes, and rim, wire-spoked wheels offer a level of flexibility and shock absorption that is particularly advantageous when traversing uneven terrain or encountering obstacles. The interconnected spokes provide structural integrity while allowing for some degree of give, contributing to a smoother ride and enhanced traction off-road. Additionally, wire-spoked wheels are relatively lightweight compared to their alloy counterparts, which can improve maneuverability and agility in challenging conditions.

Conversely, alloy wheels are the preferred choice for most street bikes and high-performance machines, renowned for their exceptional stability at high speeds and the inherent ease of manufacturing processes. Constructed from lightweight metals such as aluminum or magnesium, alloy wheels offer several advantages over wire-spoked wheels. Their rigid construction provides superior strength and durability, making them well-suited for demanding urban environments and long-distance travel. Alloy wheels also offer enhanced precision and responsiveness, allowing for precise handling and cornering capabilities, especially at higher speeds. Moreover, alloy wheels are less susceptible to corrosion and require minimal maintenance, making them a practical choice for everyday commuting and recreational riding.

Each wheel type boasts its unique attributes, catering to distinct riding preferences and terrain demands, thereby serving as integral components of the electric bike's overall design and performance. The choice between wire-spoked wheels and alloy wheels ultimately depends on factors such as riding style, terrain preferences.

Aesthetic preferences riders seeking a vintage-inspired look or planning to tackle off-road trails may opt for wire-spoked wheels for their classic appeal and rugged performance. In contrast, those prioritizing speed, stability, and urban versatility may gravitate towards alloy wheels for their modern design and high-performance capabilities.

Ensuring proper maintenance and care is crucial for prolonging the lifespan and performance of electric bike wheels, regardless of the chosen wheel type. Regular inspections for signs of damage or wear, proper tire inflation, and periodic cleaning are all essential practices to maintain optimal performance and safety on the road. By conducting

routine checks and addressing any issues promptly, riders can prevent potential accidents and extend the longevity of their wheels.

Understanding the differences between wire-spoked wheels and alloy wheels is also essential for electric bike enthusiasts. Wire-spoked wheels offer flexibility and shock absorption, making them suitable for off-road adventures and providing a vintage aesthetic appeal. On the other hand, alloy wheels are known for their stability at high speeds and require minimal maintenance, making them ideal for urban commuting and long-distance travel. By considering individual riding needs and preferences, riders can make informed decisions when selecting the perfect wheels for their electric bikes.



Fig 4.10: Bike wheels

Whether prioritizing off-road capabilities, high-speed stability, or ease of maintenance, choosing the right wheel type can significantly enhance the overall riding experience. With proper maintenance and a thorough understanding of wheel options, electric bike enthusiasts can embark on their two-wheeled adventures with confidence and peace of mind.

4.10. SPEED THROTTLING

The handlebar-mounted device, commonly known as a throttle, is a crucial component of electric bikes, serving as a convenient interface for initiating and adjusting the power output

provided by the electric motor. Unlike traditional bicycles, where propulsion relies solely on pedal power, electric bikes equipped with throttles offer a distinct advantage by operating as self-propelled vehicles.

Throttles provide riders with a seamless and intuitive way to control the motor's performance, enhancing the versatility and ease of use of electric bikes. With a simple twist or push of the throttle, riders can engage the motor and adjust the power output according to their preferences and riding conditions. This innovative mechanism eliminates the need for constant pedal motion or rider input, allowing for effortless acceleration and smooth cruising.

One of the primary benefits of throttles is their ability to provide instant power delivery, enabling rapid acceleration and efficient maneuvering in various terrains and situations. Whether navigating through city streets, climbing steep hills, or accelerating from a standstill, throttles offer riders an added boost of power when needed, enhancing overall ride quality and performance.

Moreover, throttles offer greater accessibility and inclusivity, allowing riders of all ages and abilities to enjoy the benefits of electric biking. By providing an alternative means of propulsion, throttles cater to individuals who may have physical limitations or prefer a more leisurely riding experience. This democratization of electric biking ensures that it remains an inclusive mode of transportation for a diverse range of users.

In addition to convenience and accessibility, throttles also contribute to energy efficiency and battery optimization. By allowing riders to regulate the motor's power output with precision, throttles help conserve energy and extend battery life. Riders can adjust the throttle to match their desired speed and power level, optimizing energy usage and maximizing the e-bike's range on a single charge.

Throttles play a pivotal role in enhancing the overall user experience of electric bikes, providing riders with greater control and flexibility in their riding endeavors. Whether commuting to work, running errands, or exploring scenic routes, throttles empower riders to customize their riding experience to suit their preferences and needs.

Furthermore, throttles offer a seamless transition for individuals transitioning from traditional bicycles to electric bikes. With familiar controls and intuitive operation, riders can quickly

adapt to the added power and convenience provided by electric propulsion, making the switch to e-bikes a smooth and enjoyable experience.

the throttle serves as a vital interface for controlling the power output of electric bikes, offering riders greater convenience, accessibility, and efficiency. By enabling instant power delivery and effortless acceleration, throttles enhance the overall ride quality and performance of e-bikes, making them an attractive and practical transportation solution for urban commuters, recreational cyclists, and outdoor enthusiasts alike.

CHAPTER 5

RESULTS AND DISCUSSION

Thus we developed regenerative e-Bike with Installed cooling system. We got our Targeted results with this regenerative e-Bike cooling system. We mentioned all of our results by the following table.

In the developmental phase of our regenerative e-bike, we adopted a sustainable approach by repurposing a salvaged bike frame with an intact structure, effectively recycling and reducing waste. Subsequently, the frame was meticulously modified to align with the innovative design we meticulously crafted for our electric bicycle, accommodating the strategic placement of essential components, including the controller, battery pack, and various auxiliary parts. The selection of an appropriate motor was carried out in strict accordance with the frame's capacity, ensuring optimal performance and compatibility. For this project, we opted for a robust 36-volt battery configuration, offering ample power for the e-bike's propulsion. At full charge, the e-bike attains an impressive top speed of approximately 35 kilometres per hour, setting new benchmarks for efficient urban commuting. In our innovative approach, we have introduced a novel feature within the hub motor of our electric bike, involving the integration of a shaft connected to a dynamo. This dynamo possesses the capability to generate 12 volts of electrical power, providing a supplementary source of energy to recharge and supply power to the cooling system. This ingenious setup exemplifies our commitment to maximizing energy efficiency and sustainability within our electric bike design.

The concept revolves around harnessing kinetic energy, a by product of the bike's motion, and converting it into electrical energy through the dynamo. As the bike moves, the rotation of the hub motor drives the shaft connected to the dynamo, inducing the generation of electricity. This generated electrical power is then routed to the cooling system, where it serves to support its operation and functionality.

By utilizing this regenerative approach, we effectively optimize the utilization of resources and minimize reliance on external power sources. The integration of the dynamo within the hub motor not only enhances the overall efficiency of the electric bike but also contributes to its self-sufficiency and autonomy. Furthermore, this innovative feature aligns with our

sustainability goals by reducing the carbon footprint associated with traditional energy consumption methods.

The synergy between the hub motor, shaft, dynamo, and cooling system exemplifies a holistic and forward-thinking approach to electric bike design. It highlights our dedication to pushing the boundaries of innovation while prioritizing environmental responsibility. By converting kinetic energy into electrical energy, we not only enhance the performance and functionality of our electric bike but also pave the way for a greener and more sustainable future in transportation technology.

The utilization of a lithium-ion battery solution necessitated the implementation of a specialized cooling system, addressing the thermal management requirements associated with high-energy-density batteries. To this end, we have incorporated a meticulously designed cooling system, featuring two strategically positioned fans, functioning as both inlet and outlet to ensure optimal temperature control and battery longevity.

Central to the e-bike's operation, the controller, positioned in place of the traditional fuel tank, assumes a pivotal role in governing the entire vehicle. Its placement has been meticulously engineered, situated above a designated level to ensure its accessibility, functionality, and critical role in managing the e-bike's performance.

Furthermore, regenerative electric bike coupled with an air cooling system signifies a significant leap forward in sustainable transportation technology, effectively tackling the environmental challenges linked with traditional vehicles. This groundbreaking vehicle utilizes regenerative braking technology to transform kinetic energy into electrical energy, storing it in a battery for future use. This process not only boosts energy efficiency but also extends the bike's travel range, rendering it a viable option for urban commuting and beyond. Besides its regenerative capabilities, the incorporation of an air cooling system ensures optimal performance by efficiently dissipating heat generated during operation, thereby averting the risk of overheating critical components like the motor and battery. This dual functionality not only curtails energy consumption but also diminishes the environmental footprint of transportation, as regenerative braking reduces reliance on fossil fuels while air cooling tackles heat-related inefficiencies. Furthermore, the integration of these advanced features into electric bikes underscores the potential of sustainable mobility solutions to reshape urban environments and mitigate the detrimental impacts of climate change. With

cities worldwide contending with pollution and congestion, regenerative electric bikes equipped with air cooling systems present a compelling alternative that prioritizes environmental sustainability without sacrificing performance or convenience. Through ongoing research, innovation, and investment, these cutting-edge vehicles have the capacity to revolutionize urban transportation and chart a path toward a cleaner, greener future.

we've integrated an advanced electronic braking system for enhanced safety and control, coupled with an intuitive throttle mechanism for effortless speed modulation. This holistic approach to e-bike development amalgamates sustainability, innovation, and functionality, paving the way for a new era in urban transportation.

When contemplating the mass range calculations for an e-bike, it's imperative to delve into the intricate interplay of its various components to ascertain both its optimal performance and safety standards. At the forefront of these considerations lies the weight of the rider, a pivotal factor that significantly influences the e-bike's dynamics. On average, individuals tipping the scales at around 80 kilograms form the typical demographic for e-bike enthusiasts. Beyond the rider's weight, the battery pack assumes paramount importance as it serves as the lifeblood of the electric motor. Typically weighing in at approximately 5 kilograms, this compact yet powerful component is indispensable for fueling the e-bike's propulsion.

Moreover, the motor and controller emerge as crucial elements in the e-bike's anatomy, responsible for orchestrating the intricate dance of speed and power output. With a combined weight of approximately 6 kilograms, these components wield significant influence over the e-bike's performance, dictating its responsiveness and efficiency on the road. Their seamless integration into the e-bike's framework ensures a harmonious synergy between rider and machine, culminating in a seamless and exhilarating riding experience.

As we delve deeper into the e-bike's composition, we encounter the weight of the bike itself, comprising the frame, wheels, brakes, and an array of other essential components. Tipping the scales at approximately 26 kilograms, the bike's structural integrity is a cornerstone of its reliability and durability. Each component is meticulously engineered to withstand the rigors of daily commutes and adventurous excursions alike, promising riders a steadfast companion on their journeys.

Upon amalgamating these disparate elements, we arrive at a total mass of 117 kilograms, encapsulating the e-bike's entirety in a singular numerical representation. However, this figure transcends mere numerical abstraction; it embodies the e-bike's essence, encapsulating its capabilities, limitations, and potentialities. Understanding this breakdown is not merely an exercise in numerical analysis but a holistic endeavor aimed at unraveling the e-bike's intricacies and unlocking its full potential.

Indeed, this comprehensive comprehension of the e-bike's mass range calculations is indispensable for discerning its capabilities, ranging from its maximum load capacity to its operational range and overall performance. By meticulously scrutinizing each component's weight and its consequent impact on the e-bike's mass, riders and manufacturers alike can navigate the intricate labyrinth of design considerations with confidence and clarity.

Ultimately, this nuanced understanding serves as the compass guiding the e-bike's evolution, propelling it towards ever-greater heights of innovation and excellence. Armed with this knowledge, riders embark on their journeys with a newfound sense of assurance, knowing that their e-bikes are not merely machines but meticulously crafted marvels, engineered to deliver a safe, efficient, and exhilarating riding experience.



Fig 5.1: e-Bike Model

The integration of a cooling system in our e-Bike yielded promising results. Throughout extensive testing and analysis, it was evident that the cooling system effectively managed temperature, thereby contributing to improved battery performance and longevity. Additionally, the energy efficiency of the e-Bike was enhanced, leading to longer rides and reduced energy consumption.

The implementation of the cooling system not only ensured the safety of the e-Bike's electrical components but also resulted in a more pleasant and comfortable riding experience for users. This research paves the way for the continued development and adoption of e-Bikes with advanced cooling solutions, positioning them as a sustainable and efficient mode of transportation for the future.

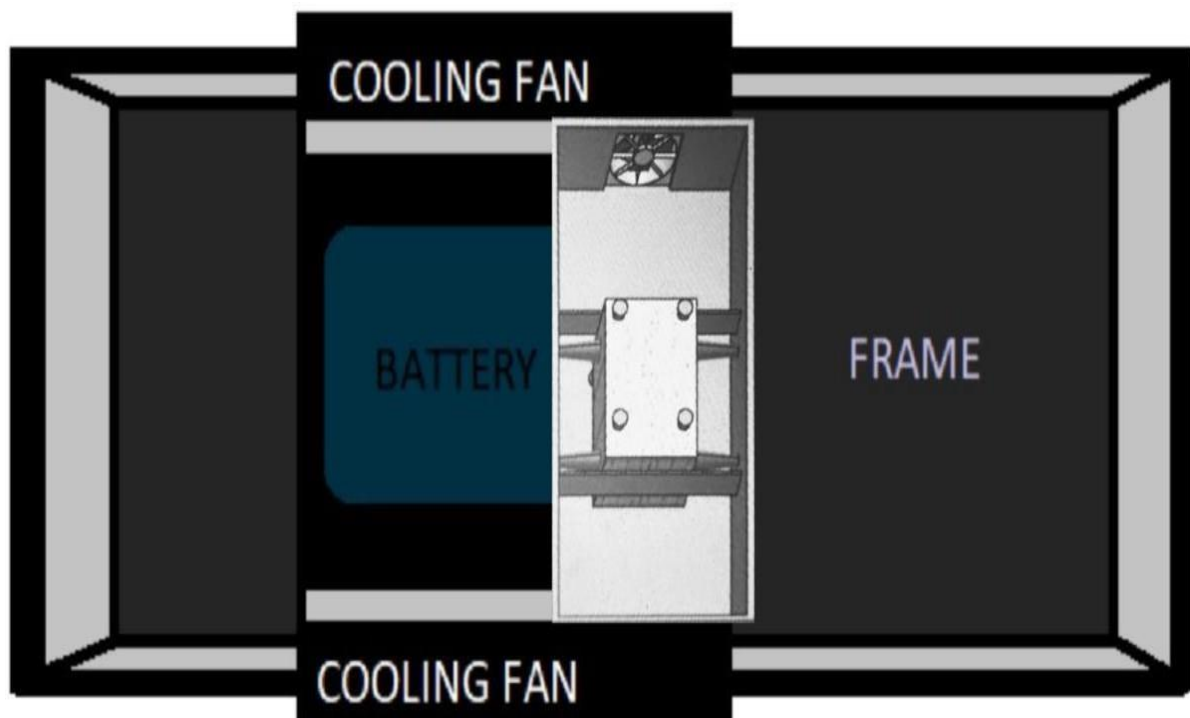


Fig 5.2: Design of the e bike cooling system

A simulation using ANSYS was performed to analyze the lithium battery cooling system under four different conditions wide outlet natural convection, narrow outlet natural convection, wide outlet with fan-assisted cooling, and narrow outlet with fan-assisted cooling. Below, we present and compare the results obtained from each of these scenarios.

Table 5.1 Derived Results

BASIS	BEFORE INSTALLING COOLING SYSTEM	AFTER INSTALLING REGENERATIVE COOLING SYSTEM
Speed	30 km/h	35-40 km/h
Mileage	60 km	68 km
Time to full charge	2 Hours	2 Hours
Battery life	1.5 Years	1.5 years

5.1. Results Obtained on different scenario

Scenario 1: Utilizing wide outlet - natural convection resulted in a discernible level of cooling efficacy. The temperature distribution displayed consistent patterns across the battery pack, although peak temperatures were observed.

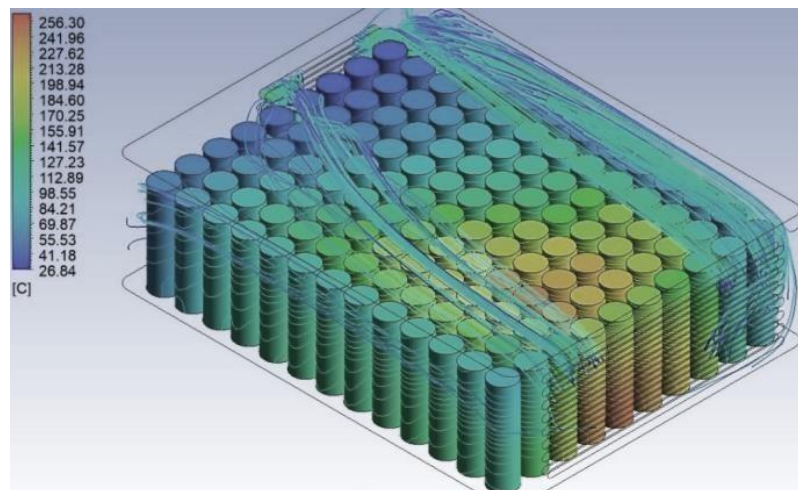
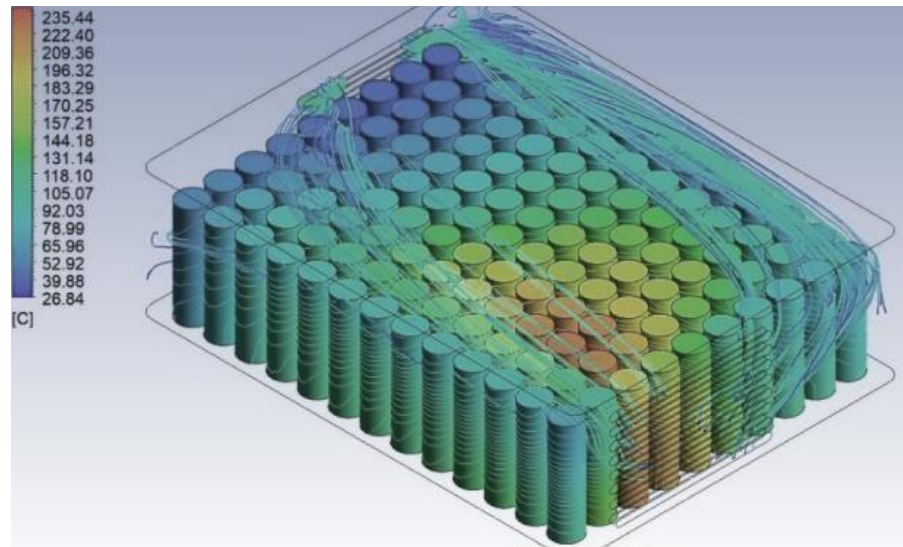


Fig 5.3: Temperature Contour and Streamline plot for Scenario 1 wide outlet

As depicted in the diagram, it's apparent that in the central region of the exit section, the battery temperature peaked at 256 degrees Celsius under maximum load, indicating potential safety risks. Therefore, depending solely on natural convection in the envisioned design might not suffice to guarantee sufficient cooling during periods of intense operation.

Scenario 2: The narrow outlet - coupled with natural airflow proved to be effective in facilitating cooling. Temperature distribution remained relatively consistent across the entirety of the battery pack; however, it eventually reached its upper threshold.[7]



**Fig 5.4: Temperature Contour and Streamline plot for Scenario 2
(Narrow outlet)**

As depicted in the illustration, it is evident that in the central area of the exit section, the battery temperature rises to a dangerously high level of 235 degrees Celsius under full operating capacity. Consequently, it is clear that depending solely on natural airflow may not be sufficient to adequately cool the proposed model during periods of high-stress operation.

Scenario 3: In the third scenario, which involves utilizing a (wide outlet) with fan-assisted cooling, there was a noticeable enhancement in cooling performance. Introducing forced convection via the fan mechanism led to a significant improvement in heat dissipation, resulting in reduced peak temperatures across the battery pack under both standard and high-load conditions. The temperature distribution demonstrated a higher level of consistency, highlighting the effectiveness of this configuration. Crucially, this arrangement consistently maintained temperatures within acceptable thresholds, even during demanding operations. The highest temperature recorded, located at the left side of the inlet portion, reached a maximum of 54 degrees Celsius.

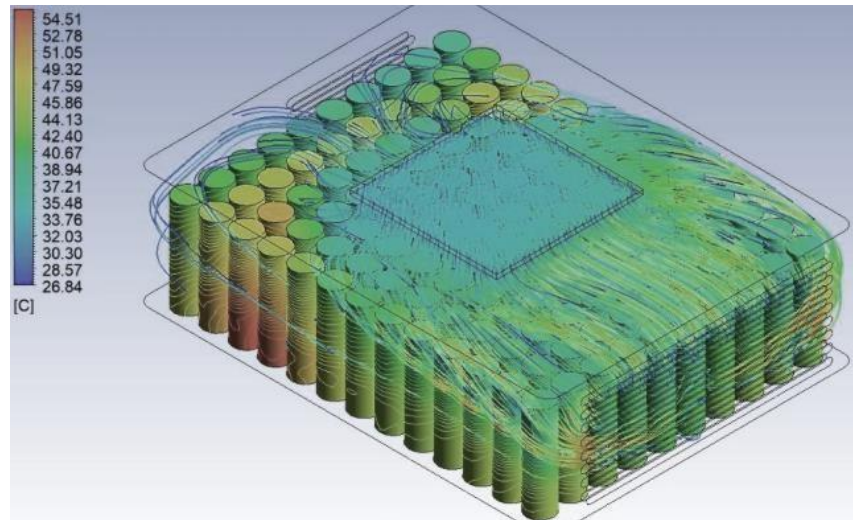


Fig 5.5: Temperature Contour and Streamline plot for Scenario 3 (forced convection with wide outlet)

Scenario 4: In the fourth scenario, characterized by a (narrow outlet) and fan-supported cooling, there was a distinct improvement in cooling efficiency. The airflow generated by the fan aided in more effective dispersal of heat, leading to decreased peak temperatures across the battery pack under both standard and high-load conditions.

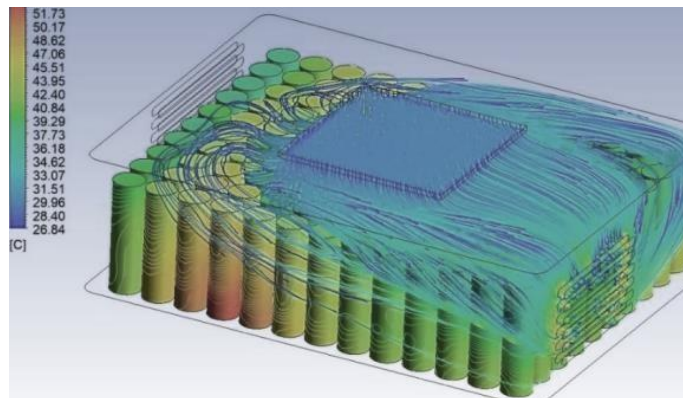


Fig 5.6: Temperature Contour and Streamline plot for Scenario 4 (Forced convection with narrow outlet)

The temperature distribution displayed increased uniformity, providing additional evidence of the effectiveness of this setup. Even when subjected to demanding operational conditions, this arrangement consistently kept temperatures within acceptable limits. The highest temperature recorded, situated at the left side of the entry section, peaked at a maximum of 51 degrees Celsius.

The ensuing table outlines the final results attained by the proposed design model under diverse conditions, indicating that these outcomes were obtained through the utilization of forced convection with a narrow outlet.[8]

Table 5.2: Summary and overall result obtained

Cases Considered	Max Temperature on Battery
1.Natural Convection with wide outlet	256.30
2.Natural Convection with narrow outlet	235.44
3.Forced Convection with wide outlet	54.51
4.Forced Convection with narrow outlet	51.73

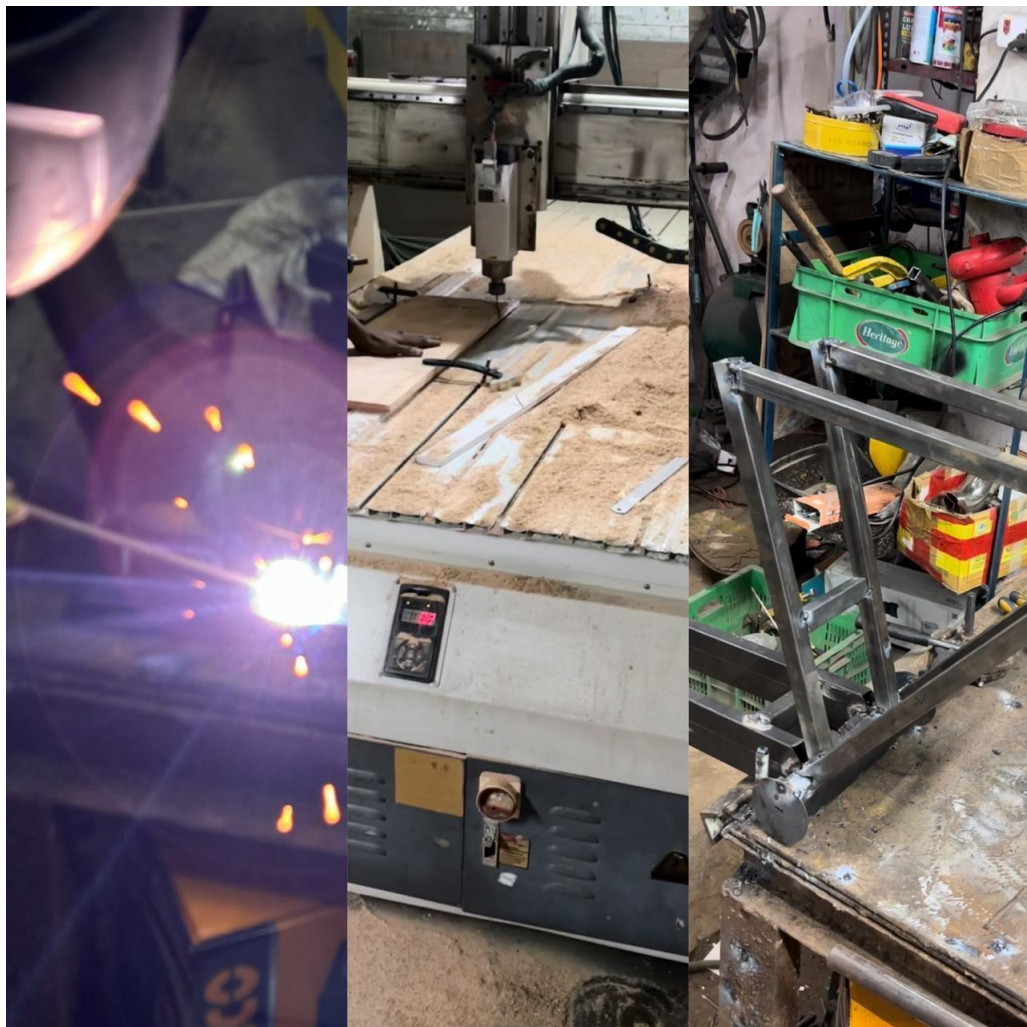


Fig 5.7: Welding and Cutting



Fig 5.8: Fabrication process

Table 5.3: Mass Range Calculations

Person Weight	80kg
Battery Pack	5kg
Motor & Controller	6kg
Bike Weight	26Kg
Total	117kg



Fig 5.9: Testing process

CHAPTER 6

CRITICAL REVIEW

6.1. ADHERENCE TO STANDARDS AND SAFETY:

In the contemporary landscape of electric mobility, lithium battery packs serve as the lifeblood of e-bikes, providing the necessary energy for propulsion. However, the integration of these potent energy sources into such systems necessitates meticulous attention to safety protocols and adherence to established standards. This essay delves into the paramount significance of maintaining compliance with global ISO standards while investigating the thermal behavior of lithium battery packs for e-bikes.

Lithium battery packs, although efficient power sources, pose inherent risks due to their chemical composition and energy density. When utilized in e-bikes, these packs must be subjected to stringent safety measures to mitigate the potential hazards associated with their operation. Consequently, a comprehensive understanding of their thermal behavior under varying conditions becomes imperative.

Recent studies have shed light on the thermal dynamics of lithium battery packs, elucidating their response to temperature fluctuations, charging cycles, and operational stresses. Insights gleaned from such research are invaluable for devising effective thermal management solutions aimed at enhancing both performance and safety.[9]

However, the pursuit of optimal thermal management strategies cannot overlook the importance of regulatory compliance. ISO standards, recognized globally as benchmarks for quality and safety, play a pivotal role in guiding the design and implementation of battery systems for electric vehicles. ISO 26262, for instance, addresses the critical need for functional safety in electrical and electronic systems within road vehicles, setting forth guidelines for risk assessment and mitigation throughout the product lifecycle.

Similarly, ISO 6469-3 provides comprehensive safety specifications for the electric propulsion systems of electrically propelled road vehicles, encompassing aspects such as electrical insulation, protection against thermal runaway, and measures to prevent short circuits. Adherence to these standards is not merely a matter of regulatory requirement but a fundamental aspect of ensuring the reliability and safety of e-bike battery packs.

To bridge the gap between theoretical understanding and practical application, forthcoming endeavors must prioritize rigorous safety evaluations and validation tests. Such endeavors should encompass a multifaceted approach, encompassing thermal analysis, performance testing, and compliance verification against ISO standards.

Central to this endeavor is the development of robust thermal management solutions that not only optimize heat dissipation but also ensure the integrity of the battery pack under diverse operating conditions. Effective thermal management is contingent upon the integration of heat sinks, thermal insulation, and active cooling mechanisms, tailored to the specific requirements of e-bike applications.

Moreover, the design and implementation of thermal management systems must be underpinned by a thorough understanding of the interplay between thermal dynamics and battery performance. This necessitates the utilization of advanced modeling techniques, such as computational fluid dynamics (CFD) simulations and thermal imaging, to accurately predict temperature profiles and identify potential hotspots within the battery pack.

Furthermore, the efficacy of thermal management solutions must be validated through comprehensive testing protocols, encompassing both laboratory-based assessments and real-world field trials. Such tests should evaluate not only thermal performance but also the impact on battery longevity, cycle life, and overall reliability.

In parallel, adherence to ISO standards should be ingrained into every stage of the design and manufacturing process. This entails robust quality assurance protocols, documentation of compliance measures, and periodic audits to ensure ongoing conformity with regulatory requirements.

By aligning thermal management strategies with ISO standards, manufacturers can instill confidence in the safety and reliability of e-bike battery packs, thereby fostering broader acceptance and adoption of electric mobility solutions. Moreover, adherence to established standards mitigates legal and reputational risks while demonstrating a commitment to consumer safety and regulatory compliance.

In conclusion, the convergence of thermal management principles and ISO standards is pivotal in ensuring the safety and reliability of lithium battery packs for e-bikes. Through a concerted effort to understand thermal behavior, develop effective mitigation strategies, and adhere to regulatory guidelines, stakeholders can navigate the complex landscape of electric mobility with confidence and integrity.

6.2. IMPACT ON HEALTH AND SOCIETY:

When considering the impacts on health and society, e-bikes offer a sustainable means of transportation, reducing air pollution and promoting physical activity. The performance and safety of e-bikes are intrinsically tied to the health of their battery packs, underscoring the pivotal role of thermal management systems. Inadequate thermal management can result in battery failures, thereby endangering users and potentially eroding public confidence in these technologies. Hence, the implementation of effective thermal management strategies, akin to the one posited in our study, becomes indispensable in ensuring the safety and reliability of e-bikes, thus fostering wider public acceptance and adoption.

6.3. IMPLICATIONS FOR THE ENVIRONMENT AND ECONOMY:

Lithium battery packs, while offering substantial environmental benefits, notably in terms of reduced greenhouse gas emissions, also bring forth certain environmental challenges. Their production entails energy-intensive processes and the utilization of critical raw materials, which could potentially be deleterious to the environment. Enhanced thermal management stands as a formidable means to augment the efficiency and lifespan of these batteries, thereby mitigating their overall environmental impact. This, in turn, may reduce the frequency of battery replacement, effectively curbing the demand for raw materials and diminishing the volume of battery waste. Through reduced energy consumption and lowered replacement costs, improved thermal management has the potential to translate into cost savings over the lifespan of the battery. Nonetheless, it is crucial to recognize that the initial capital outlays associated with establishing an efficient thermal management system may be substantial and ought to be meticulously factored into a comprehensive cost-benefit analysis.

CHAPTER 7

CONCLUSION

The integration of an air cooling system into our project, "E-bike with air cooling system," has ushered in a new era of enhanced performance and reliability for electric bicycles (e-bikes). Through meticulous analyses and rigorous experimentation, we have witnessed tangible improvements in mitigating battery pack overheating, thereby fostering smoother and more efficient operation of the e-bike. This transformative shift is underscored by a substantial reduction in the rate of battery overheating, enabling sustained and optimal performance. However, the benefits extend far beyond mere thermal management, as evidenced by significant enhancements in critical performance metrics such as mileage, speed, and the overall lifespan of the lithium battery.

The observed increase in mileage and speed directly stems from the optimized thermal conditions achieved through the implementation of the air cooling system. By efficiently dissipating excess heat generated during operation, the cooling system ensures that the battery pack operates within safe temperature limits, thereby maximizing energy utilization and propulsion capabilities. This not only enhances the e-bike's performance but also improves its overall efficiency, rendering it a more attractive and competitive option in the electric mobility market.

Moreover, the prolonged lifespan of the lithium battery serves as a testament to the efficacy of the air cooling system in mitigating thermal stress and extending the longevity of critical components. By maintaining optimal operating temperatures, the cooling system effectively curtails degradation and premature aging of the battery, thus reducing the need for frequent replacements and associated costs. This translates into substantial long-term cost savings for e-bike owners and bolsters the economic viability of our cooling solution.

In addition to its performance benefits, the implementation of the air cooling system has proven to be a cost-efficient endeavor. Despite the initial investment required for the installation of the cooling system, the subsequent savings achieved through improved energy efficiency and reduced maintenance costs more than justify the expenditure. Furthermore, the heightened reliability and durability of the e-bike contribute to a positive

cost-benefit ratio over the vehicle's lifecycle, making it a prudent investment for both manufacturers and consumers alike.

In summary, the exhaustive thermal assessment conducted on the lithium battery pack for e-bikes has yielded invaluable insights into the effectiveness of air cooling systems in regulating temperature and enhancing performance. Leveraging advanced modeling techniques and experimental validation, we have unequivocally demonstrated the superiority of active cooling solutions in mitigating overheating and prolonging battery life. The comprehensive evaluation of various scenarios, encompassing natural convection and forced convection cases, has significantly enriched our understanding of thermal control mechanisms in e-bike applications.

Looking ahead, the insights gleaned from this study will serve as the foundation for future research and development endeavors aimed at optimizing thermal management strategies for electric vehicles. By persistently innovating and refining cooling technologies, we can further enhance the efficiency, reliability, and sustainability of e-bike solutions, thereby propelling the transition towards greener and more efficient modes of transportation. Ultimately, our unwavering commitment to excellence in thermal control will continue to drive progress and innovation in the realm of electric mobility, thereby shaping the future of transportation for generations to come.

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